EFFECTS OF PHOSPHORUS FERTILIZER AND INOCULATION ON YIELD AND NUTRITIVE VALUES OF GRAIN AND HAULM OF SELECTED GRAIN LEGUMES IN MIXED CROP-LIVESTOCK PRODUCTION SYSTEM OF ETHIOPIA

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Advisor's Approval Sheet (Submission sheet -1)

This is to certify that the thesis entitled "**Effects of Phosphorus Fertilizer and Inoculation on Yield and Nutritive Values of Grain and Haulm of Selected Grain Legumes in Mixed Crop-Livestock Production System of Ethiopia"** submitted in partial fulfillment of the requirements for the degree of Master with specialization in Animal Nutrition, the Graduate Program of School of Animal and Range Science, and has been carried out by Sisay Belete Asefa, under our supervision. Therefore, we recommended that the student has fulfilled the requirements and hence hereby can submit the thesis to the thesis to the department.

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DEDICATION

I dedicate this thesis manuscript to my beloved parents, **W/ro GADISSE BEDADA** and **Ato BELETE ASEFA**, for nursing me with affection and love and for their dedicated partnership for the success of my life.

Name……………………………………… Signature………………………..

Date…………………………………………….

STATEMENT OF THE AUTHOR

I declare that this thesis is my genuine work and all sources of materials used in 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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Place: Hawassa University College of Agriculture, Hawassa, Ethiopia

Date………………………………………….

ACRONYMS AND ABBREVIATIONS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
ANOVA	Analysis of Variance
ARARI	Amhara Region Agricultural Research Institute
BNF	Biological Nitrogen Fixation
CF	Crude fiber
Cm	Centimeter
CP	Crude Protein
CSA	Central Statistical Agency
CV	Coefficient of variance
DAP	Diammonium Phosphate
DE	Digestible energy
DM	Dry Matter
EE	Ether extract
EIAR	Ethiopia Institute of Agricultural Research
G	Gram
GLM	General linear model
GY	Grain yield
Ha	Hectare
HDMY	Haulm dry matter yield
HI	Harvest Index
HwU	Hawassa University
I	Inoculants
ILRI	International Livestock Research Institute
Kcal	Kilo calorie
Kg	Kilo gram
M	Meter
m.a.s.l	Meter above sea level
m^2	Meter square
ME	Metabolizable energy

MJ	Mega joule
Mm	millimeter
N	Nitrogen
NDF	Neutral detergent fiber
NFE	Nitrogen free extract
NIRS	Near infrared reflectance spectroscopy
NPK	Nitrogen, Phosphorus, Calcium
NPS	Nitrogen, Phosphorus, Sulfur
OARI	Oromia Agricultural Research Institute
OM	Organic matter
P	Phosphorus
PDB	Phosphorus dissolving bacteria
PSB	Phosphate solublizing bacteria
RCBD	Random complete block design
S	Sulfur
SAS	Statistical analysis system
SE	Standard error
SEM	Standard error of mean
SPSS	Statistical Package for Social Science
T	Tone
TBMY	Total above ground biomass yield
TFW	Total fresh weight of haulm
IVOMD	*In vitro* organic matter digestibility
TLU	Tropical livestock unit

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ABSTRACT

A study was conducted to evaluate the effects of phosphorus (P) fertilizer and rhizobium inoculation on important grain and haulm traits in selected grain legumes and to assess farmers' perception on the uses of haulm and the effects of P fertilizer and inoculation on haulm traits. This study involved field experiment and household survey. Four grain legumes (faba bean, chickpea, haricot bean and soybean) were subjected to four fertilizer treatments (inoculation + P fertilizer (+P+I), inoculation alone (-P+I), P fertilization alone (+P-I) and control i.e. no inoculation and no fertilizer (-P-I)) and established on selected farmers plots. Grain and haulm yield data were recorded during grain harvesting and subsequently representative samples were collected for quality analysis. A semi-structured questionnaire was administered to collect data on household characteristics. Analysis of variance was run in general linear model of SAS for experimental data in randomized complete block design and household data was analyzed using descriptive statistics of SPSS. Faba bean grain and haulm DM yield were significantly improved ($P<0.05$) due to the treatments and the highest mean grain yield (2.87 and 2.84 t/ha) were obtained from +P-I and +I+P treatments, and maximum haulm DM yield (3.61 t/ha) recorded in treatment +P+I. Faba bean haulm CP content, IVOMD and ME values of treatment +P+I, -P+I and +P-I were found to significantly ($P<0.05$) surpass the control, whereas treatment +P+I, -P+I and +P-I resulted the lowest mean haulm NDF, ADF and ADL content than the control. Application of rhizobium inoculants and P fertilizer had a highly significant effect ($P<0.001$) on grain yield but non-significant effect ($P>0.05$) on haulm DM yield of chickpea. The maximum mean grain yield (2.13 t/ha and 1.98 t/ha) of chickpea was recorded in treatment +I+P and +I-P, respectively. The haulm CP content, IVOMD and ME of chickpea responded positively ($P<0.05$) to the treatments, but the responses of ash, NDF, ADF and ADL content were not significant ($P>0.05$). The highest mean grain (1.98 t/ha) and haulm DM (1.84 t/ha) yield of haricot bean was obtained from treatment +P+I. Treatment +P+I was also resulted into significantly high ($P<0.05$) haulm ash and CP contents, and IVOMD and ME values of haricot bean, while the same treatment (+P+I) had lower NDF and ADF contents than the others. In soybean, significantly maximum mean grain (2.56 and 2.46 t/ha) and haulm DM (3.07 and 3.23 t/ha) yield were recorded in treatments +P+I and -P+I, respectively. Except haulm ash content and ME value, all feed quality variables analyzed (CP, NDF, ADF, ADL and IVOMD) were significantly ($P<0.05$) affected due to the treatments in soybean. The maximum mean values of soybean haulm CP and IVOMD were obtained in the inoculated treatments (+P+I and –P+I), meanwhile treatment +P+I contained the lowest NDF, ADF and ADL. The result also showed that households used grain legume haulms as a source of feed (76.7%), fuel (11.4%), for mulching and compost making (8.8%) and income generation (3.1%). Majority of the respondents (62.2%) perceived that inoculation and P fertilization positively affects haulm biomass yield. The current results demonstrated the possibility of improving both grain and haulm yield and quality of faba bean, haricot bean and soybean by using P fertilizer and inoculation. Moreover, regardless of haulm yield and grain food values; improvement of grain yield of chickpea is also possible with the combined application of P fertilizer and inoculation.

Key Words: Grain legumes, grain legumes haulm, haulm traits, *rhizobium* inoculants

1. INTRODUCTION

Livestock population of Ethiopia is estimated to be around 56.7 million cattle, 58.4 million shoats, 9.8 millions equines, 1.7 million camels and 56.9 million chickens, excluding animals from non-sedentary areas of the country (CSA, 2015a). The greatest concentration of these livestock population, except camels, is found in the mid and highland altitude areas where cultivation of a variety of crops and rearing of different livestock species are practiced together by smallholder farmers. Livestock production play very important role in the livelihood of smallholder farmers in the mixed crop-livestock farming system. They are main sources of draught power, nutritious foods, cash, and manures and have a big social value. In most cases, the livestock and crop sub-systems have a strong interdependence and complementarities (Getachew *et al.*, 1993a; Solomon *et al.*, 2009). Generally, livestock play a crucial role both for the sustainability and intensification of agricultural productivity of the mixed crop-livestock production system.

Among the constraints facing livestock production in the small scale mixed crop-livestock farming system, inadequate feed supplies and low quality of available feeds stands as the most important (Bayush *et al.*, 2008; Belay *et al.*, 2013; Malede and Takele, 2014). The major livestock feed resources in these areas are natural pasture, crop residues, stubble grazing and other agricultural by products (Getachew, 2002; Seyoum *et al.*, 2001; Solomon, 2004). The role of grazing as sources of feed is diminishing due to continuous expansion of cropping into grazing lands (Yayneshet, 2010). As a result, crop residues are increasingly becoming the major sources of feed for livestock (Bayush *et al*., 2008; Daniel, 1988; Malede and Takele, 2014) and contribute up to 30-80% of the total feed dry matter available for animals in the highland part of Ethiopia (African RISING, 2014). Therefore, crop residues are valuable low cost roughage sources for animals in extensive ruminant production systems particularly during the long dry season of the year when green fodder is critically scarce.

However, the utilization of crop residues (cereal straws and stovers and legume haulms) as an ultimate year round diet source are limited by their low nutritive value because of high fiber content, low energy and protein content, low digestibility, and seasonal availability. For instance, the reported value of CP content of most abundantly available crop residues in Ethiopia (Dereje *et al*., 2010: Seyoum and Zinash, 1989; Solomon *et al*., 2008) is lower than the critical value of 7% required for normal rumen microbial action and feed intake (Van Soest, 1994). On the other hand, availability of crop residues for utilization at a particular time of the year is markedly affected by the seasonal and inter-year variations in crop residue production (Williams *et al.*, 1997).

Dry matter yield and nutritional values of crop residues of different crops are influenced by genotypes and various environmental factors (Sannasgala and Jayasuria, 1987). Regardless of the biomass yield, grain legume haulms have relatively better nutritional values such as CP and metabolazable energy (ME) contents and digestibility than cereal straws and stovers (Lopeze *et al*., 2005). Crop residues of most grain legumes (pulse crops) in Ethiopia can be categorized under medium quality roughages depending on their CP content which range from 5% to 12% (Adugna, 2008). Hence, grain legume haulms can be considered as a good option in ruminant feeding.

Grain legumes are the second largest crops produced next to cereals in Ethiopia. Annually around 1.6 million hectare of land is planted to grain legumes and more than 2.6 million metric tons of grain is produced (CSA, 2015b). Moreover, it touches the lives of about 10 million smallholder farmer households and low income urban dwellers. In the subsistence type of farming system, legume crops have a great recognition as they play a big role in intensifying the productivity and interactions among soil, crop and livestock. But the use of legumes haulm as feeds in Ethiopia is limited for two possible reasons. The first one is associated with limited annual production of the legume residues due to the smaller land allocation for these crops by smallholder farmers (Leulseged and Jemal,1989; Solomon *et al*., 2008) and lower straw yielding potential of these crops as compared to cereals (Lopez *et al*., 2005). Akinola *et al*. (2015) stated that the size of land used by the household has positive and significant influence on the decision to use legume crop residue as feeds for livestock because the quantity of crop residue produced on the farm is the main determinant for the intensity of use of legume haulm as livestock feed.

The other one may be related to the efficiency of post harvest managements like storage condition. In Ethiopia, farmers store their crop residues dominantly in the form of traditional heaps with exposure to vagaries of weather condition. As compared to cereals residues grain legumes haulms are more susceptible to spoilage (decomposition) if exposed to adverse environmental condition particularly rainfall and this can cause considerable decline in nutritive value of the haulm (Alkhtib *et al*., 2014). Additionally, awareness of the farmers on the feeding value of grain legume haulms also can determines the extent of utilization in livestock feeding (Akilona *et al*., 2015).

Currently multiple works are being undertaken by various governmental and non-governmental organizations to benefit smallholder farmers from legume crop production in Ethiopia, which will create a big opportunity to boost annual production of grain legumes with concomitant increase in grain legumes haulm production and availability for livestock feeding. However, most of previous works on development of varieties and agronomic studies were basically targeting improvement of grain yield without considering crop residue yield and quality.

Improvement of whole plant values of grain legumes is possible through combined efforts of variety selection and breeding together with application of better agronomic practices like soil fertility nutrients supply without marginalizing grain yield. Study by Ibsa (2013) showed significant improvement in yield performance and total haulm nitrogen and phosphorus content of chickpea due to phosphorus fertilizer and inoculants application, while the improvement is more prominent with combined application. Additionally, a remarkable increase in dry matter yield and CP content of annual forage legumes (vetch species) was also found due to inoculation with more effective rhizobium bacteria on two soil types in Ethiopia, though the crop was not grain type (Muluneh, 2006).

Generally, it was timely to work on generating and promoting best bet agricultural technologies which can optimize the uses of whole plant values under smallholder farmers in Ethiopia. So far only limited information is available on the effect of phosphorus fertilizer and rhizobium inoculations on haulm dry matter yield and haulm quality of grain legumes in mixed-crop livestock production system of Ethiopia. Furthermore, current status of farmers' perception on the utilization of grain legume residues for animal feeding and the effects of agronomic practices on haulm yield and quality traits was not well studied and documented. Thus, this study was initiated with the following objectives:

- To evaluate effects of phosphorus fertilizer and *rhizobium* inoculations on grain and haulm dry matter yield of selected grain legumes.
- To evaluate the nutritive values of grain and haulm of selected grain legumes as affected by phosphorus fertilizer and *rhizobium* inoculation.
- To assess farmers' perception on the use of grain legumes' haulm for livestock feeding and the impact of phosphorus fertilizer and *rhizobium* inoculation on yield and quality of the haulm.

2. LITERATURE REVIEW

2.1. Overview of Mixed Crop-Livestock Production System of Ethiopia

Mixed crop-livestock farming is a predominant production system in Ethiopia and mainly found in altitudes ranges between 1500 and 3200 m.a.s.l (Alemayehu, 2003). More than 60% of human population and nearly two thirds of the ruminant livestock population of the country are found in this farming system (Dejene, 2003). This production zone receives adequate rainfall and has moderate temperature which makes the area suitable for cultivation of various crops and rearing of different livestock species (Malede and Takele, 2014). Thus, a wide range of crops are grown and many species of livestock kept for different ends by smallholder farmers (Alemayehu, 2003). Accordingly, many studies had conducted in different parts of the country and revealed that mixed crop-livestock farming as predominant mode of agricultural activity in the highlands of the country (Belay *et al.*, 2012; Dawit *et al*., 2012; Mergia *et al.*, 2014; Solomon *et al.*, 2014).

Livestock production is an integral component in the mixed crop-livestock production system of Ethiopia. The two sub sectors, *i.e.* crops and livestock production are interdependent and complementary (Getachew *et al*., 1993a; Solomon *et al.*, 2009). Livestock play a crucial role in crops cultivation through provision of draft power, organic fertilizer (manure), and cash availablity for purchase of agricultural inputs whereas crop provide in return inputs for livestock production in the form of crop residues (Getachew *et al.*, 1993b; Powell *et al*., 2004).

There are also variations in the degree of integration exist between livestock and crops (Malede and Takele, 2014) as well as type of crops integrated with livestock production (Fekadu, 2009). For instance, studies conducted in cereal dominated mixed crop-livestock farming system of

Bale highlands showed highly significant interaction exist between livestock holding and crop production (Solomon, 2004; Solomon *et al*., 2009). On the other hand, the integration of livestock with crops is lower in perennial crops-livestock system (coffee growing areas) of South Ethiopia where livestock have less importance (Malede and Takele, 2014). Generally, although the major liking elements that integrating crop and livestock sub-sectors in the mixed crop-livestock farming areas are crop residues and draught power. Increasing productivity of either crop or livestock alone is impossible without due consideration of the interaction exist between the two components (Hart and McDowell, 1985).

Despite of the valuable importance's livestock has in food security and food self sufficiency of the farming households and presence of huge resources potential, the current production and productivity of livestock in the mixed-crop system is by far below the existing potential. Inadequate feed availability both in quantity and quality is identified as a major bottleneck that constraining the productivity of livestock subsector in this farming system (Bayush *et al.,* 2008; Belay *et al.,* 2013; Gezu *et al.,* 2014; Malede and Takele, 2014; Solomon *et al.,* 2014).

2.2. Major Feed Resources in Mixed Crop-Livestock Production System

The dominantly used feed resources in the mixed crop-livestock production system of Ethiopia are obtained from natural pastures, crop residues and stubble grazing (Alemayehu, 1985; Mergia *et al.,* 2014; Samuel, 2014; Seyoum *et al.,* 2001; Solomon, 2004; Solomon *et al.,* 2014). However, the great variability observed on the availability and quality of these feed resources has been remaining as a major determinant for exhaustive utilization of the resources. Intensity of crop production and amount and distribution of the rainfall have a big function in determining the availability of each types of feeds in general (Mohammed and Abate, 1995). In addition to the above described feed supplies, hays, agro-industrial by products, improved forages species, and other non-conventional feed sources have also contributed about 7.44, 1.22, 0.30 and 4.76%, respectively in annual livestock feed supplies in sedentary area of the country (CSA, 2015a). The most commonly used feed resources in mixed crop-livestock production system of Ethiopia are further discussed below.

2.2.1. Natural Pasture and Browses

Natural pasture is grassland that is available for grazing herbivores and it dominated with native herbaceous plants species and some indigenous browse trees. According to Alemayehu (2004), natural grassland in Ethiopia was accounts for about 30.5% of the area of the country and mainly found in highland parts. It was also a key source of livestock feeds in Ethiopia highlands where more livestock and human population found (Seyoum *et al.,* 2001).

According to the reports of some recent assessments (Belay *et al*., 2012; Endale, 2015; Samuel, 2014; Solomon *et al.,* 2014); natural pasture remains as a major component in livestock feed supplies in different parts of the country where mixed crop-livestock production is a predominant agricultural activity. CSA (2015a) recent estimation has shown that green fodders that are obtained through grazing from natural pasture are contributing about 56.23% of the total annual feed supplies in sedentary areas of the country above ahead of the others. However, the contribution of natural pasture reaches this peak during a certain season of the year.

Moreover, better quality forages was obtained from this source particularly during wet season of the year. The availability and quality aspect of forages from native pasture is governed by different factors which directly and indirectly influence species composition, *i.e.* climate (rainfall and temperature), altitude, soil and farming intensity (Alemayehu, 2004; Malede and Takele, 2014). Seasonal fluctuation in the availability and quality of pastures is a common feature of Ethiopia's grazing lands which results in serious feed shortage thereby affecting livestock production and productivity (Alemayehu, 2004; Solomon, 2004).

The problems of natural pasture is a growing concern as the share it has in smallholder farmers feed supplies in mixed farming areas is drastically declining as a result of continuous expansion of cropping, poor management system and overstocking. For instance, study conducted to analyze land use change in the last 27 years in Amhara Regional State had revealed rapid shifting of grazing lands into arable land and 30.52% grazing land has been converted to crop field in the described time period (Tadesse and Solomon 2014). The same authors noticed that the remaining grassland has also changed into degraded grassland, degraded shrubby bush land, urban settlement, and eucalyptus woodland. Similarly, shrinkage of overall contribution of grazing lands for livestock feeding due to grazing pressure and farm land expansion into grazing areas had reported in West Shewa Zone due to (Seyoum and Fekede, 2003) and North Shewa zone of Ahmara Regional State (Ahmed, 2006). Furthermore, majority of the interviewed households (81.2%) were also reflected continues decrease of grazing lands due to conversation of grazing land to crop field as consequence of ever increasing population growth in Metekel zone (Solomon *et al.,* 2014).

As noted by Alemayehu (1985) losses of valuable plant species and replacement by unpalatable ones as a result of sever overgrazing and poor managements are core problems observed on most natural pastures in Ethiopia. Generally, in mixed farming areas of the country, better soils are used for cropping and the main permanent pasturelands are found on the upper slop of hills, seasonally water logged areas and broader of lands and rivers (Alemayehu, 2003).

2.2.2. Crop Residues

Crop residues are the fibrous by-products obtained from the cultivation of cereals, pulses, oil plants, roots and tubers; and can be used as an important feed resource for ruminant production particularly in subsistent type of farming. Crop residues also represent the largest agricultural harvest and incorporate more than half of the world's agricultural biomass (Lopez *et al.*, 2005).

Similarly, substantial amount of crop residues is produced annually in Ethiopia following cultivation of various grain crops. Smallholder farmers are used these crop by-products for different purposes including livestock feeding, domestic fuel, bedding material, source of income, as housing material and for mulching crop lands (Adugna, 2007a; Ahmed, 2006; Zinash and Seyoum, 1989). The most commonly used crop residues for animal feeding in Ethiopia are obtained after grain harvest of barley, *teff*, wheat, maize, sorghum, lentil, faba bean, field pea, chickpea, haricot bean, etc (Endale, 2015; Solomon *et al.*, 2008). These crop residues are either grazed by animals on field *in situ* or collected and stored for stall feeding.

Different scholars have made an attempt to predicate annual total DM production of crop residues in Ethiopia. For instance, Adugna (2007a) was estimated the quantity of available cereal and pulse crop residues for livestock feeding in Ethiopia to be about 29.2 and 1.4 million tons in DM bases, respectively. Moreover, availability of different types of crop residues for livestock feeding is depends on multiple factors such as agro-ecology, altitude, season of the year and size of land allocated for different crops species by farmers *etc*, (Ahmed, 2006; Solomon *et al.*, 2014). In association with this, Williams *et al.*, (1997) stated that availability of crop residues at farm level depends not just on production level only, but also on a variety of social and economic factors. Therefore, land, crop and animal ownership patters, cultural practices, the use of modern crop varieties and the opportunities for market and non-market exchanges are can influence a farmer's access to the residues that are locally produced (Williams *et al.*, 1997).

Due to the decreasing role of grazing land in feed supply as a consequence of farm land expansion to meet the demand for food, urbanization and land uses for other purposes, the potential uses of crop residues as feed sources have been increasing significantly from time to time (Daniel, 1988; Bayush *et al.,* 2008; Malede and Takele, 2014; Solomon *et al.,* 2008). Consequently, different studies (Bayush *et al*., 2008; Endale, 2015; Malede and Takele, 2014) ranked crop residues on the tops of all the other feed resources based on availability and contribution to the total annual dry matter supplies in the mixed crop-livestock farming system.

Different researchers and development workers were made an estimate on the contribution of crop residues in livestock feed supply in different farming systems and areas of Ethiopia. However, estimates of the contribution of this feed resource vary greatly. Accordingly, the contribution of crop residues is estimated to reach up to 30-80% of the total dry matters available for livestock in highlands of the country (African RISING, 2014). Further, report of Adugna (2007a) indicated that almost half of (50%) the national feed supplies come from crop residues in Ethiopia. Similarly, assessment made in mixed crop-livestock system in Blue Nile Basin of Ethiopia was also indicated that the contribution of crop residue to livestock feed sourcing ranged from 58.5% to 78.2% in the area (Bedasa, 2012).

The major challenges in the use of crop residues for animal feeding come from its inherent property of having low nutrient concentration, less nutrient digestibility and limited availability of the nutrients to the animals. Since, crop residues are harvested after the plant reaches physiological maturity, and therefore they are high in cell walls and lignin and low in nitrogen content, deficient in sulfur, phosphorus and other minerals (Sundstøl and Owen, 1984). Therefore, the most dominantly used crop residues are characterized by the predominance of lignocelluloses cell wall materials (cellulose, hemicelluloses and lignin) as main components, a high content of ash and a low content of CP, vitamin, minerals and storage carbohydrates (Cheeke, 1999; Sundstøl and Owen, 1984). Consequently, crop residues particularly cereal straws fail to meet the productive function of livestock because of their poor nutrients profiles such are soluble carbohydrate, crude protein, vitamins and minerals as well as lower digestibility (Cheeke, 1999).

There are many other factors that influence the extent of crop residues utilization in livestock feeding by smallholder farmers. For example, problems associated with collection, transportation, storage, processing and feeding can be mentioned as causes for poor utilization of crop residues as feed in Ethiopia (Adugna, 2007a; Ahmed, 2006). Collection and preservation of straws when the availability is better and application of different processing and treatment methods to improve the feeding value could be an option to enhance the benefits expected from crop residue in animal feeding (Daniel, 1988).

2.2.3. Improved Forage Crops and Browses

Different efforts were made in Ethiopia to study the adaptation and productivity of different forage species for different agro-ecologies and to adopt them to the different farming systems. As a result, many improved forage and browse species have been identified and recommended for different ecologies. The most promising pasture and fodder species under mid and highland altitudes include *Chloris gayana, Panicum coloratum*, *Panicum maximum*, *Melinis minutiflora, Pennisetum purpureum*, *Desmodium uncinatum*, *Leucanea leucocephala*, *Lablab purpureus,* *Vicia species, Avena sativa, Cajanus cajan, Vigna unguiculata, Sesbania spp., Chamaecytisus palmensis etc (*Adugna, 2007a; Lulseged and Alemu, 1985).

Improved forages mainly legumes have appreciated benefits as they supply high quality fodders for livestock and maintaining soil fertility and health through their nitrogen fixing capability (Tilahun, 2003). Nutritional profiles especially CP, ME and *in vitro* DM digestibility of some improved browse and legume forages are comparable with oilseed cakes and these make them a potential supplements for poor quality roughage feeds (Dirba *et al.,* 2013). A number of works have been also done on evaluation of potentiality of forage legumes as supplementary diets in poor quality roughages based feeding and promising results have been found in terms of production and reproduction performance of animals (Adugna, 2007b; Dawit, 2007). However, different improved fodder species and varieties are identified and recommended in Ethiopia; their contribution in national feed supply is very low and accounts only for 0.3% (CSA, 2015a). As lower adoption rate of the technologies by smallholder farmers remain as a major contributor for the minimal production of improved fodders in the country. In line with this, study conducted in Northeast Highlands of Ethiopia was revealed that only 1.3% of the total cultivated land is covered with improved forage seeds (Hassen, 2013).

2.2.4. Agro-industrial by Products

The major agro-industrial by products commonly used in Ethiopia are obtained from different agro-industries such as flour milling industries (wheat bran, wheat short, wheat middling and rice bran), edible oil extracting plants (Noug cake, cottonseed cake, peanut cake, linseed cake, sesame cake, sunflower cake etc), breweries and sugar factories (molasses) (Adugna, 2008; Malede and Takele, 2014).

However, the nutritional qualities of these agro-industrial by products are excellent, their relative contribution in smallholder farmers feed supply are very minimal (Berhanu *et al.,* 2009). This could be attributed by unaffordable prices of the products by most smallholder farmers, limited availability of the resources and lack of enough awareness on feeding values of these feed resources. Thus, the availability and utilization of these feed resources are limited only around towns where different agro-industries are found and the beneficiaries of the products are mainly livestock fattening operations and urban and peri-urban dairies located in the area with better accessibility to the resources (Berhanu *et al.,* 2009; Birhan, 2014). The fast growing trend of agro-industries in different parts of the country to satisfy the growing demand for the edible main agricultural products is expected to create a big opportunity for the growth of agro-industrial by products production which can be used in livestock feeding (Yayneshet, 2010).

2.3. Importance of Grain Legumes as Food and Feed Sources

Grain legumes are the second largest crops produced next to cereals based on area harvest and total production and grown on about 160 million hectare of arable land globally (Graham and Vance, 2003). Similarly, in Ethiopia around 1.56 million hectare of land (12.4% of total cultivated lands) planted to grain legumes annually and more than 2.67 million tons of grain (9.88% grain production) is produced (CSA, 2015b). An estimated 3.12 million tones of haulm could be also produced annually in Ethiopia by considering the 1.2 conversion factor suggested for grain legumes to estimate crop residues production from grain yield by FAO (1987). Thus, grain legumes have well recognized importance in food security and socio-economic of most Ethiopian households.

In human nutrition, grain legumes are good sources of protein, vitamins and minerals as they are contained these nutrients in better balance. For instance, protein contents of grain legume seeds are estimated to 20-40% and good complements for the carbohydrate sources foods (cereals or root crops) in terms of amino acid composition (Gepts *et al.*, 2005). Legume seeds contain lysine amino acid which is deficient in cereal seed proteins, while cereal seed proteins have good balance of sulfur-containing amino acids such as methionine and cystine which are deficient in legumes seeds (Wang *et al.,* 2003). Generally, the contributions of grain legumes alone in the dietary protein nitrogen of human needs are reach about 33% (Vance *et al.,* 2000). The same author was noticed that under subsistence condition, the percentage of legume protein nitrogen in the diet of human can reach twice of this figure.

On the other hand, as livestock feed shortage both in quantity and quality is increasing become the major bottleneck for livestock production in mixed crop-livestock dominant farming areas, cultivation of grain legumes can be serves as a good buffering mechanism for this constraint. The main components of grain legumes that are used for livestock feeding include grains, grain processing by products (bran and hulls) and haulms. In line with this, soybean and peanut seeds and meals (produced during oil extraction) are the main sources of protein in the diet of modern chicken and pork industries (Graham and Vance, 2003). The highest CP content of these legume seeds and legume seed processing by-products is attributing for the increasing interest in use of them as main sources of protein in the nutrition of mono-gastric animals. Grain legumes hulls that produced during de-hulling of the seeds using mill machine or traditional available millstone for human consumption is also has good CP content and can be used in livestock feeding. For example, CP content of faba bean hull is ranging from 12.78 to 16% (Abdi *et al.,* 2015; Jansman *et al.,* 1995). Thus, it has a potential to be used as supplement in poor quality roughage based diets. Accordingly, importance of bean and pea hulls in feed supply for smallholder dairy producers had reported in Ethiopia (Belay and Greet, 2016).

Grain legume haulms are also playing a significant role in supplying fodders for ruminant feeding in small scale mixed farming system. An assessment done by Alkhlib *et al.* (2014) in highlands Ethiopia demonstrated increasing trends in the use of grain legumes haulms as livestock feed by smallholder farmers. In association with this, a dramatic decline of using grain legume haulms for soil fertility improvement practices in the mixed crop-livestock farming system had reported (Alkhlib *et al*., 2014). Similarly, area specific livestock feed technologies prioritization work done with the aid of TechFit tool in selected sites of Bale highlands was identified feeding home grown legume residues as a potential feed technology for intervention in mixed crop-livestock farming system of the area (Sisay *et al.*, 2012).

The increasing interests in using grain legume haulms in livestock feeding could be considered as positive response to the existing feed problem. The better nutritional value of legume haulms which can be described in terms of high CP, ME and digestibility values with low fiber contents make preferable of legume haulms than cereals (Lopez *et al.,* 2005). In Ethiopia also various studies have identified better nutritional quality of different grain legumes haulms than cereals (Dereje *et al.*, 2010; Yetmwork *et al.*, 2011). However, basic problem in legumes haulms use is that they easily lose their leaves, and then the haulms basically constituted by stems which tend to lower their nutritive value.

2.4. Biomass Yield and Nutritional Value of Grain Legume Haulm

Grain legume haulms have already became constant components of ruminant diet in small scale mixed crop-livestock farming areas. Similar to other crop yield attributes, haulm DM yield of grain legumes is also a result of interaction between plant genetic makeup and environmental factors. Thus, based on plant factors, agro-ecology of the area, crop management conditions and related factors, variations have been observed among different reports in haulm DM yield of different grain legumes. According to Lulseged and Jemal (1989) haulm biomass yield of field pea and faba bean are 5.0 t/ha and 3.8 t/ha, respectively in Ethiopia. Likewise, haulm DM yield ranging from 3.44 to 7.11 t/ha was obtained from study conducted on faba bean cultivars at two different sits in Ethiopia (Yetmiwork *et al.,* 2011). Furthermore, crop residues yield of grain legumes is relatively lower than that of cereal in most cases (Lulseged and Jemal, 1989).

Nutritional values of feeds in general and crop residues in particulars are determined based on their nutrient composition, intake, and utilization efficiency of the digested DM. Different research findings have been reported on the nutritional value of grain legumes haulms. According to Lopez *et al.* (2005) grain legume haulms have CP and NDF contents, and DM digestibility coefficients of 74 gm/kg DM, 584 gm/kg DM and 0.67, respectively. In other study, CP and NDF contents ranging from 4.2 to 10.6% and 58.0 to 82.4% NDF, respectively and voluntary intake value of 48gm to 77gm/kg $LW^{0.75}$ were reported for grain legume haulms (Abreu and Bruno-Saores, 1998). Adugna (2008) also noted CP value ranging from 5 to 12% in pulse crops haulms in Ethiopia with associated higher ME and lower fiber fraction contents. The same author stated that haulms produced in Ethiopia can be categorized under medium quality roughages. Additionally, different scholars have studied chemical composition and nutritional values of the haulms produced from grain legumes used in the current study. Results of two different studies had showed nutrient contents of the faba bean haulms as follow; 10.3% ash, 8.8% CP 59.2% NDF, 46.8% ADF, 13.2% ADL with 58.8% of *in vitro* DM digestibility (Solomon *et al.,* 2008) and 94.9% DM, 6.8% Ash, 7.7% CP, 48% NDF, 43.3% ADF, 17.9% lignin (Ermias, 2008).

Tesfaye and Musimba (2003) had reported 91.5% OM, 5.4% CP, 69.2% NDF, 56.5% ADF, and 8.3% ADL with DE and ME content of 2.4 and 2.0 Kcal/g DM, respectively in haricot bean haulms. Finding of the same study was showed digestibility coefficient of the nutrients in haricot bean haulms as follow; 53.0% DM, 55.0% OM, 26.6% CP, 49.2% NDF and 47.1% ADF. Study conducted to determined chemical composition and rumen degradability characteristics of soybean haulms had also figured out value of 89.18, 5.10, 2.85, 96.90, 80.80, 63.20 and 13.00% for DM, CP, EE, OM, NDF, ADF and ADL contents, respectively and rumen degradability of DM and OM of this haulms was very low, although it has better rumen degradable CP (Maheri-Sis *et al.,* 2011). Nutritional values of chickpea haulms was also studied by Golshani *et al*. (2012) and chemical composition of 6.1% CP, 5.5% EE, 34.3% CF and 46.2% NFE were reported. In the mean time, degradability kinetics of chickpea haulms was evaluated; and the result showed soluble fraction (a) of OM (17.5%) and CP (40.8%) and potential degradability (*a*+*b*) of OM (56.7%) and CP (72.0%) (Golshani *et al.*, 2012).

2.5. Factor Affecting Biomass Yield and Nutritional Value of Grain Legume Haulm

Haulm biomass yield and quality characteristics of different crops are under influence of various factors. Genetic makeup, crop growing and harvesting condition, soil, temperature, threshing and storage methods all can influence dry matter yield, chemical composition and palatability of crop residues (Daniel, 1988; Reddy *et al.,* 2003). Effect of species and varietal difference and application of fertilizers on haulm biomass yield and quality are discussed below.

2.5.1. Effect of Species and Varietal Difference on Yield and Quality of Haulm

The variability comes due to species and varietal differences of the crops are a result of genetic makeup of the given plants. Thus, beyond the remarkable differences observed in yield and quality attributes of crop residues from crops of different botanical families such as cereals versus legumes, crop species of the same botanical families have show a big variation in terms of yield and quality related traits (Leulseged and Jemal, 1989; Lopez *et al.*, 2005).

Nutritional value, *i.e.* CP, ME and *in vitro* DM digestibility of 5.0 - 9.7%, 6.1 -7.1MJ/kg DM and 45.1 to 55.3 %, respectively were noticed for chickpea and field pea haulms (Abreu and Bruno-Saores, 1998). Study conducted to predict nutritional value of common crop residues with NIRS in Ethiopia also showed big variations in chemical composition and *in vitro* OM digestibility among haulms of different species of pulse crops (Dereje *et al.,* 2010). Similarly, Solomon *et al.* (2008) had demonstrated differences in ash, CP and fiber fraction contents as well as *in vitro* DM digestibility between field pea and faba bean haulms. Research conducted on crop residues of three beans species (*Phaseolus Vulgaris L., Phaseolus Calcaratus and Phaseolus Vulgaris var)* was also showed noticeable difference among the three species with the mean CP content of 7.57%, 7.61% and 8.01% and CF content of 29.6%, 28.2% and 27.4% in *Phaseolus Vulgaris L.*, *Phaseolus Calcaratus and Phaseolus Vulgaris var* haulms, respectively (Karami, 2015). According to the same finding, total mean DM and OM digestibility of *Phaseolus Vulgaris L.*, *Phaseolus Calcaratus and Phaseolus Vulgaris var* haulms were 66.7%, 65.9% and 69.6%; and 54.9%, 55.3% and 58.6%, respectively.

Cultivar differences are also the main sources of variation in yield and quality of grain legume haulms. The experiment conducted by Yetimwork *et al.* (2011) to evaluated the effect of varietal difference of faba bean on haulms dry matter yield and nutritional values the residues has showed a significant variability in most parameters studied including yield traits (grain yield, straw yield and harvest index*).* Another study on faba bean cultivars found, significantly highest (5.1 t/ha) and lowest (3.3 t/ha) haulms dry matter yield in improved (Mosisa) and local varieties, respectively (Teklu, 2016). Significant variations have bean also reported in chemical composition and digestibility of faba bean haulms (Teklu, 2016; Yetimwork *et al.*, 2011) and chickpea haulms (Tena, 2016) due to cultivar difference in Ethiopia. For instance, from the five faba bean varieties evaluated by Teklu (2016); the lower mean CP (4.3%), ME (6.5 MJ/kg DM), and TIVOMD (45.1%) was noted in Shallo variety than that of local variety (CP 6.2%, ME 9.2MJ/kg DM and TIVOMD 62.6%). Generally, possibility of incorporating straw traits in crop variety development programs without marginalizing grain parameters have been demonstrated with the studies conducted on various grain crops so far in Ethiopia (Adugna *et al.*, 1999; Diriba *et al.*, 2011; Tena, 2016; Yetmiwork *et al.*, 2011*).*

2.5.2. Effect of Soil Fertility Inputs on Yield and Quality of Grain Legume Haulm

Nutrient availabilities are among the major determinants of crop productivity in all cases, because plants require balanced amount of all essential nutrients for their normal physiological process that facilitate optimum growth and then final yield performance. Therefore, any crop management practices including fertilizer applications applied with an objective to increasing grain yields could be result in higher yield of crop residues also, because all yield components of any crops are a function of active vegetation growth which can be altered with different nutrient management activities (Leulseged and Jemal, 1989).

According to Asnakew *et al.* (1991) deficiency of nutrients especially N and P is a characteristic of most soils in Ethiopia and application of fertilizers to overcome these has showed significant increase in yield. On the other hand, low soil P availability and poor utilization efficiency of added P was reported as a major constraint limiting productivity of most grain legumes (Aulakh *et al.*, 2003). Nitrogen is an essential nutrient for normal plant growth and development as it has a direct roles in biochemical, physiological and morphological process of plant production (Novoa and Loomis, 1981). Unlike cereal crops, legume crops have a capacity to fix atmospheric N_2 through the symbiotic association exist between soil microbes (*Rhizobium* bacteria) and their nodules (Giller, 2001). Thus, biological nitrogen fixation (BNF) is a natural cycle that is available for solving the problem of N deficiency in agricultural systems. According to Peoples *et al.* (1995) the contribution of BNF to the nitrogen cycle is under control of many factors as it can be altered through manipulation of various nutritional, biological, physical and environmental factors. Therefore, effectiveness of BNF capacity of legume crops can be controlled through different management approaches like applications of P fertilizer and inoculations of crop seeds with more effective strains of rhizobium bacteria. Furthermore, the two components have a big interaction effect, because soil P deficiency is among the factors which can affect BNF efficiency of legume crops through its effects of root infection, nodule development and function, and plant growth (Giller, 2001; Yakubu *et al.*, 2010).

In research system, substantial numbers of experiments have been conducted to evaluate the effects of different nutrient source fertilizers including P and inoculants application separately and in combination on various legume crops with primary goal of grain traits improvement. Study conducted with an objective to evaluate effect of S and P source fertilizer on yield and yield contributing parameters of pigeon pea was showed a significant increment in haulm yields, and the maximum haulm yield (4.12 t/ha) was obtained with combined application of 20 kg S/ha with 50 kg P_2O_5/ha (Deshbhratar *et al.*, 2010). Field experiment conducted on soybean using inorganic and organic fertilizer also demonstrated variation in straw yield of the crop during two different cropping season, while significantly higher haulm yield of 5.31 t/ha harvested with application of NPK followed by urea (5.13 t/ha), compost (4.31 t/ha) and control (4.29 t/ha) in second year (Yagoub *et al*., 2012).

Study done by Ibsa (2013) had demonstrated a significant improvement obtained in chickpea due to P and inoculants application and the improvement was more prominent with combined application of phosphorus and inoculants. The same study was also illustrated an increase of haulms N content by 56% and 82% due to inoculation and phosphorus-inoculation treatments, respectively compared to the control. Another important mineral (P) content of feeds was also showed significant improvement in the chickpea haulm with higher mean value of 567mg/kg and 334mg/kg in sole P and combined P with inoculants supplied treatments, respectively (Ibsa, 2013). Significant improvement attended in haulms yield and other economically important traits and nutrient contents of haulms in chickpea at different level of P fertilizer application was discussed in detail in the literatures reviewed by Dataniya *et al.* (2014).

Similarly, Tagore *et al.* (2013) find out the effects of *rhizobium* and phosphate solubilizing bacterial (PSB) inoculants on symbiotic traits, nodule leghemoglobin, and yield of chickpea. Their study revealed significant increase in grain and haulm yields due to microbial inoculation and the highest mean grain and haulms yield (2150 kg/ha and 2461Kg/ha) were obtained in inoculation of chickpea seed with *Rhizobium* + PSB. Experiment carried out by Bozorgi *et al.* (2011) to see the effects of biological and mineral fertilization and foliar zinc spraying on yield and yield components of faba bean had demonstrated significant increment in yield and yield contributing traits of the crops. Accordingly, maximum haulms yield was obtained at 60 kg/ha pure N treatment (Bozorgi *et al.*, 2011). This study was showed significant interaction effect between N fertilization and foliar zinc spraying on the yield and yield related attributes of faba bean. Marked increment of grain and haulms yield of faba bean was also reported with the application of mineral P fertilizer with phosphorus dissolving bacteria (PDB) by Gizawy and Mehasen (2009).

In addition to grain crops, efforts were also made on evaluation of forage legumes responses to various nutrient sources fertilizers with emphasis on yield (DM and seed) and nutritional quality. Mohamed-saleem and Kaufmann (1985) had reported significant effects of P supply on DM yield, CP content, P concentration and digestibility of forage legumes. Similarly, significant improvement had obtained in DM yield and CP content of annual forage legumes in central highlands of Ethiopia due to seed inoculation with effective *Rhizobium* bacteria (Muluneh, 2006). The same finding showed that DM yield increment of inoculated vetch species over uninoculated treatments of the same species was 20.55%, 29.30%, 21.10 % and 33.56% for V. *dasycarpa, V. villosa, V. narbonensis and V. sativa*, respectively at Holleta (Nitisols).Whereas the increment reached up to 27.27%, 9.8%, 16.1% and 40.00 % for *V. dasycarpa, V. villosa, V. narbonensis and V. sativa*, respectively at Ginchi (Vertisols).

Overall, although some information available on the effect of both mineral and biological fertilizers application on crop residue yields of grain crops in general and grain legumes in particular. Limited information is available on the responses of grain legumes to the application of different fertilizers in terms of straw quality. This shows low attention given for the straw traits in most crop improvement programs. In the mixed crop-livestock farming systems where both crops and livestock have valuable importance for livelihood of the farming communities; improvement of whole plant values has a big contribution in increasing productivity of overall households farming activities.

3. MATERIAL AND METHODS

3.1. Description of the Study Area

The study was conducted in selected districts that have been used by N_2-Africa project as pilot implementation sites throughout the country. Four regional states (Amhara, Oromia, Benishangul-Gumz, and Southern Nations, Nationalities and People) were represented with different number of districts. These districts were further grouped under different clusters and tagged with different grain legumes based on the potential of the areas for the study (Table 1).

Table 1: Summary of N_2-Africa project target districts with target crops and national collaborating research partners

Partnership Clusters	Partners	Target Districts	Target Crops
North	ARARI	Enemay, Farta and Yilmana-densa, Gonder Zuria, Dembia	Chickpea and Faba Bean
Central	EIAR	Ada'a, and Gimbichu	Chickpea
Pawe	EIAR	Dibate, Pawe and Mandura	Soybean and Haricot bean
Jimma	EIAR	Kersa and Tiroafeta	Soybean
South	HwU and EIAR	Boricha, Damot-Gale, Halaba, Soddo-zuria and Shalla	Haricot Bean and Chickpea
Chewaka	OARI	Bako-Tibe, Dano, Gobu-Sayo, Illu-Gelan, and Wayu-Tuka	Soybean and Haricot bean
Southeast	OARI	Agarfa, Goba, Sinana and Ginir	Faba Bean and Chickpea

As these study districts were selected from different parts of the country and locations their agro-ecological condition also differed. Agro-ecological zone of the country is shown in Figure 1. Most of the study districts are found in agro-ecological zone of Derived Savannas, while only few numbers of districts considered from Southern Guinea Savanna, Northern Guinea Savanna and Humid Forest agro-ecological zones (Figure 1).

In general, these different locations from various agro-ecological zones are also different in soil type, temperature, rainfall, humidity and light intensity which are the major determinants for the type of crop species distributed and/or grown in the respective areas. Thus, districts used in current study are representing subsistence based small scale mixed crop-livestock farming system in which livestock production is integrated with cultivation of different crops. Overall, good annual rainfall distribution and temperature make these areas favorable for production of different crops by farmers. Altitude, mean annual rainfall and mean annual temperature of the study districts are summarized in Table 2.

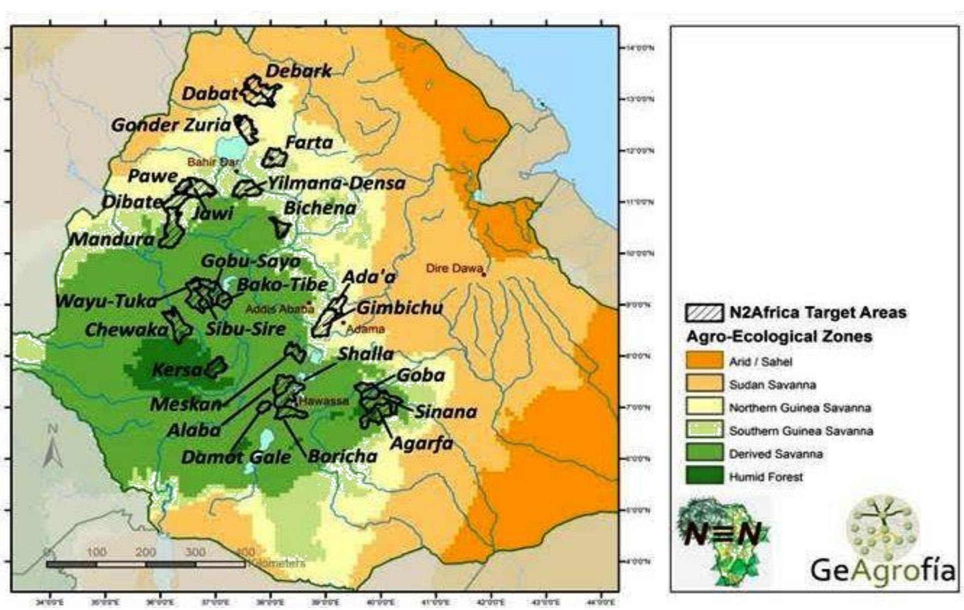

Figure 1: Map of N_2 -Africa Target Districts with Agro-ecological Zone Classification

Table 2: Altitude, annual mean rainfall and temperature profiles of the study districts

District	Altitude (m.a.s.l)	Rainfall (mm)	Temperature (^{0}C)	Target crop
Ada'a	1500-2250	877.2	12.35-26.55	Chickpea
Agarfa	1250-3855	800	17.5	Faba bean
Bako-tibe	1500-2872	-	9-31	Haricot bean and soybean
Boricha	1250-2000	500-1242	10-25	Soybean
Damot Gale	1900	1200-1300	11 – 26	Chickpea
Dibatie	1200	-	-	Haricot bean
Farta	1920-4235	1250-1599	9-25	Faba bean
Gimbichu	2400	902	-	Chickpea
Ginir	1976	1300	18-27	Chickpea
Halaba	1554-2149	857-1085	17-20	Haricot bean
Pawe	1120	-	-	Haricot bean and soybean
Shalla	1000-2300	1000	15-25	Haricot bean
Sinana	2000-2500	900-1150	15-18	Faba bean
Sodo -zuria	1950-2400	1225	13-26	Haricot bean
Yilmana Densa	2240	1000.54	-	Faba bean
Tiroafeta	1640-2800	-	-	Soybean

3.2. Crop Types and Experimental Treatments

Four grain legumes, namely faba bean (*Vicia faba*), chickpea (*Cicer arietinum*), soybean (*Glycine max*) and haricot bean (*Phaseolus vulgaris*) which are already grown in the areas were used. The experimental treatments included control (without inputs, -P-I), separate applications of phosphorus fertilizer (+P-I) and inoculants (-P+I), and combined application of phosphorus fertilizer and inoculants (+P+I) for each crop species. Hence, there were four treatments for each respective crop as arranged below.

Experimental Treatments

- T1: DAP or NPS fertilizer application and *rhizobium* inoculation (+P+I)
- T2: *Rhizobium* inoculation only (-P+I)
- T3: DAP or NPS fertilizer application only (+P-I)
- T4: Without inputs/control (-P-I)

3.3. Crop Establishment and Management

This study was applied on the crops established on selected farmers' plots in 2015/16 main cropping season for the demonstration of best bet grain legumes technologies across all locations (Table 2). Accordingly faba bean, chickpea, haricot bean and soybean were established on 20, 12, 26 and 17 selected farms, respectively. The crops were established on well prepared plots of lands. All treatments were applied on all farmers plot without replication. The plot size was $100m^2$ per treatment with one meter walking space between each treatment plots. The seed was sown to the experimental plots using row planting method. Recommended seed rate for each respective crop under a given area was used for planting, while for treatments of sole P fertilizer and inoculated-phosphorus fertilizer plots, DAP/NPS was applied at a rate of 50 kg per hectare.

For inoculated treatments, seed of faba bean, chickpea, haricot bean and soybean were inoculated with HB-1035, CP-39, HB-429 and MAR-1495 *rhizobium* strains respectively using the recommended procedures and rates by producers/manufacturer. In all cases, uninoculated seed was sown first and followed by the inoculated seeds to avoid cross contamination and the inoculated seeds were planted on the same day they have been inoculated. Moreover, all other crop husbandry practices were done by farmers under close supervision of the researchers and development workers until the crops reach physiological maturity for grain harvesting.

3.4. Harvesting, Sample Collection and Yield Determination

At appropriate stage of physiological maturity of the crops for grain harvesting, plants from entire plot area were harvested manually using sickles and total above ground biomass yield was recorded for each plot. Then, the harvested plants were threshed separately for each plot to separated grain from haulms, and the grain yield was measured. Furthermore, the haulm weight was determined by subtracting weight of grain from the total above ground biomass weight. In the mean time, representative samples of grain (100-200gm) and whole plant haulm composed of stems, leaf and pod husks (500-1000gm) were collected into sample bags for each plot separately and labeled with all necessary information.

3.5. Estimation of Haulm Dry Matter Yield and Harvest Index

Haulm dry matter yield (HDMY) was estimated according to the formula developed by Tarawalie *et al.* (1995) by using above ground total biomass and grain yield data. Dry matter (DM %) used for HDMY estimation was determined using NIRS prediction. Harvest index (HI) was calculated as a ratio of total grain yield to total above ground biomass yield.

$$HDMY = \frac{DM\% * TFW}{100}$$

Where: HDMY=Haulm dry matter yield, TFW= total fresh weight of the haulm, DM %= dry matter percent of the haulm

$$HI = \frac{GY}{TBMY}$$

Where: HI=harvest index, GY=grain yield, TBMY=total above ground biomass yield

3.6. Laboratory Analysis of Grain and Haulm Samples

Collected grain and haulm samples were transported to ILRI Animal Nutrition Laboratory, Addis Abeba for laboratory analysis. The samples were given laboratory number and ground to 1mm mesh size using Wiley mill and packed into paper bags and stored pending to further laboratory works. Near Infrared Reflectance Spectroscopy (NIRS) prediction were employed for the analysis of the intended nutritional value variables of both grain and haulm samples.

Accordingly, haulm samples were scanned for predication of DM (%), Ash (%), N (%), ME (MJ/kg DM), IVOMD(%),and fiber fractions (NDF%, ADF% and ADL%) contents, while in grain samples the scanning was done for the predication of DM (%), Ash (%), CP (%), ME (MJ/kg), IVOMD (%), and essential amino acid contents of the grain. Crude protein (CP %) of grain and haulm samples were determined by multiplying N content of the samples with the conversion factor of 6.25. For scanning purpose, already ground sample was dried overnight at 60^0C in oven to standardize the moisture conditions. Then, the partially dried sample was filled into NIRS cup and scanned using Foss NIRS 5000 with software package WinISI II in the 1108-2492nm spectra ranges (Win Scan version 1.5, 2000, intrasoft international, L.L.C). Finally, NIRS scanned information of the haulm and grain samples were used for the prediction of the above mentioned nutritional value variables, using predictive equations developed based on previously conducted conventional analyses.

3.7. Selection of Survey Districts and Household Data Collection

After crop harvest, three districts (Sinana, Damot-Gale and Ada'a) were selected purposively based on their accessibility and intensity of crop production for the survey purpose from the districts which were used for experimental study (Table 2). Then, single-visit survey was carried out to assess farmers' grain legume haulm utilization practices and their perception of the effects of P fertilizer and *rhizobium* inoculation on the haulm yield and quality using semi-structured questionnaires. Accordingly, 28 households from each of Ada'a and Sinana districts, and 34 households from Damot-Gale district were considered for the collection of household data. Then, the selected households were interviewed individually.

During the survey, information was mainly gathered on livestock holding, total landholding and land use pattern, type of grain legumes grown in earlier year, household level uses of legume haulms, method of straw collection, treatment, storage and feeding to animals, their perception on the effect of P fertilizer and *rhizobium* inoculants on yield and quality the haulms, trends in use of grain legume haulms for livestock feeding, limitations of using legume haulm for livestock feeding.

3.8. Statistical Analysis

Household survey data was analyzed using Statistical Package for Social Science (SPSS, Ver.16). Descriptive statistics (percentage, mean and standard error) are used to present the survey result. Further, data on livestock and land holding and land use pattern of the surveyed households were subjected to general linear model (GLM) of SPSS for analysis of variance. Yield and laboratory result data were checked for compliance of homogeneity of variances in Minitab software using Levene’s test prior to actual analysis of the variance (Levene, 1960). Then, combined analyses of variance (ANOVA) was performed using general linear model (GLM) procedure of SAS 9.1 in random complete block design (RCBD) considering farms as block factor. P value of <0.05 was used to declare significance effects of the treatment. In case of significant difference in means, Duncan Multiple Range Test was used to locate mean separation. Effect of treatment, location and the interaction between treatment and location were included in the statistical model for yield and quality data. Thus, the following model was used:

$$\mathbf{Y_{ijk} = \mu + T_i + L_j + TL_{ij} + F_{k(j)} + e_{ijk},}$$

Where; Y_{ijk} = Quantity and quality attributes of the crops

μ = overall mean

T_i = the effect of treatment i

L_j= the effect of location j

TL_{ij} = the effect of interaction of treatments i and location j

$F_{k(j)}$ = the effect of farm (block) k in location j

e_{ijk} = random error

4. RESULTS

4.1. Effects of the *Rhizobium* Inoculation and Phosphorus Fertilizer on Yield and Yield Components of Grain Legumes

Faba bean, chickpea, soybean and haricot bean were grown on-farm during main cropping season of 2015/16 to evaluate their responses to the soil fertility treatments which include seed inoculation with *rhizobium* bacteria and application of P fertilizer alone and in combination. The effects of *rhizobium* inoculation and P fertilizer application on grain and haulm yield as well as harvest index of the four grain legumes is presented and discussed below.

4.1.1. Grain Yield and Haulm Yield and Harvest Index of Faba Bean

The mean grain yield, haulm DM yield and harvest index of faba bean grown under different soil fertility treatments are presented in Table 3. There was significant effect ($P<0.05$) of the treatments on the grain and haulm DM yield of faba bean in the present study. However, the interaction effect of treatment with location was not significant ($P>0.05$) in all studied yield parameters (Appendix Table 1).

The highest mean grain yield of faba bean (2.87 t/ha) was obtained with treatment +P+I followed by treatment +P-I (2.84 t/ha) (Table 3). Similarly, significant improvement was observed in haulm DM yield of faba bean (3.61 t/ha) due to combined application of *rhizobium* inoculants and P fertilizer (Table 3). On the other hand, haulm DM yield of the remaining three treatments (-P+I, +P-I and -P-I) showed only numerical differences ($P>0.05$). In contrast to grain and haulm DM yield, harvest index of faba bean was not significantly affected ($P>0.05$) by the treatments. Harvest index of faba bean ranged between 0.42 and 0.46 (Table 3).

Table 3: Mean grain and haulm yield and harvest index of faba bean as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatments				*SEM*	*SL*
	+P+I	**-P+I**	**+P-I**	**-P-I**		
GY (t/ha)	2.87^{a}	2.55^{b}	2.84^{a}	2.65^{ab}	***0.38***	*
HDMY (t/ha)	3.61^{a}	3.00^{b}	2.95^{b}	2.85^{b}	***0.77***	*
HI	0.42	0.44	0.46	0.46	***0.70***	***ns***

$^{a, b, c}$ Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, GY: grain yield. HDMY: haulm dry matter yield, HI: harvest index, SEM: Standard error of mean, SL: significance level, ns: not significant

4.1.2. Grain Yield and Haulm Yield and Harvest Index of Chickpea

The mean grain yield, haulm DM yield and harvest index of chickpea grown under *rhizobium* inoculation and P fertilizer application are presented in Table 4. The soil fertility treatments were found to significantly affect (P<0.05) grain yield and harvest index of chickpea. But analysis of variance showed that all studied yield parameters in chickpea were not significantly (P>0.05) affected by the interaction of treatment by location (Appendix Table 2). The mean grain yields of treatment +P+I and -P+I were significantly higher (P<0.05) than that of the control and +P-I treatments (Table 4). The haulm DM yield of chickpea varied between 2.25 t/ha (control) to 2.47 t/ha (treatment -P+I) but the difference among the treatments were not significant (P>0.05). The harvest index was highest (0.46) in treatment +P+I, while the lowest value (0.40) was obtained in the two uninoculated treatments (Table 4).

Table 4: mean grain and haulm yield and harvest index of chickpea as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatments				*SEM*	*SL*
	+P+I	**-P+I**	**+P-I**	**-P-I**		
GY (t/ha)	2.13^{a}	1.98^{a}	1.65^{b}	1.50^{b}	***0.26***	***
HDMY (t/ha)	2.44	2.47	2.30	2.25	***0.39***	***Ns***
HI	0.46^{a}	0.42^{ab}	0.40^{b}	0.40^{b}	***0.07***	*

$^{a, b, c}$ Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, GY: grain yield. HDMY: haulm dry matter yield, HI: harvest index, SEM: Standard error of mean, SL: significance level, ns: not significant

4.1.3. Grain Yield and Haulm Yield and Harvest Index of Haricot Bean

Table 5 shows the mean grain yield and haulm DM yield as well as harvest index of haricot bean. The yield parameters (grain and haulm DM yield and harvest index) of haricot bean were significantly influenced ($P<0.05$) by the application of *rhizobium* inoculants and P fertilizer. Analysis of variance also revealed significant interaction effect ($P<0.05$) of treatment by location on haricot bean yield parameters (Appendix Table 3).

Grain yield of haricot bean showed increasing trend with application of the soil fertility treatments, although the improvement attended in the case of separate applications of the inputs (treatment -P+I and +P-I) was not significant ($P>0.05$) over the control treatment (-P-I). Accordingly, the highest mean grain yield (1.98 t/ha) was recorded in the +P+I treatment, whereas the lowest value (1.60 t/ha) was recorded in the control (Table 5). The haulm DM yield was higher (P<0.05) in the +P+I treatment than the single input supplied treatments but was not significantly different from the control. Harvest index calculated for haricot bean also revealed the presence of significant variations among the treatments (P<0.05) and the highest (0.52) and lowest (0.47) values of harvest index were obtained in sole P fertilized (+P-I) and control treatments, respectively.

Table 5: Mean grain and haulm yield and harvest index of haricot bean as affected by *rhizobium* inoculation and P fertilizer

Parameters	**Treatments**				***SEM***	***LS***
	+P+I	**-P+I**	**+P-I**	**-P-I**		
GY (t/ha)	1.98^{a}	1.80^{ab}	1.74^{ab}	1.60^{b}	***0.43***	*****
HDMY (t/ha)	1.84^{a}	1.55^{b}	1.54^{b}	1.62^{ab}	***0.35***	*****
HI	0.50^{ab}	0.51^{ab}	0.52^{a}	0.47^{b}	***0.06***	*****

$^{a, b, c}$ Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, GY: grain yield. HDMY: haulm dry matter yield, HI: harvest index, SEM: Standard error of mean, SL: significance level

4.1.4. Grain Yield and Haulm Yield and Harvest Index of Soybean

The mean grain yield, haulm DM yield and harvest index of soybean are presented in Table 6. Analysis of variance showed that yield parameters of soybean significantly responded (P<0.05) to the treatments with increasing in grain and haulm DM yield compared to the control. On the other hand, there was non-significant interaction effect (P>0.05) between treatment and location on yield parameters of soybean (Appendix Table 4). The maximum mean grain yield (2.56 t/ha) of soybean was obtained from the treatment +P+I, followed by -P+I (2.46 t/ha) and +P-I (2.10

t/ha) treatments (Table 6). Meanwhile, grain yield harvested from control treatment (1.75 t/ha) was significantly lower than the two inoculated treatments but in par with treatment +P-I (Table 6).

Table 6: Mean grain and haulm yield and harvest index of soybean as affected by *rhizobium* inoculation and P fertilizer

Parameters	**Treatments**				***SEM***	***SL***
	+P+I	**-P+I**	**+P-I**	**-P-I**		
GY (t/ha)	2.56^{a}	2.46^{a}	2.10^{ab}	1.75^{b}	***0.79***	***
HDMY (t/ha)	3.07^{a}	3.23^{a}	2.32^{b}	2.12^{b}	***0.25***	****
HI	0.50	0.48	0.52	0.50	***0.11***	***ns***

[a, b, c] Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, GY: grain yield. HDMY: haulm dry matter yield, HI: harvest index, SEM: Standard error of mean, SL: significance level, ns: not significant

The effect of *rhizobium* inoculation was more prominent than P fertilizer supply in both grain and haulm DM yield of soybean. The highest mean haulm DM yields (3.23 t/ha and 3.07t/ha) were obtained from the inoculated treatments (-P+I and +P+I). Haulm DM yields of the two uninoculated treatments (+P-I= 2.32 t/ha and -P-I=2.12 t/ha) were not significantly different (Table 6). On the other hand, no significant effects were observed among the different treatments in harvest index of soybean (Table 6).

4.2. Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer on Nutritional Values of Grain Legume Haulm

4.2.1. Nutritional Values of Faba Bean Haulm

The effects of *rhizobium* inoculants and P fertilizer on chemical composition, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) values of faba bean haulm are shown in Table 7. Analysis of variance done on haulm quality revealed significant difference (P<0.05) among the treatments in all studied parameters except the ash content. Moreover, except the CP content of the haulm, the remaining parameters were not significantly affected by the interaction between treatment and location (Appendix Table 5).

The mean ash (%) content of faba bean haulm obtained in the current study ranged from 6.91% in control treatment (-P-I) to 7.78% in treatment +P-I but the ash content was not significantly varied across the treatments (Table 7). The results showed that application of soil fertility treatments had a significant positive influence (P<0.05) on CP (%) content of faba bean haulm. As a consequence, the CP content was higher in input supplied treatments (+P+I, -P+I and +P-I) compared with the control treatment (-P-I) and the values were similar among the input supplied treatments (Table 7).

The application of *rhizobium* inoculants and P fertilizer had significant negative effects (P<0.05) on haulm NDF, ADF and ADL contents of faba bean. Thus, control treatment (-P-I) contained significantly higher mean NDF, ADF and ADL values than the remaining treatments (Table 12). There was no significant differences among the input supplied treatments (+P+I, -I+P and +P-I) in NDF, ADF and ADL contents of the haulm. The IVOMD (%) and ME (MJ/kg DM) values of faba bean haulm were significantly lower (P<0.05) in the control than in the different soil fertility treatments supplied groups (Table 7).

Table 7: Mean nutritional values of faba bean haulm as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatment				*SEM*	*SL*
	+P+I	**-P+I**	**+P-I**	**-P-I**		
DM (%)	90.07	90.06	90.05	90.28	***0.19***	*
Ash (%DM)	7.64	7.67	7.78	6.91	***1.28***	***ns***
CP (%DM)	6.52[a]	6.45[a]	6.38[a]	5.25[b]	***1.01***	*
NDF (%DM)	64.93[b]	64.85[b]	64.75[b]	70.53[a]	***4.76***	*
ADF (%DM)	58.91[b]	58.64[b]	58.56[b]	64.15[a]	***4.68***	*
ADL (%DM)	12.66[b]	12.48[b]	12.61[b]	13.46[a]	***0.88***	*
IVOMD (%DM)	46.99[a]	46.44[a]	46.65[a]	42.99[b]	***3.69***	*
ME (MJ/Kg DM)	6.85[a]	6.77[a]	6.81[a]	6.29[b]	***0.51***	*

[a, b, c] Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin, IVOMD: *in vitro* organic matter digestibility, ME: metabolisable energy, SEM: Standard error of mean, SL: significance level, ns: not significant

4.2.2. Nutritional Values of Chickpea Haulm

Haulm chemical composition, IVOMD and ME values of chickpea are given in Table 8. Analysis of variance revealed that the CP and ME contents and IVOMD value of chickpea haulm were significantly improved (P<0.05) with the applications of *rhizobium* inoculants and P fertilizer. No significant differences (P>0.05) were observed in ash, NDF, ADF and ADL contents of the haulm among the different treatments. The result also showed highly significant (P<0.001) interaction effect of treatment by location on haulm CP content of chickpea (Appendix Table 6).

Table 8: Mean nutritional values of chickpea haulm as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatment				*SEM*	*SL*
	+P+I	-P+I	+P-I	-P-I		
DM (%)	90.57	90.57	90.56	90.54	***0.23***	***ns***
Ash (%DM)	6.78	6.90	6.58	6.73	***1.04***	***ns***
CP (%DM)	4.32[a]	3.66[b]	3.60[b]	3.31[c]	***0.48***	***
NDF (%DM)	62.1	62.95	63.53	63.22	***2.94***	***ns***
ADF (%DM)	49.16	50.54	50.84	50.76	***2.73***	***ns***
ADL (%DM)	10.93	10.91	11.11	11.04	***0.59***	***ns***
IVOMD (%DM)	47.67[a]	46.51[ab]	45.81[b]	45.90[b]	***2.33***	**
ME (MJ/Kg DM)	7.36[a]	7.14[b]	7.07[b]	7.06[b]	***0.31***	**

Mean values with different letters of superscript [a, b, c] within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin, IVOMD: *in vitro* organic matter digestibility, ME: metabolisable energy, SEM: Standard error of mean, SL: significance level, ns: not significant

The CP content of chickpea haulm was highest (4.32%) in the +P+I, treatment and lowest (3.31%) in the control treatment. The remaining treatments (-P+I and +P-I) had an intermediate values of CP content. The IVOMD and ME values of chickpea haulm also showed positive responses (P<0.05) to the soil fertility treatments. A significant improvement was achieved in IVOMD and ME values of the haulm when combined application of *rhizobium* inoculants and P fertilizer (treatment +P+I) were used (Table 8).

4.2.3. Nutritional Values of Haricot Bean Haulm

Table 9 shows the mean nutritional values of haricot bean haulm as affected by *rhizobium* inoculation and P fertilizer application. The *rhizobium* inoculation and P fertilizer application had significant effects (P<0.05) on all nutritional quality components of haricot bean haulm except the ADL content.

The ash content of the haricot bean haulm was increased significantly (P<0.05) with the combined application of *rhizobium* inoculants and P fertilizer over sole P fertilization and control. Similarly, *rhizobium* inoculation and P fertilizer had significant positive effect (P<0.01) on CP content of haricot bean haulm. The highest mean haricot bean haulm CP content (7.50%) was obtained from +P+I treatment followed by -P+I (6.85%) and +P-I (6.72%) treatments, whereas significantly lowest CP content (5.94%) was recorded from the control treatment (Table 9).

The NDF and ADF contents of haricot bean haulm were significantly decreased (P<0.05) with the application of soil fertility treatments. The IVOMD of haricot bean haulm was increased (P<0.05) from 55.70% in control treatment (-P-I) to 57.79% in the +P+I treatment. The ME content of haricot bean haulm also showed significant increment (P<0.05) due to *rhizobium* inoculation over uninoculated treatments (Table 9).

Table 9: Mean nutritional values of haricot bean haulm as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatments				*SEM*	*SL*
	+P+I	**-P+I**	**+P-I**	**-P-I**		
DM (%)	91.15	91.07	91.14	91.04	***0.29***	***ns***
Ash (%DM)	8.50[a]	8.01[ab]	7.82[b]	7.63[b]	***1.06***	*
CP (%DM)	7.50[a]	6.85[ab]	6.72[b]	5.94[c]	***1.2***	**
NDF (%DM)	67.76[b]	69.02[ab]	69.94[a]	69.79[a]	***2.63***	*
ADF (%DM)	54.96[b]	56.05[ab]	57.18[a]	56.99[a]	***2.73***	*
ADL (%DM)	7.93	8.21	8.35	8.38	***0.83***	***ns***
IVOMD (%DM)	57.79[a]	56.80[ab]	55.80[b]	55.70[b]	***2.53***	*
ME (MJ/Kg)	8.72[a]	8.65[ab]	8.58[b]	8.58[b]	***0.21***	*

Mean values with different letters of superscript [a, b, c] within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin, IVOMD: true *in vitro* organic matter digestibility, ME: metabolisable energy, SEM: Standard error of mean, SL: significance level, ns: not significant

4.2.4. Nutritional Values of Soybean Haulm

Nutritional value parameters analyzed for soybean haulm are presented in Table 10. The soil fertility treatments had significant effects ($P<0.05$) on CP content, IVOMD and cell wall constituents of the haulm of soybean. The study also showed treatment by location interaction effects on CP content, IVOMD and ME values of soybean haulm (Appendix Table 8). Soybean haulm CP content was significantly increased ($P<0.05$) due to the application of *rhizobium* inoculants both with and without P fertilization. The mean CP contents of +P+I (6.74%) and -P+I

(6.08%) were significantly higher than the results of the remaining treatments viz. +P-I (5.30%) and the control (4.67%).

Table 10: Mean nutritional values of soybean haulm as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatments				*SEM*	*SL*
	+P+I	-P+I	+P-I	-P-I		
DM (%)	90.6	90.59	90.57	90.39	***0.28***	***ns***
Ash (%DM)	5.88	5.87	5.73	6.06	***0.74***	***ns***
CP (%DM)	6.74^{a}	6.08^{a}	5.30^{b}	4.67^{b}	***0.97***	***
NDF (%DM)	74.06^{b}	75.27^{ab}	75.48^{a}	76.35^{a}	***2.24***	*
ADF (%DM)	57.02^{b}	57.54^{b}	57.90^{b}	59.75^{a}	***2.36***	*
ADL (%DM)	10.60^{b}	10.71^{b}	10.62^{b}	11.23^{a}	***0.47***	*
IVOMD (% DM)	50.62^{a}	50.19^{ab}	49.38^{b}	49.55^{b}	***1.39***	**
ME (MJ/Kg DM)	8.82	8.79	8.76	8.74	***0.13***	***ns***

$^{a, b, c}$ Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin, IVOMD: *in vitro* organic matter digestibility, ME: metabolisable energy, SEM: Standard error of mean, SL: significance level, ns: not significant

The soil fertility treatments resulted in reduced NDF, ADF and ADL contents of soybean haulm. Thus, the control treatment (-P-I) contained significantly higher NDF, ADF and ADL contents than the treatments that received soil fertility enhancing inputs, though single input supplied treatments contained similar NDF with the control treatment. The IVOMD of soybean haulm showed significant increase as a result of the use of *rhizobium* inoculants. As a result, the maximum mean IVOMD (50.62%) value of soybean haulm was recorded in treatment +P+I, whereas the lowest mean value of IVOMD (%) was obtained in uninoculated treatments (+P-I = 49.38% and -P-I = 49.55%). As shown in Table 10, all treatments had similar ME value of soybean haulm in the current study.

4.3. Effect of *Rhizobium* Inoculation and Phosphorus Fertilizer on Grain Quality Parameters of Grain Legumes

4.3.1. Thousand Seed Weight

Mean thousand seed weight (gram) of chickpea, haricot bean and soybean grain is presented in Table 11. The thousand grain weight of haricot bean showed significant increase (P<0.001) as a result of *rhizobium* inoculation and P fertilizer application. Thus, the highest mean thousand seed weight (210.55 g) was recorded in the treatment with combined application of the inputs (+P+I) whereas the lowest (199.15 g) was observed in the control (-P-I). Thousand seed weight of soybean and chickpea grains from +P+I, -P+I and +P-I treatments were heavier than the control (-P-I), although the difference was not significant (P>0.05).

Table 11: Mean thousand seed weight (gram) of chickpea, haricot bean and soybean as affected by *rhizobium* inoculation and P fertilizer

Crop species	**Treatments**				***SEM***	***SL***
	+P+I	**-P+I**	**+P-I**	**-P-I**		
Chickpea	284.09	283.57	280.77	277.69	**11.24**	***ns***
Haricot bean	210.55^{a}	204.01^{bc}	207.16^{ab}	199.15^{c}	***8.25***	*******
Soybean	142.76	145.45	145.74	137.1	***11.52***	***ns***

[a, b, c] Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, SEM: standard error of mean, SL: significance level, ns: not significant

4.3.2. Grain Chemical Composition, Digestibility and Metabolizable Energy Values

The mean chemical composition, ME and IVOMD value of chickpea, haricot bean and soybean grain are given in Table 12, 13 and 14, respectively. There were significant differences ($P<0.05$) among the treatments in grain CP, ME and IVOMD values of haricot bean, whereas the ash content was not affected ($P>0.05$) by the treatments. The highest mean grain CP content (27.80%) of haricot bean was obtained from treatment +P-I, while the lowest values (26.82 and 26.95%) were recorded from the treatments without P fertilizer applications (-P+I and -P-I).

Table 12: Mean nutritional values of chickpea grain as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatments				*SEM*	*SL*
	+P+I	-P+I	+P-I	-P-I		
DM (%)	96.38	96.50	96.37	96.43	***0.22***	***ns***
Ash (%DM)	3.79	3.77	3.70	3.72	***0.19***	***ns***
CP (%DM)	20.19	19.74	19.76	19.83	***0.94***	***ns***
ME (MJ/Kg DM)	10.49	10.46	10.5	10.49	***0.10***	***ns***
IVOMD (% DM)	72.07	71.79	72.01	71.95	***0.77***	***ns***

Mean values with different letters of superscript [a, b, c] within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, ME: metabolizable energy, IVOMD: *in vitro* organic matter digestibility, SEM: standard error of mean, SL: significance level, ns: not significant

As shown in Table 13, there was significant variation (P<0.05) among the treatments in ME content and IVOMD of haricot bean grain. The +P-I treatment resulted in highest mean ME content (11.98 MJ/Kg DM) and TIVOMD value (83.15%) compared to the other treatments; although the IVOMD value was not significantly different from that of +P+I (Table 13).

Table 13: Mean nutritional values of haricot bean grain as affected by *rhizobium* inoculation and P fertilizer

Parameters	Treatments				*SEM*	*SL*
	+P+I	-P+I	+P-I	-P-I		
DM (%)	95.27	95.14	95.24	95.22	***0.24***	***ns***
Ash (%DM)	5.25	5.16	5.23	5.20	***0.15***	***ns***
CP (%DM)	27.48^{ab}	26.82^{b}	27.80^{a}	26.95^{b}	***1.00***	***
ME (MJ/Kg DM)	11.92^{b}	11.87^{b}	11.98^{a}	11.89^{b}	***0.10***	****
IVOMD (% DM)	82.64^{ab}	82.25^{b}	83.15^{a}	82.38^{b}	***0.83***	****

$^{a, b, c}$ Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, ME: metabolizable energy, IVOMD: *in vitro* organic matter digestibility, SEM: standard error of mean, SL; significance level, ns: not significant

The ash, CP and ME contents and IVOMD value of soybean grain showed significant response (P<0.05) to the application of soil fertility treatments (Table 14). The *rhizobium* inoculation had highly significant (P<0.001) effect on grain CP content of soybean and the highest mean values (42.97 and 43.17%) were recorded in +P+I and -P+I treatments, respectively (Table 14). The ME and IVOMD values of soybean grain were also increased significantly (P<0.001) with the application of *rhizobium* inoculants. The highest mean ME contents (10.14 and 10.15 MJ/Kg DM) recorded in inoculated treatments (+P+I and -P+I) were significantly higher than the mean values of ME (9.50 and 9.73 MJ/Kg DM) obtained from uninoculated treatments (+P-I and -P-I). The IVOMD of soybean grain showed similar trend of change with CP and ME (Table 19). The interaction effect of treatment by location was significant only for CP content and IVOMD of the haricot bean grain (Appendix Table 9, 10). In soybean grain, significant (P<0.05) treatment by location interaction effects were observed for all studied parameters (Appendix Table 11).

Table 14: Mean nutritional values of soybean grain as affected by *rhizobium* inoculation and P fertilizer

Parameters	**Treatments**				***SEM***	***SL***
	+P+I	**-P+I**	**+P-I**	**-P-I**		
DM (%)	97.83	97.78	98.78	97.81	***0.13***	***ns***
Ash (%DM)	6.06[a]	6.08[a]	5.88[b]	5.81[b]	***0.19***	**
CP (%DM)	42.97[a]	43.17[a]	40.73[b]	39.32[b]	***2.27***	***
ME (MJ/Kg DM)	10.14[a]	10.15[a]	9.73[b]	9.50[b]	***0.38***	***
TIVOMD (% DM)	78.12[a]	78.32[a]	75.13[b]	73.40[b]	***2.86***	***

[a, b, c] Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, DM: dry matter, CP: crude protein, ME: metabolizable energy, IVOMD: *in vitro* organic matter digestibility, SEM: standard error of mean, SL: significance level, ns: not significant

4.3.3. Grain Essential Amino Acid Contents

Essential amino acid contents of chickpea, haricot bean and soybean grain are presented in Table 15, 16 and 17, respectively. The essential amino acid contents of haricot bean and soybean grain were significantly affected ($P<0.05$) by the application of the *rhizobium* inoculants and P fertilizer. The essential amino acid contents of haricot bean grain improved significantly ($P<0.05$) with the application of P fertilizer with more prominent improvement in the case of sole P fertilizer application in most parameters. Accordingly, higher mean value of histidine (0.95%), threonine (0.96%), valine (1.10%), isoleucine (0.86%), leucine (1.96%), tryptophane (0.27%), cystine (0.41%) and tyrosine (0.69%) were obtained from treatment +P-I (Table 16). On the other hand, higher mean value of total amino acid (22.90 and 23.01%) and phenylalanine (1.36 and 1.37%) content of haricot bean grain were recorded in +P+I and +P-I treatments (Table 16).

The essential amino acid contents of soybean grain showed highly significant ($P<0.001$) response to soil fertility treatments. In most parameters, the significant increment was obtained in *rhizobium* inoculated treatments (+P+I and -P+I) than uninoculated treatments (Table 17). Furthermore, histidine, tryptophane and tyrosine in treatment +P-I showed significant increment over the control (Table 17). As a consequence, significantly higher mean values of individual essential and total amino acids were recorded in *rhizobium* inoculated treatments both with and without P fertilization (Table 17).

Table 15: Mean essential amino acid contents of chickpea grain as affected by *rhizobium* inoculation and P fertilizer

Essential amino acids (% DM)	Treatments				*SEM*	*SL*
	+P+I	-P+I	+P-I	-P-I		
Cystine	0.31	0.31	0.31	0.31	***0.01***	***ns***
Histidine	0.79	0.78	0.78	0.78	***0.02***	***ns***
Isoleucine	0.67	0.66	0.66	0.66	***0.03***	***ns***
Leucine	1.71	1.69	1.69	1.69	***0.05***	***ns***
Lysine	1.28	1.26	1.27	1.27	***0.05***	***ns***
Methionine	0.19	0.18	0.18	0.18	***0.01***	***ns***
Phenylalanine	1.03	1.01	1.01	1.01	***0.04***	***ns***
Threonine	0.73	0.72	0.72	0.72	***0.03***	***ns***
Tryptophane	0.18	0.18	0.18	0.17	***0.01***	***ns***
Valine	0.72	0.70	0.70	0.70	***0.04***	***ns***
Total Amino acid	17.70	17.39	17.37	17.39	***0.63***	***ns***

+P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, SEM: standard error of mean, SL: significant level, ns: not significant

Table 16: Mean essential amino acid contents of haricot bean grain as affected by *rhizobium* inoculation and P fertilizer

Essential amino acids (% DM)	Treatments				*SEM*	*SL*
	+P+I	**-P+I**	**+P-I**	**-P-I**		
Cystine	0.40^{bc}	0.39^{c}	0.41^{a}	0.40^{bc}	***0.01***	*
Histidine	0.94^{ab}	0.92^{c}	0.95^{a}	0.93^{bc}	***0.02***	*
Isoleucine	0.84^{ab}	0.82^{b}	0.86^{a}	0.83^{b}	***0.04***	*
Leucine	1.94^{ab}	1.90^{b}	1.96^{a}	1.90^{b}	***0.07***	*
Lysine	1.52	1.51	1.56	1.53	***0.05***	***ns***
Methionine	0.26^{a}	0.25^{ab}	0.25^{ab}	0.24^{b}	***0.01***	*
Phenylalanine	1.36^{a}	1.32^{b}	1.37^{a}	1.32^{b}	***0.05***	*
Threonine	0.94^{ab}	0.92^{c}	0.96^{a}	0.92^{bc}	***0.03***	*
Tryptophane	0.26^{ab}	0.25^{b}	0.27^{a}	0.26^{ab}	***0.01***	*
Valine	1.07^{ab}	1.05^{b}	1.10^{a}	1.06^{b}	***0.04***	*
Total Amino acid	22.90^{a}	22.28^{b}	23.01^{a}	22.37^{b}	***0.78***	*

$^{a, b, c}$ Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, SEM: standard error of mean, SL: significant level, ns: not significant

Table 17: Mean essential amino acid contents of soybean grain as affected by *rhizobium* inoculation and P fertilizer

Essential amino acids (% DM)	Treatments				*SEM*	*SL*
	+P+I	-P+I	+P-I	-P-I		
Cystine	0.52[a]	0.52[a]	0.50[b]	0.48[c]	***0.02***	***
Histidine	1.07[a]	1.08[a]	1.01[b]	0.97[c]	***0.06***	***
Isoleucine	1.70[a]	1.72[a]	1.61[b]	1.55[b]	***0.10***	***
Leucine	2.86[a]	2.88[a]	2.70[b]	2.60[b]	***0.16***	***
Lysine	2.16[a]	2.16[a]	2.07[b]	2.00[b]	***0.11***	***
Methionine	0.40[a]	0.41[a]	0.38[b]	0.36[b]	***0.03***	***
Phenylalanine	1.96[a]	1.97[a]	1.83[b]	1.76[b]	***0.12***	***
Threonine	1.44[a]	1.45[a]	1.36[b]	1.31[b]	***0.08***	***
Tyrosine	0.48[a]	0.48[a]	0.45[b]	0.43[c]	***0.03***	***
Valine	1.84[a]	1.85[a]	1.73[b]	1.67[b]	***0.11***	***
Total Amino acid	36.57[a]	36.80[a]	34.25[b]	32.82[b]	***2.25***	***

[a, b, c] Mean values with different letters of superscript within the rows are significantly different at 5% probability level, +P+I= phosphorus fertilizer with inoculation, -P+I= inoculation only, +P-I= phosphorus fertilizer only, -P-I=control, SEM: standard error of mean, SL: significance level

4.4. Socio-economic Characteristics and Perception of the Households on the Effects of *Rhozobium* Inoculation and Phosphorus Fertilizer

In this study, household survey was also conducted to get farmers viewpoint on the effects of *rhozobium* inoculation and P fertilizer on haulm yield and quality as well as to know the current status of grain legume haulm use practices under smallholder farmers' conditions. The results on household socio-economic characteristics, livestock feed sources, household level uses of grain legume haulm, and farmers' perception on the effects of these soil fertility treatments on haulm yield and quality are presented in the following sections.

4.4.1. Household Characteristics

The demographic characteristics of the sampled households of the study area i presented in Table 18. Majority of respondents were male headed households (95.6%). As indicated in Table 18, the overall mean age of the household heads was 42.61±0.92 years, with a range of 39-68 years. There was significant difference ($P<0.05$) among districts in mean age of the household heads and it was 39.29±1.06, 43.75±1.87 and 45.50±1.70 years at Damot-Gale, Ada'a and Sinana districts, respectively. The overall result concerning level of education of household heads showed that 62.2% and 17.8% of the respondents attended primary (grade 1-8) and secondary (above grade 8) school education, respectively (Table 18). About 12.2% of the respondents also have the ability to read and write (obtained through basic and traditional education), while the remaining 7.8% were illiterate.

Table 18: Basic households' characteristics of surveyed farmers

Descriptors		Ada'a (N=28)	Sinana (N=28)	Damot-Gale (N=34)	Overall (N=90)
Age	Years (Mean ±SE)	43.75 (1.87)[a]	45.50 (1.70)[a]	39.29(1.06)[b]	42.61 (0.92)
Sex (%)	Male	92.1	100	94.1	95.6
	Female	7.1	-	5.9	4.4
Educational status (%)	Illiterate	10.7	7.1	5.9	7.8
	Basic education	25	10.7	2.9	12.2
	1-8 grade	64.3	71.4	52.9	62.2
	Above grade 8	-	10.7	38.2	17.8

4.4.2. Livestock and Land Holding and Land Use Pattern of the Households

The average livestock (TLU) and landholding (ha) per household and land use patterns of the respondents are presented in Table 19. The overall mean livestock holding of the smallholder farmers in the study area was 5.86±0.42 TLU per household. The average livestock holding per household was significantly higher ($P<0.05$) in Ada'a district (8.63±0.61 TLU) than the other two districts. On the other hand, the livestock holding in Damot-Gale district (3.04±0.56 TLU) was significantly lower ($P<0.05$) with intermediate value in Sinana district (Table 19).

The current survey showed that the overall average total land holding per household in the study area was 2.10±0.13ha.Total land (3.24±0.14 ha) and cultivated land (2.57±0.12 ha) holding per household in Sinana district was significantly higher ($P<0.05$) than in Ada'a (2.52±0.14 ha total land and 2.02±0.12ha cultivated land) and in Damot-Gale (0.81±0.13ha total land and 0.53±0.11ha cultivated land) districts. On the other hand, land allocated for grain legumes production in Ada'a district (0.95±0.07ha) was significantly ($P<0.05$) higher than in Sinana

(0.21±0.07 ha) and Damot Gale (0.24 ±0.06ha) districts. Common grain legumes (pulse crops) grown by smallholder farmers in the surveyed districts are shown in Figure 2.

The average grazing landholding per household was very small and not significantly different (P>0.05) among the study districts. The overall mean grazing land owned per household in the study area was 0.12±0.02 ha (Table 19). Moreover, the land allocated for cultivated fodder per household was significantly different (P<0.05) among the surveyed districts. As shown in Table 4, the average farm size (0.11±0.02ha) allocated for fodder production per household in Sinana district was significantly larger than the remaining two districts.

Table 19: Mean livestock holding and land holding and land use patterns of the farming households

Particulars	Ada'a	Sinana	Damot-Gale	Overall	SL
	Mean (±SE)	Mean (±SE)	Mean (±SE)	Mean (±SE)	
Livestock holding (TLU)	8.63 (0.61)^{a}	6.51 (0.61)^{b}	3.04 (0.56)^{c}	5.86 (0.42)	***
Total land (ha)	2.52 (0.14)^{b}	3.24 (0.14)^{a}	0.81 (0.13)^{c}	2.10 (0.13)	***
Cultivated land (ha)	2.02 (0.12)^{b}	2.57 (0.12)^{a}	0.53 (0.11)^{c}	1.63 (0.11)	***
Land allocated for pulses (ha)	0.95 (0.07)^{a}	0.21 (0.07)^{b}	0.24 (0.06)^{b}	0.45 (0.05)	***
Grazing land (ha)	0.14 (0.03)	0.11 (0.03)	0.10 (0.03)	0.12 (0.02)	Ns
Land allocated for cultivated fodder (ha)	0.02 (0.02)^{b}	0.11 (0.02)^{a}	0.04 (0.01)^{b}	0.06 (0.01)	***

$^{a, b, c}$ Mean values with different superscript within the rows are significantly different at P<0.05, SL: significant level, ns: not significant, Conversion factors of livestock number to TLU adapted from Jahnke, 1982 (ox/bull=1, cow=0.7, heifer= 0.5, calf =0.2 sheep/goat=0.1, horse = 0.8, donkey = 0.5)

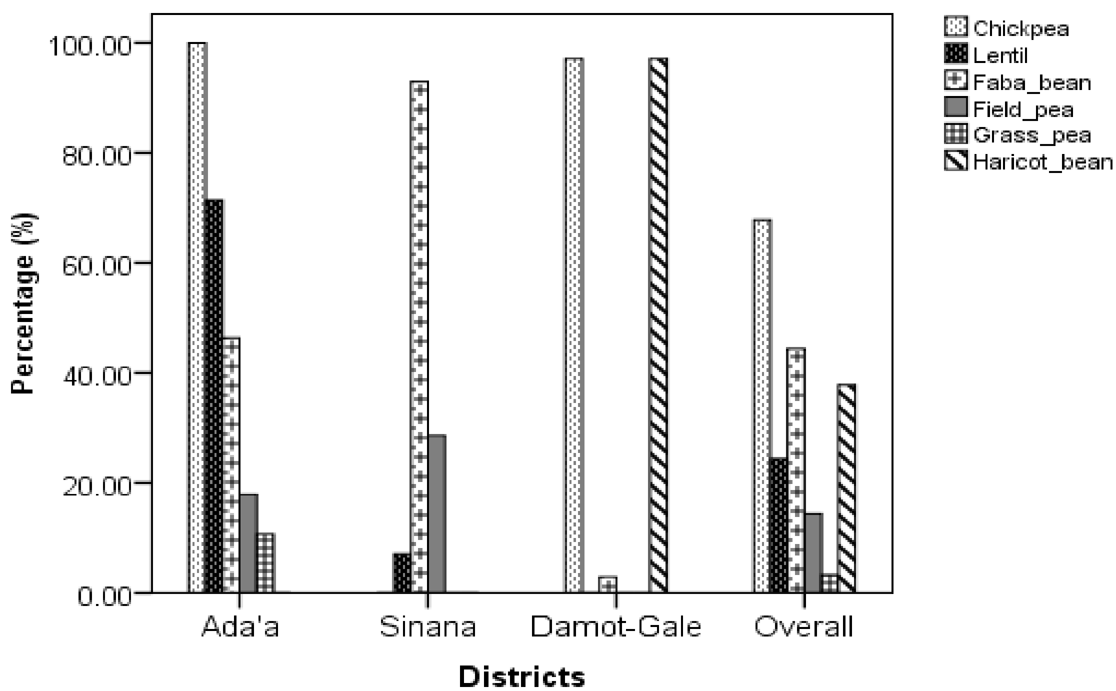

Figure 2: Percentage of respondents growing common legumes in the surveyed districts

4.4.3. Major Household Feed Sources in Study Area

The major feed resources prioritized by the sampled households according to the perceived contribution of each type of feeds to total feed supply in the study area are presented in Table 20. The result showed that crop residues (32.5%), natural pasture (22.1%), stubble grazing (18.8%), other feeds (11.9%), cut and carry forages (8.9%), agro-industrial by products or concentrates (5.3%) and hay (0.5%) were the major feed resources utilized by smallholder farmers in the study area (Table 20).

As shown in Figure (3-A), about 72.2% of the households have reported livestock feed shortage as an important constraint that challenged them in livestock production. The respondents also stated that feed scarcity occurred in different periods of the year. Accordingly, majority of the households (73.4%) reported that they experience feed shortages in the dry seasons of the year

(Figure 3-B), whereas the remaining 25.0% and 1.6% of the respondents reported feed shortage to be a critical challenge during wet season and throughout the year, respectively.

The farmers of the study area adopted different coping strategies in time of limited feed availability (Figure 3-C). The major coping strategies identified in the present survey includes efficient utilization of conserved crop residues (32.8%), use of different farm and home by-products (29.7%), use of purchased feed (18.8%) and exploration of other alternative like moving animals where better grazing (including stubble grazing) available during the day time and obtaining from fellow farmers (18.7%).

Table 20: Major feed resources as ranked by sampled households in the surveyed districts

Feed Resources	**#Household responses (%) (N=90)**	**Rank**
Crop residues	32.5	1
Natural pasture	22.1	2
Stubble grazing	18.8	3
Cut and carry forages	8.9	5
Agro-industrial by products	5.3	6
Hay	0.5	7
Other feeds**	11.9	4
Total	**100**	

******: Lists of other feeds include leaves of *Enset* and different horticultural crops, household waste and grain screenings; weeds collected from farms, poultry litters *etc*., # Index means x 100, Index mean= sum of (5 × number of responses for 1st rank + 4 × number of responses for 2nd rank + 3 × number of responses for 3rd rank + 2 × number of responses for 4th + 1 x number of responses for 5th) divided by (5 × total responses for 1st rank + 4 × total responses for 2nd rank + 3 × total responses for 3rd rank + 2 × total responses for 4th rank +1 x number of responses for 5th).

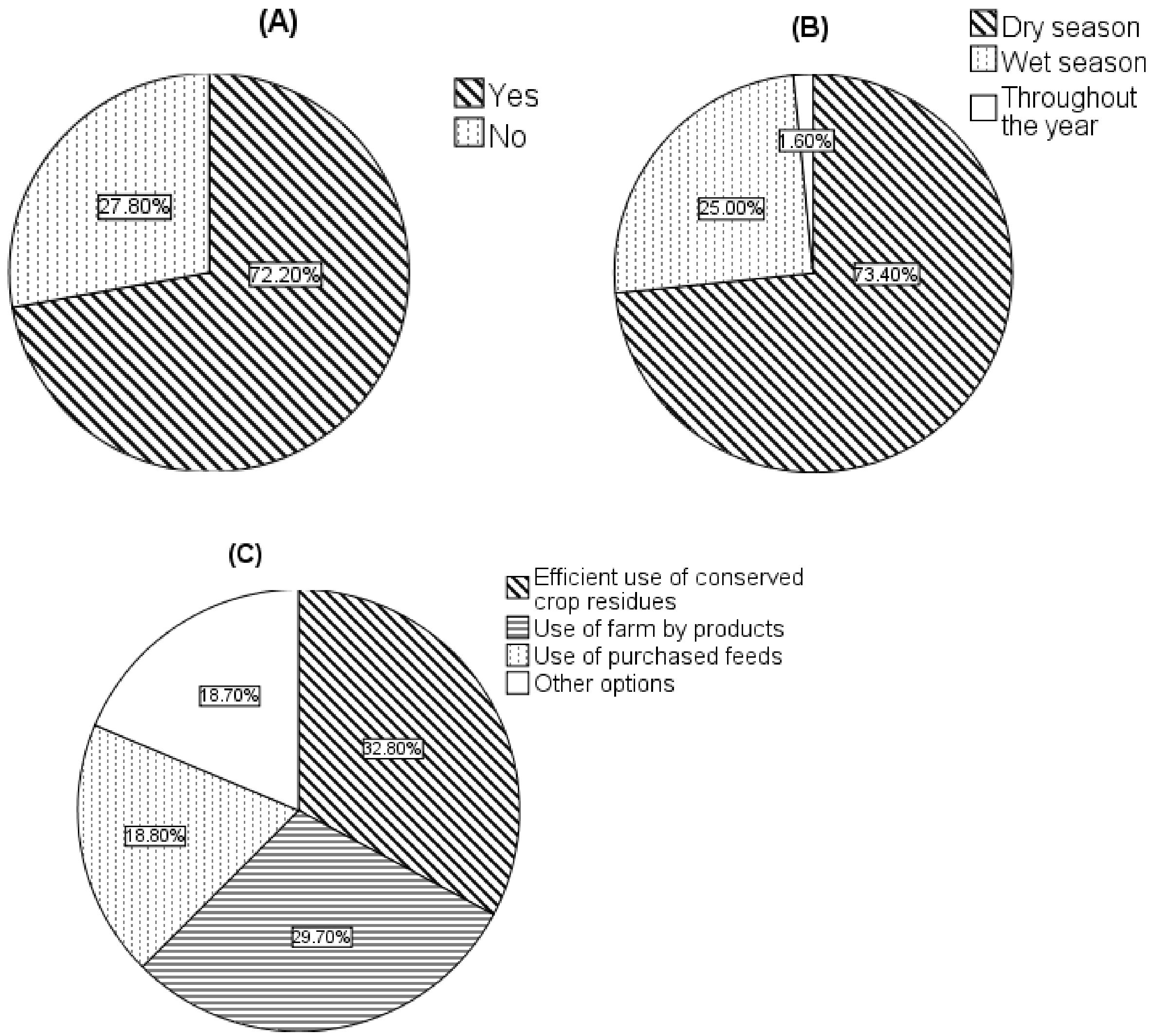

Figure 3: Sampled households perceived feed shortage (A), time of scarcity (B) and coping strategies (C) in the study area

4.4.4. Uses of Grain Legume Haulm in the Study Area

Grain legume haulm has multiple uses for the smallholder farmers (Table 21). The farmers prioritized and ranked the importance of grain legumes haulm in their area based on the amount of residues allocated for different alternative uses. Regardless of the variations among the districts, the result showed that primary use of grain legume haulm in the study areas was reported to be as source of feed (76.7%) and followed by source of household fuel (11.4%), for mulching and compost making (8.8%) and for sale as alternative source of cash (3.1%).

Table 21: Household prioritized use of grain legumes haulm in the surveyed districts

Uses of haulms	**#Household responses (%) (N=90)**	**Rank**
Feed source	76.7	1
Domestic fuel	11.4	2
Mulching/bio-fertilizer	8.8	3
For sale/income source	3.1	4
Total	100	

Index means x 100, Index mean= sum of (2x number of response of 1st rank + 1x number of responses of 2nd rank) divided by (2x total response of 1st rank + 1x total response of 2nd rank)

Majority (90.0%) of the sampled households stated that the trend of haulm utilization in livestock feeding is increasing from time to time (Table 22). There are many factors that triggered the rapid shifting of legume haulm use as livestock feed source than other roles in the mixed crop-livestock farming areas. Shortage of livestock feed and lack of other options, improved awareness on the nutritional advantages of legume haulms than cereal residues and increased annual production of grain legume haulm are the three main drivers prioritized by the respondents for the increasing interest in including grain legume haulm in livestock diets (Table 22).

Table 22: Trends of haulm use as feed and reasons for the increasing trends in using as livestock feed in the survey districts

Variables	Indicators	Percent (%) (N=90)
Trend of haulms use as feed	Increasing	90.0
	No change	5.6
	Don't know	4.4
	Total	**100**
Reasons for increasing trends of using haulms as feed	Feed shortage and lack of other options	59.3
	Improved awareness on nutritional advantage	28.4
	Increased annual production	12.3
	Total	100

4.4.5. Household Perception on the Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer on Haulm Yield and Quality

Responses of the sampled households on the effect of applying P fertilizer and inoculants on the biomass yield and feeding value of grain legume haulm is shown in Figure 4. As illustrated in Figure (4-A), about 62.2 % of the interviewed households believed that applying P fertilizer and inoculants have an effect on haulm yield of the grain legumes. They correlated the influence of these soil fertility enhancing treatments with the improved vegetative growth of the crops which in return increased the final above ground biomass production. Meanwhile, the remaining 24.5%

of households did not recognize the impacts of the fertilizers on the haulms yield, whereas 13.3% of the respondents said that the treatments did not bring any change on the haulm biomass yield of the crops (Figure 4-A).

Similarly, questions were raised to the respondents to capture their perception on the effect of the treatments on nutritional quality of the haulm. The proportion of the morphological fractions (leaf to stem ratio) of the harvested haulm and animals' preference to the haulm harvested from different plots were used as key indicators to assess the farmers perception of the nutritional quality of the haulm. Accordingly, 46.7% of the interviewed households replied that they did not know the impact of the treatments on the nutritional value of the haulms (Figure 4-B). Moreover, among the 32.2% respondents reflected considerable effect of the soil fertility treatments on haulm nutritional values (Figure 4-B), most of them (62.1%) pointed out that application of P fertilizer and *rhizobium* inoculants improved the feeding value of the haulms (Figure, 4-C).

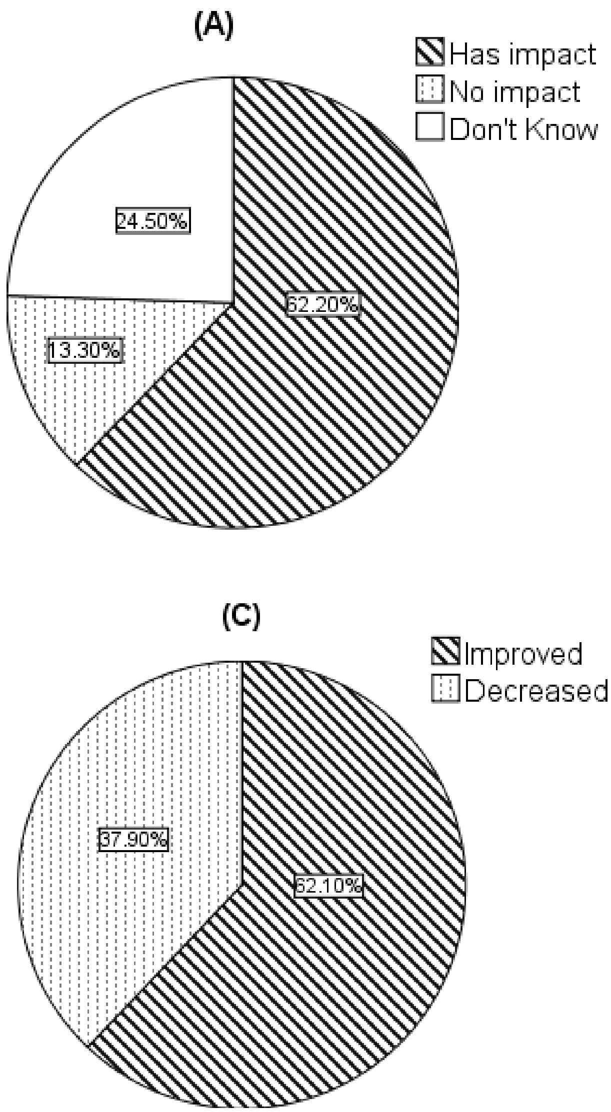

Figure 4 Household perceptions on the effects of *rhozobium* inoculation and P fertilizer on haulm yield (A), haulm quality (B) and trend of impact on haulm quality (C)

5. DISCUSSION

5.1. Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer on Grain Yield, Haulm Yield and Harvest Index of Grain Legumes

The increased grain yield of the different grain legumes as a result of soil fertility treatments is consistent with the findings of different authors (Ibsa, 2013; Tagore *et al*., 2013, 2014). Similar to present result, significant improvement of chickpea grain yield was reported with the inoculation of chickpea seed with dual microbial fertilizers (Tagore *et al*., 2013, 2014). Similarly, Ndlovu (2015) also reported about 16.15-27.50% grain yield increment in two dry bean (*Phaseolues vulgaris*) cultivars due to *rhizobium* inoculation. The result obtained in soybean grain yield is in accordance with the earlier research finding that showed mean grain yield of 1.75, 1.42 and 1.42 t/ha in inoculation plus P fertilizer, seed inoculation alone and sole P fertilizer applied treatments, respectively (Ronner *et al*., 2015). The current result also in agreement with report that showed a significant increment in soybean grain yield due to inoculation with two isolates (SB_6B_1 and legumfix) of *Bradyrhizobium* inoculants in Ethiopia (Tesfaye, 2015). Additionally, comparable soybean grain yield was also reported with the use of various N source fertilizers (Khaim *et al*., 2013).

Significant improvement of haulm DM yield of all the studied crops except chickpea was possible due to the application of *rhizobium* inoculants and P fertilizer. Combined applications of *rhizobium* inoculants and P fertilizer (treatment +P+I) resulted in highest mean haulm DM yield in faba bean (3.61 t/ha) and haricot bean (1.84 t/ha), while the two inoculated treatments (+P+I and -P+I) gave maximum yield of 3.07 and 3.23 t/ha respectively, in soybean. Similarly, Yagoub *et al.* (2012) and Khaim *et al.* (2013) reported significant improvement in soybean haulm yield as a result of application of N and P source fertilizers. However, of the improvement in chickpea haulm DM yield due to the application of the inputs was not significant in contrast to the positive responses reported earlier for the same crops by Tagore *et al*. (2013, 2014)

Variations were also observed among the studied grain legumes in their responses to the inputs in terms of harvest index. In the present study, chickpea and haricot bean harvest index were affected significantly due to the soil fertility treatments. The results illustrated that the maximum harvest index of chickpea (0.46) and haricot bean (0.52) were recorded in treatment +P+I and treatment P-I, respectively. Contrary to the current result, lack of response to *rhizobium* inoculants application and P fertilizer level was reported in two dry bean (*Phaseolus vulgaris*) cultivars in terms of harvest index (Ndlovu, 2015). On the other hand, unlike the finding of the current study which showed non-significant effect of the treatments on soybean harvest index, significant effect of N and P fertilizer on harvest index were also reported (Yagoub *et al.*, 2012; Khaim *et al.*, 2013).

Generally in the present experiment, the increased levels of plant available nutrients particularly N and P in the rhizosphere due to the application of P fertilizer and seed inoculation with more effective *rhizobium* strain might have positively affected the nodulation and vegetative growth of the plants, which ultimately resulted in increased yield performance.

5.2. Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer on Nutritional Values of Grain Legumes Haulm

5.2.1. Nutritional Values of Faba Bean Haulm

The current result showed that all nutritional quality variables of faba bean haulm except ash content were significantly affected with the treatments. The CP content of faba bean haulm was significantly increased over the control as a result of *rhizobium* inoculation and P fertilizer application by 24.19%, 22.85% and 21.53% in +P+I, -P+I and +P-I treatments, respectively. Similarly, positive and highly significant effect of P level and bio-fertilizer on N (CP) content of faba bean straw was reported by Habbasha *et al*. (2007). According to the same authors, the highest straw N (1.93%) content which is equivalent to 12.06% CP was achieved with the combined application of *rhizobium*, Nitrobein and P_2O_5 fertilizers in faba bean. On the other hand, despite showing significant improvement over the control treatment, the haulm harvested from faba bean grown on *rhizobium* inoculants and P fertilizer supplied plots contained lower CP content to be classified in medium quality roughage category according to Nsahlai *et al*. (1996), who put roughage feeds with CP content of 9.92-15.2%, 6.6-9.1% and 3.0-6.5% as high, medium and low quality roughages, respectively.

Furthermore, the recorded haulm CP content for all treatments in the present study were lower than the CP content reported for the same crops under unknown soil nutrient regimes in different parts of the country (Solomon *et al*., 2008; Yetmwork *et al*., 2011), but higher than the value reported for five faba bean cultivars in Ethiopia (Teklu, 2016). Regardless of the treatments, some extraneous factors like crop husbandry practices during growing period, stage of crop harvesting (associated with leave shattering) and environmental condition could have attributed for the variations observed among different reports in haulm CP value of faba bean.

The soil fertility treatments resulted in reduced NDF, ADF and ADL contents of faba bean haulm where treatments that received soil fertility inputs (+P+I, -P+I and +P-I) had significantly lower NDF, ADF and ADL contents than the control treatment (-P-I). The values of haulm NDF, ADF and ADL content were similar among nutrient supplied treatments. The mean NDF, ADF and ADL contents found in faba bean haulm harvested from *rhizobium* inoculated and/or P fertilized treatments were lower than the result of earlier study for the same crop species (Teklu, 2016). But, the mean values recorded in haulm NDF, ADF and ADL contents of faba bean from all treatments in this study were higher than the values reported by Solomon *et al*. (2008) and Yetmwork *et al*. (2011).

The decrease in NDF, ADF and ADL contents of faba bean haulm due to the treatments can also contribute to concomitant improvement in the rumen soluble plant cell constituents. These cell wall components (NDF and ADF) have direct effects on animal performance through their influence on DM intake and nutrient digestibility. Singh and Oosting (1992) pointed out that roughage feeds containing NDF values of less than 45% to be classified as high, those with values ranging from 45 to 65% as medium and those with values higher than 65% as low quality. Meanwhile, Kellems and Church (1998) indicated that roughage with less than 40% ADF is categorized as high quality and those with greater than 40% as poor quality. Thus, taking into consideration the criteria of Singh and Oasting (1992) based NDF composition, unlike haulm harvested from the control treatment, haulm of faba bean grown using soil fertility treatments can be classified as medium quality roughages, although haulm from all treatments do not fulfill the criteria of Kellem and Church (1998) to be a good quality roughage feed based on their ADF profile.

Faba bean haulm IVOMD and ME values were significantly improved due to the application of *rhizobium* inoculants and P fertilizer. The improvement achieved in IVOMD and ME values of faba bean haulm due to the treatments might be associated with the increased haulm CP content and decreased NDF, ADF and ADL contents. Overall, the improvement obtained in terms of CP, IVOMD and ME with associated decline in NDF, ADF and ADL contents entail important achievements from nutritional point of view.

5.2.2. Nutritional Values of Chickpea Haulm

Positive effect of *rhizobium* inoculation and P fertilizer application was observed on haulm CP content, IVOMD and ME values of chickpea. Improvement of haulm CP content of chickpea was significant in all soil fertility treatments supplied groups compared to the control, while combined application of the inputs (+P+I) resulted in significant change over separate use of *rhizobium* inoculants and P fertilizer. The improvement obtained in haulm CP content due to the application of soil fertility treatments over control was 30.51% in treatment +P+I, 10.57% in treatment -P+I and 8.76% in +P-I treatment. The increased haulm CP content might be associated with the enhanced N availability to the plant through atmospheric N_2 fixation. The current finding is in agreement with Ibsa (2013) who reported significant increment of chickpea haulm N content due to the application of the same treatments in Southern Ethiopia. Similarly, significant improvement of haulm protein content of chickpea due to application of different type of bio-fertilizers in combination and separately was noticed by Tagore *et al*. (2014). According to those authors, the highest protein content of chickpea haulm (3.93%) was obtained with application of combined *rhizobium* and PSB as compared to sole *rhizobium* (3.81%) and PSB alone (3.61%) and the control (3.59%).

Significant improvement of haulm IVOMD and ME values of chickpea was observed in combined application of inoculants with P fertilizer (+P+I). The improvement of haulm digestibility and ME might be related with increased haulm CP content. Generally, although most of the maximum mean values recorded in each nutritional value components per respective treatment in present study of chickpea haulm were lower than the earlier reports for the same crops in Ethiopia (Dereje *et al.*, 2010; Tena, 2016). The positive responses that the crop demonstrated for the application of soil fertility inputs in terms of the major feed quality indicators (CP , IVOMD and ME) showed the possibility of improving the nutritional value of chickpea residues with the use of bio-inoculants and P fertilizer.

On the other hand, as the crop was managed and harvested by the farmers themselves; harvesting at appropriate stage of maturity without losses of all plant components (mostly the leaves) may not be expected, which in fact can determine proportion of different morphological fractions (leaf to stem ration) in the final haulm harvest. Therefore, this might be a cause for the decline of overall protein content of the chickpea haulm studied in the present experiment. In line with this, Lopez *et al.* (2005) demonstrated the presence of significant variation in CP content of leaf rich (7.2% CP) and stem rich (4.3% CP) chickpea haulm.

5.2.3. Nutritional Values of Haricot Bean Haulm

In haricot bean haulm, all analyzed nutritional quality components except ADL content were significantly affected by *rhizobium* inoculation and P fertilizer application. In the current study, the ash content of haricot bean haulm was significantly increased with the application of *rhizobium* inoculants with P fertilizer (+P+I) over the control and sole P fertilization (+P-I). The observed positive effect of P in combination with inoculation on ash content of the haricot bean haulm might have been resulted from increased availability of P in the soil and its favorable effect on nutrient uptake. In association with this, regulatory role of P in plant nutrient uptake was reported by Ayub *et al*. (2012) which could be mentioned as a possible reason for improvement in ash content.

The current results also demonstrated that the CP content of haricot bean haulm significantly increased over the control with more prominent improvement in combined application of inoculants and P fertilizer. Accordingly, haulm CP content of treatment +P+I, -P+I and +P-I exceeded the control treatment by 26.26%, 15.32% and 13.13%, respectively. Enhanced atmospheric N_2 fixation due to seed inoculation with more effective *rhizobium* bacteria and P fertilizer supply could have caused increased N availability in the soil and N uptake which could have likely improved the CP content of the haulm.

Haulm CP content recorded for haricot bean crop harvested from soil fertility treatments applied plots were higher than the values of 5.4% and 5.9% reported for haricot bean haulm in Ethiopia by Tesfaye and Musimba (2003) and Seyoum and Fekede (2008), respectively. Haricot bean haulm produced on plots supplied with *rhizobium* inoculants and/or P fertilizer can be grouped under medium quality roughage feeds based on criteria of Nsahlai *et al*. (1996). Thus, haulm CP content of treatment +P+I, -P+I and +P-I can fulfill the rumen microbial requirement for fermentation and effective degradation which is 6.25-7.5% crude protein (Van Soest, 1994).

Effects of *rhizobuim* inoculation and P fertilizer were significant on the two cell wall components (NDF and ADF) of haricot bean haulm. In haricot bean, the lowest mean haulm NDF (67.76%) and ADF (54.96%) contents were recorded in treatment +P+I. The mean values of haulm NDF and ADF contents recorded for all treatments in the present study were above the medium range forage quality (45-65% and 31-45%, respectively) as indicated by Ball *et al.* (2007). On the other hand, except treatment +P+I which had the lowest mean values of NDF, ADF and ADL; comparable result with the present finding was reported for the remaining treatments in haulm NDF, ADF and ADL contents of haricot bean (Tesfaye and Musimba, 2003).

The IVOMD of haricot bean haulm was significantly increased due to application of *rhizobium* inoculants and P fertilizer and the minimum (55.70%) and maximum (57.79%) values were recorded in control (-P-I) and +P+I treatments, respectively. Evitayani *et al*. (2004) reported that digestibility of legumes depends on chemical composition (particularly, fiber, lignin and silica contents), forage species, stage of maturity, leafiness, and soil fertility and other environmental factors. Thus, the improvement achieved in organic matter digestibility of the haulm is a positive result obtained from the application of soil fertility treatments.

Furthermore, the mean IVOMD value of haricot bean haulm found in all treatments were higher than the minimum threshold level (50%) required for acceptable digestibility of forages according to Owen and Jayasuriya (1989). Application of *rhizobium* inoculants and P fertilizer also resulted in significant improvement of ME value of haricot bean haulm and the highest mean value was obtained in combined use of inoculants with P fertilizer (treatment +P+I). Generally, the improvement attained in terms of haulm IVOMD and ME values of haricot bean could be associated with the positive result achieved in protein content of the haulm as well as the decreased NDF and ADF contents due to the treatments. As described by Seyoum and Fekede (2008); grain legume haulm has better IVOMD and ME value than cereals due to their better composition of nitrogen or crude protein.

5.2.4. Nutritional Values of Soybean Haulm

Except the ash content and ME contents, all analyzed nutritional value variables of soybean haulm showed significant difference among the treatments. The improvement of CP content of soybean haulm was attained due to *rhizobium* inoculations and the highest mean CP value of the haulm was recorded in treatment +P+I (6.74% CP). Generally, the CP content of soybean haulm from +P+I, -P+I and +P-I treatments exceeded the control with 44.36%, 30.19% and 13.49%, respectively. The current result is in agreement with the finding of Tesfaye (2015) who reported significant improvement of soybean haulm nitrogen or CP content due to application of

Bradyrhizobium inoculants in Ethiopia. Moreover, based on Nsahlai *et al.* (1996) criteria, soybean haulm produced on plot with combined application of both inputs (treatment +P+I) can be classified under medium quality roughages. Haulm produced on plot which supplied with *rhizobium* inoculants and P fertilizer in combination can also satisfy the rumen microbial protein requirement for fermentation and effective degradation (Van Soest, 1994). The better CP content of the soybean haulm produced in inoculated treatments in the present study clearly is associated with enhanced N availability and uptake through atmosphere N_2 fixation by *rhizobium* bacterium.

The result shows that soybean haulm NDF, ADF and ADL contents were significantly decreased due to the application of *rhizobium* inoculants and P fertilizer compared to the control. Thus, *rhizobium* and/or P fertilizer supplied plots had lower mean value of NDF, ADF and ADL content than the control. Regardless of the improvement obtained in CP, IVOMD and ME, soybean haulm produced from different treatment plots in the present study could be categorized under poor quality roughage feeds based on the composition of NDF (Singh and Oosting, 1992) and ADF (Kellems and Church, 1998).

Combined application of *rhizobium* inoculums and P fertilizer (treatment +P+I) resulted in significant increment in digestibility of soybean haulm (IVOMD=50.62%). Owen and Jaysuriya (1989) noticed that 50% digestibility is a critical threshold level to consider a given feed to be in acceptable range of digestibility and combined treatment +P+I advanced soybean haulm quality into this range. The improvement achieved in IVOMD value in treatment +P+I in this regard, might be associated with the increased CP value and lowered proportion of NDF, ADF and ADL contents.

5.3. Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer on Grain Quality Parameters of Grain Legumes

Effects of *rhizobium* inoculation and P fertilizer on grain quality of chickpea, haricot bean and soybean were evaluated based on thousand seed weight (physical quality), chemical composition (ash and CP), IVOMD, ME and essential amino acids contents. The present findings illustrated that only haricot bean had positive respondes to the treatments in thousand seed weight and the heaviest (210.55 g) thousand seed weight of haricot bean grain was recorded in treatment +P+I. In conformity with the current finding, Ndlovu (2015) reported significant response of two drybean (*Phaseolus vulgaris*) cultivars to the application of inoculants in thousand seed weight. Contrary to the non-responsiveness observed in thousand seed weight of chickpea and soybean to seed inoculation and P fertilization in the current study, various scholars demonstrated significant effects of the fertilizers on thousand seed weight of these crops (Ibsa, 2013; Tesfaye, 2015; Zarei *et al*., 2012).

Effects of *rhizobium* inoculation and P fertilizer on grain ash, CP, IVOMD, ME and essential amino acid contents in chickpea were not significant. Contrary to this finding, significant response of chickpea in grain protein content to the application of two different microbial-fertilizers (separately and in combination) was reported by Tagore *et al* .(2014). As reported by the same authors, CP content of chickpea grain was 20.73%, 18.73%, 17.31% and 17.14% in combined inoculation of *rhizobium* and phosphate solublizing bacteria, only *rhizobium* inoculation, PSB alone and control, respectively. The non-responsiveness of chickpea in terms of grain protein and amino acid contents in this study might be associated with the low efficiency of nitrogen stabilizer nodes in the late growth period of the crop. In haricot bean, except the ash content all grain nutritional quality parameters were significantly responded to the treatments and the improvement obtained due to P fertilization was more prominent than *rhizobium* inoculation. Thus, the highest value of grain CP content, IVOMD and ME as well as most essential amino acids contents of haricot bean crop were recorded in P fertilized treatments with more prominent increase in sole P fertilizations (treatment +P-I). The improved availability of P nutrient in the root area of the crop might have increased the CP content of haricot bean grain through its direct effect on nodule development and functioning. Phosphorus with other soil nutrients has significant role in root proliferation and thereby atmospheric nitrogen fixation of legumes which is in turn used for the synthesis of crude protein (Ayub *et al*., 2012; Tairo and Ndakidemi, 2013). Importance of P in the production of protein, phospholipids and phytin in legume grains was also reported by Rahman *et al.* (2008).

All analyzed nutritional value parameters of soybean grain were also significantly affected due to the treatments. The significant improvement of grain ash, CP, IVOMD, ME and most essential amino acids were attained due to *rhizobium* inoculation than P fertilizer in soybean. The mean value of grain ash, CP, IVODM, ME and essential amino acids of *rhizobium* inoculated treatments (+P+I and -P+I) were significantly higher than uninoculated treatments (+P-I and -P-I). In agreement with the current finding, significant improvement of seed protein content of soybean was reported with the use of two strains of *rhizobium* inoculants in Ethiopia (Tesfaye, 2015). The same author stated that seed inoculation with more effective *rhizobium* bacteria can enhance the nitrogen supply of soybean grain which in turn results in higher protein content. Similar reasons can be mentioned for the improvement achieved in amino acid compositions since amino acids are building blocks for protein. The improvement obtained in grain digestibility and ME value due to the treatments might be also associated with increased grain CP content.

5.4. Household Characteristics

Majority of the respondents were male headed households, which means most of the responses were given by men on behalf of their households. According to Akinola *et al*. (2015) age can determine how active and productive the head of the household is. The average household age (42.61±0.92 years) recorded during the current survey indicated that household heads of the study area fall in economically active age group. The average household age recorded in the current assessment was comparable with reports of some earlier studies in similar farming areas (Ahmed, 2006; Endale, 2015; Mekdes, 2011). The smallest mean household age recorded in Damot-Gale district was supported with the previous report in the area that put a large proportion (66.7%) of the household heads in the age category of 31-40 years (Ermias, 2014).

Household education is a human capital and it can be used to define socio-economic features of the households. This study demonstrated that majority of the interviewed households across all surveyed districts had education status of primary level and above (Grade 1-12). Overall, only small proportions of the sampled households were illiterate. The high level of education of the households observed in this study could have a positive impact on the adoption of improved agricultural technologies easily. The higher the level of education of the households, the higher the probability of taking the right decision, read simple instruction relating to farming and take necessary precautions where necessary (Akinola *et al*., 2015).

5.5. Landholding and Land Use Pattern

Total and cultivated land holding as well as land allocated for various agricultural activities by farmers were quantified in the current study. The result showed significant difference among the districts in total land holding, cultivated farm size, land allocated for pulse crop and land used for fodder production per household. The smallest land holding and land use pattern per households observed at Damot-Gale district, while except land used for pulse production, farmers from Sinana district came on the top of the remaining districts in total land holding, farm lands and land allocated for fodder cultivation. The landholding per household found in Sinana and Ada'a districts is above the national average (1.77 ha) and Oromia region average (1.98 ha) rural land holding (ERSS, 2013). Average landholding per household recorded in Damot Gale district is comparable with the estimated average rural land holding in the SNNP (0.88 ha) but below the national data (ERSS, 2013). Additionally, the smallest landholding (0.81ha total land and 0.53ha cultivated land) per household observed in Damot-Gale district is comparable with the reports of 0.6 ha in Wolayta Area (Ibsa, 2013) and 0.7 ha in Umbulo-Watershed of Southern Ethiopia (Funte *et al*., 2010). Generally, due to very high population density (746 persons per square kilometer) in Wolayta zone, average landholding of the area decreased to about 0.25-1 ha per household (Jufare, 2008).

Furthermore, the overall average total landholding per household (2.10±0.13ha) observed in this study was in comparable range with some previous reports in similar agricultural production system (Ahmed, 2006; Tsedeke, 2007; Solomon *et al.*, 2014), but lower than the report made by others in similar farming situation (Bayush *et al*., 2008; Dawit *et al*., 2012; Endale, 2015).

Differences were observed among the districts in the proportion and area of land used/household for grain legume production. Accordingly, about 47.03%, 45.3% and 8.17% cultivated land was allocated for grain legumes production per household in Ada'a, Damot-Gale and Sinana districts, respectively. This shows that unlike farmers from Ada'a and Damot-Gale districts, most smallholder farmers in Sinana district give more priority for production of cereal crops than grain legumes. The current result is in agreement with the report of Dawit *et al*. (2012), which showed that the farming system of Sinana district to be a predominantly mixed cereal-livestock type.

As the survey districts are known for their crop dominant mixed farming system, the average grazing landholding per household recorded was very small and comparable. The mean grazing land holding (0.12 ha) per household in the study area was comparable with the reports of 0.13 ha in central highlands of Ethiopia (Bayush *et al.,* 2008) and 0.10 ha in Umbulo-Wacho watershed of southern Ethiopia (Funte *et al*., 2010). But, it was smaller than the mean grazing land holding of smallholder farmers in Bosana (0.27 ha), Halaba (0.38 ha) and Meta-Robi (1.22 ha) districts (Ahmed, 2006; Tsedeke, 2007; Endale, 2015), respectively and higher than in *Enset* dominated mixed farming system (0.073 ha) of Southern Ethiopia (Samuel, 2014). The small grazing landholding per household observed in this study is an evidence to conclude that in the mixed farming areas smallholder farmers are continuously converting their productive grazing land to crop fields regardless of its role in supplying better quality feed for livestock. In line with this, Alemayehu (2004) noted that due to continuous conversion of grazing lands to crop fields, the current available grazing land is limited to the areas which have no farming potential.

On the other hand, farm land used for cultivated fodder production in Sinana district was significantly larger than the remaining two districts. But when we consider the share of cultivated fodder in terms of area coverage out of total farm land it was 7.55, 4.0 and 0.99% in Damot-Gale, Sinana and Ada'a districts, respectively. The relatively higher of cultivated forage from the total farm land in Damot-Gale, the district with the smallest total land holding per household, refutes the notion that shortage of land is the main barrier to adoption of cultivated forage production. This calls for more in-depth research to identify and address barriers to adoption of improved forage production and use. Smallholder farmers in Sinana area were reported to grow oat and maize fodder for livestock feeding. Accordingly, Dawit *et al*., (2012) reported experience of smallholder farmers in Sinana district who have been growing fodder oat and maize solely for livestock feeding purpose. Similarly, in Damot-Gale district sampled households were also reported to have established Desho and Elephant grasses on the border of their farm field to serve dual purposes *i.e*. soil conservation and feed source. In accordance with the current findings, study by Hassen (2013) showed that only 1.3% of the cultivated land is covered with fodder crops in northeast highlands of Ethiopia.

5.6. Livestock Holding and Major Feed Resources

Livestock holding of the households was assessed based on ownership of cattle, small ruminants and equine. The overall average livestock holding per household (5.86 TLU) found in this study was comparable with the findings reported in different districts where small scale crop-livestock farming is predominant mode of agricultural activity (Ahmed, 2006; Bedasa, 2012). Contrary to this finding, larger mean livestock holding per households was reported in Halaba (Tsedeke, 2007) and Meta-Robi (Endale, 2015) districts. Livestock holding per household was also significantly different among the surveyed districts and significantly lower (3.04 TLU) and higher (8.63 TLU) in Damot-Gale and Ada'a districts, respectively. The smaller livestock holding found in Damot-Gale district might be associated with limited land holding observed per household in the area. The average TLU per household recorded in Damot-Gale district was comparable with the 3.78 TLU in Umblo-Wacho watershed of Southern Ethiopia (Funte *et al*., 2010), but higher than the 1.9 TLU in Wolayta Zone (Ibsa, 2013).

The current study identified the major feed resources used by smallholder farmers of the study area. The feed sources identified and ranked according to their contribution by respondents include crop residues, natural pastures, stubble grazing, cultivated fodders, different non-conventional feeds, agro-industrial by products, and hays. Similarly, many earlier studies showed that smallholder farmers in the mixed crop-livestock farming areas use feeds obtained from various sources (Ahmed, 2006; Dawit *et al*., 2012; Endale, 2015; Funte *et al*., 2010; Solomon *et al*., 2008; Solomon *et al*., 2014). However, the contribution of each types of feed in annual household feed supply is fluctuating in line with the season of the year. On the other hand, feed shortage was noted as a major constraint for livestock production by the respondents. This is also in accordance with many earlier findings which reflected the same scenario in different parts of the country under similar farming condition (Bayush *et al*., 2008; Belay *et al*., 2012, 2013; Endale, 2015; Solomon *et al*., 2014). The current result also showed that dry season is a critical period of feed scarcity. Meanwhile, the study also identified different coping strategies adopted by smallholder farmers to feed their animals during feed scarcity. In agreement with the current finding, Belay and Greet (2016) and Funte *et al*. (2010) reported that smallholder farmers have their own experience of using various available options to feed their animals when they faced limited feed availability.

5.7. Uses of Grain Legumes Haulm

Smallholder farmers of the study area used grain legume haulm for various purposes. However the amount of haulm biomass allocated for different alternatives is variable. In the current study, smallholder farmers used grain legume haulm predominantly as fodder source than other alternatives. The finding is in agreement with earlier report in the highlands of Ethiopia (Alkhtib *et al*., 2014). Furthermore, haulm refusals from feeding systems have alternatives uses like bio-fuel, fertilizer and compost making. Additionally, sale of haulm is an alternative source of income for the households in the study area. However, the amount of crop residues (including grain legume haulm) allocated for other purposes rather than livestock feeding in mixed farming systems is very small (Ahmed, 2006; Alkhtib *et al*., 2014).

An increasing trend of grain legume haulms use as feed resource was reported by the respondents, which is in agreement with the findings of Alkhtib *et al*. (2014) who reported increasing trends of grain legume haulm use as livestock feed by smallholder farmers in the highlands of Ethiopia. As indentified in the current study, livestock feed shortage and lack of other options, improved awareness on the nutritional advantages of legume haulms than cereal residues and increased annual production of grain legume haulms are the main factors contributing for the increasing interest of farmers in including grain legume haulms in livestock diet. In support to this idea, different scholars (Akinola *et al*., 2015; Valbuena *et al*., 2015) described that many interacting factors determines farmers' decision to use crop residues for various alternatives.

5.8. Household Perception on Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer on Haulm Yield and Quality

The viewpoint of smallholder farmers on the whole plant yield improvement due to seed inoculation and P fertilizer application is very important in order to promote the use of these agricultural technologies. According to Marenya *et al*. (2008); farmers' perceptions on the impacts of fertilizer on crop yields is closely associated with estimated returns to fertilizer applications. The same authors concluded that farmers' perceptions on the impacts of fertilizer are mainly driven by observed yields. The present finding showed that most (62.2%) of the interviewed households recognized the impacts of the soil fertility treatments on biomass yield and then on haulm yield of grain legumes. They reported that haulm yield of the crops increased with the applications of *rhizobium* inoculants and P fertilizer due to improved vegetative growth of the crops.

Regarding haulm quality, however the assessment was made by taking into consideration the leaf to stem ratio of the haulm and preferences of animals to haulms harvested from plots supplied with soil fertility treatments. Most of the respondents (46.7%) did not recognize this, while those who responded on the impacts to be either negative or positive accounted for 32.2%. Their lack of recognition of the impacts of the inputs in the present assessment was associated with the fact that they mixed crop residues of different plots and different crops species together prior to feeding to livestock. Moreover, legume crops are highly susceptible to leaf shattering prior or during harvesting the crop, and this could have contributed for the lack of proper recognition of actual value of grain legume haulms by the farmers.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The result of current study showed that the majority of the farming households in the study area predominantly use grain legume haulm as feed sources. Similarly, the study revealed that use of grain legume haulm as livestock feed by smallholder farmers' has been steadily increasing over the past few years. Increasing trends of grain legume haulm use in livestock feeding appear to be associated with factors such as feed shortage and lack of other options, better awareness of their nutritional quality and increased annual production of annual grain legumes. Moreover, majority of the respondents reported positive effect of *rhizobium* inoculation and P fertilizer on the haulm biomass yield of grain legumes, whereas most of the interviewed farmers were not fully aware of the impact of the inputs on the nutritional values of the grain legumes haulm.

The results obtained from the experiment conducted with the use of four grain legumes (faba bean, chickpea, haricot bean and soybean) under application of *rhizobium* inoculants and P fertilizer showed considerable effects of the treatments on yield and quality attributes of the crops. Statistical analysis showed significant effect of the soil fertility treatments on grain and haulm DM yield of the studied crops, except haulm DM yield of chickpea. Accordingly, more prominent improvement of grain and haulm DM yield of faba bean and haricot bean was observed with combined application of *rhizobium* inoculants and P fertilizer (treatment +P+I). On the other hand, the significant improvement obtained in grain and haulm DM yield of chickpea and soybean were more associated with the application of *rhizobium* inoculants, although the effect was not significant in chickpea haulm DM yield.

Faba bean haulm quality parameters such as CP, ME, and IVOMD were significantly increased with subsequence decline in NDF, ADF and ADL contents due to the application of *rhizobium* inoculants and P fertilizer. This study also revealed that CP content, ME and IVOMD values of chickpea haulm showed significant improvement. However, NDF, ADF and ADL contents of chickpea haulm showed a decline due to the application of the inputs; the change observed in cell wall components (NDF, ADF and ADL) was not significant. Haricot bean haulm ash, CP, ME and IVOMD values were improved whereas the fiber (NDF, ADF and ADL) contents were decreased with the application of soil fertility treatments with the maximum mean values in treatment +P+I for ash, CP, ME and IVOMD. Response of haricot bean to the treatments in thousand seed weight was also highly significant. Grain CP content, ME, IVOMD and amino acid composition of haricot bean were significantly improved due to the application of the soil fertility treatments. Effect of the treatments was significant in all analyzed soybean haulm quality parameters except the ash content and ME value. Soybean haulm showed significant increment in CP and TIVOMD value with the application of inoculants, while there was a decline in NDF, ADF and ADL contents. Thus, the highest mean value of CP and IVOMD and the lowest cell wall fractions were found in soybean haulm harvested from treatment +P+I. Grain ash, CP, ME and IVOMD values as well as most essential amino acids composition of soybean were significantly increased with the application of *rhizobium* inoculants over uninoculated treatments.

In the mixed crop-livestock farming systems of Ethiopia, both grain and haulm of grain legumes have significant importance for the livelihood of the farming households. Agronomic practices which can improve both grain and haulm attributes obviously foster the benefit of smallholder farmers from grain legumes production. The finding of current study indicated the possibility of improving both grain and haulm traits of grain legumes simultaneously through the application of *rhizobium* inoculants and P fertilizer.

6.2. Recommendations

- Grain legumes can function as a key integrating factor in intensifying crop-livestock farming system through provision of protein in human diet, fodder for livestock and improving soil fertility through BNF. Therefore, effective *rhizobium* strains and P fertilizer can be used to enhance productivity of these grain legumes in this farming system for improved total crop values.
- Improvement obtained on haulm nutritional values due to *rhizobium* inoculation and P fertilizer from laboratory result may need to be further evaluated and verified under animal performance trial.
- To improve feed supply from grain legumes haulms, intervention is also important in upgrading farmers' skill on proper/timely harvesting, threshing and conservation techniques.
- In chickpea research, future work should be focused on identification of more effective *rhizobium* strain which has a positive interaction with P fertilizer and which will have a potential to improve nutritional value of the grains for human food and incorporate better yielding and quality attributes of the haulm.
- Economic feasibility of these soil fertility inputs under smallholder farmers' condition has to be further studied by taking into consideration both grain and haulms uses to come up with the information on economic profitability of the technologies.
- Further researches have to be also conducted on screening and identification of variety and location specific *rhizobium* strains for improved grain and haulm productivity.

7. REFERENCES

Abdi Nigus, Mohammed Yusuf and Getachew Animut, 2015. Determination of digestibility of Faba bean (*Vicia Faba L.)* Hull and Wheat Brain in Afar Sheep. Journal of Biology, Agriculure and Healthcare. 5 (1).

Abreu J.M.F. and Bruno-Soares A.M. 1998. Characterization and utilization of rice, legumes and rape straws. In: Antongiovanni M (ed.). Exploitation of Mediterranean roughage and byproducts. Zaragoza CIHEAM, Pp 39-51.

Adugna Tolera, 2007a. Feed resources for producing export quality meat and livestock in Ethiopia (Examples from Selected Woredas in Oromia and SNNP Regional States). Ethiopia Sanitary and Phytosanitary Standards; and Livestock and Meat Marketing Program (SPS-LMM) and Texas Agricultural Experiment Station (TAES)/Texas A&M University. Addis Abeba, Ethiopia

Adugna Tolera, 2007b. The role of forage supplements in smallholder mixed farming systems: A Pathway to Prosperity for Smallholder Farmers. Proceedings of an International Forage Symposium, Ubon Ratchathani University, Thailand (2007) 165-186.

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

Adugna Tolera, Berg T. and Sundstøl F., 1999. The effect of variety on maize grain and crop residue yield and nutritive value of the stover. Anim. Feed Sci. Tech.79: 165-177.

Africa RISING, 2014. Africa Research in Sustainable Intensification for the Next Generation Ethiopian Highlands Project Technical report, 1 April 2014 – 30 September 2014. 14pp.

Ahmed Hassen, 2006. Assessment and utilization practices of feed resource in Basona Woran Wereda of North Shewa. MSc Thesis, Haramaya University, Dire Dewa, Ethiopia. 114pp.

Akinola, A. A., Ayedun, B., Abubakar, M., Sheu, M. and Abdoulaye, T., 2015. Crop residue usage and its determinants in Kano State, Nigeria. Journal of Development and Agricultural Economics. Vol.7(4), pp.162-173.

Alemayehu Mengistu, 1985. Feed resource in Ethiopia. Proceedings of the second PANESA Workshop on Animal Feed Resources for Small Scale Livestock Producers. Nairobi, Kenya, 11-15 November 1985.

Alemayehu Mengistu, 2003. Country pasture/Forage resources profiles: Ethiopia. FAO web site: http://www.fao.org/ag/agp/agpc/doc/counprof/ethiopia/ethiopia.htm

Alemayehu Menigistu, 2004. Rangeland: Biodiversity concepts, approaches and the way forward. Addis Ababa University, Faculty of Science, Addis Ababa, Ethiopia, 80p

Alkhtib Ashraf, Jane W., Barbara R., Yahya K., and Mohannad M., 2014. Status, challenges and opportunities for sustainable utilization of pulse crop residues in Ethiopia. Africa RISING in the Ethiopian Highlands.

Asnakew W., M. Tekalign, B. Mengesha, and A. Tefera, 1991. Soil fertility management studies on wheat in Ethiopia. pp. 137-172. *In*: Hailu, G.M. Tanner, D.G. and Mengistu, H.(eds), wheat research in Ethiopia. A historical perspective. Addis Ababa. Ethiopia: IAR (CIMMYT).

Aulakh, M. S., Pasricha, N. S. and Bahl G. S., 2003. Phosphorus fertilizer response in an irrigated soybean-wheat production system on a subtropical, semiarid soil. Field Crops Res. 80:99–109.

Ayub M., M. A. Nadem, M. Naem, M. Tahir, M. Tariq and W. Ahmad, 2012. Effect of different levels of p and k on growth, forage yield and quality of cluster bean (Cyamopsis Tetragonolobus l.).The Journal of Animal & Plant Sciences, 2 (2): pp 479-483.

Ball, D., C. S, Hovel and G., Lacefield. 2007. Southern Forages.4th ed.Potash and Phosphate institute and foundation for Agronomic Research, Norcross, A.

Bayush Tsegaye, Adugna Tolera and Berg T., 2008. Livestock production and feed resource constraints in Akaki and Lume districts, central Ethiopia. Outlook on Agriculture, Vol 37:1.

Bedasa Eba, 2012. Study of smallholder farms livestock feed sourcing and feeding strategies and their implication on livestock water productivity in mixed crop-livestock systems in the highlands of the Blue Nile Basin, Ethiopia. MSc. Thesis, Haramaya University, Dire Dewa, Ethiopia. 130pp.

Belay Duguma and Greet P.J.J, 2016. Assessment of feed resources, feeding practices and coping strategies to feed scarcity by smallholder urban dairy producers in Jimma town, Ethiopia. http://www.ncbi.nlm.nih.gov/pubmed/27375986

Belay Duguma, Azage Tegegne and Hegde B.H., 2012. Smallholder livestock production system in Dandi District, Oromia Regional State, Central Ethiopia. Global Veterinarian 8 (5): 472-479.

Belay Duguma, Getachew Eshetu, Azage Tegegn and Hegde B. H., 2013. Farmers' perceived livestock production constraints in Ginchi watershed area: Result of participatory rural appraisal. International Journal of Livestock Production. Vol. 4(8), pp 128-134.

Berhanu, G., Adane, H. and K, B., 2009. Feed marketing in Ethiopia: Results of rapid market appraisal. Improving Productivity and Market Success (IPMS) of Ethiopian farmers project Working Paper 15. ILRI (International Livestock Research Institute), Nairobi, Kenya. 64p.

Birhan M. 2014. Assessment of agro-industrial by-products for animal feed supply in North Gondar Zone, Ethiopia. J Anim Prod Adv, 4(1): 342-347. www.grjournals.com

Bozorgi H.R., Ebrahim A., and Maral M., 2011. The effects of bio, mineral nitrogen fertilization and foliar Zink sprayin on yield and yield components of faba bean. World Applied Sciences Journal 13(6): 1409-1414.

Cheeke, P.R., 1999. Applied Animal Nutrition. Feeds and Feeding 2nd ed., Prince Hall Inc., New Jersey. 525pp.

CSA (Central Statistical Agency), 2015a. Livestock and livestock characteristics. Agricultural Sample Survey 2014/15 (2007 E.C). Statistical Bulletin 578.

CSA (Central Statistical Agency), 2015b. Area and production of major crops. Agricultural Sample Survey 2014/15 (2007 E.C). Statistical Bulletin 578.

Daniel Keftasa, 1988. Role of crop residues as livestock feed in Ethiopia highlands. In: B.H. Dzowela (ed.). African Forage Plant Genetic Resources, Evaluation of Forage Germplasm and Extensive Livestock Production Systems. Proceedings of a Workshop Held in Arusha, Tanzania, 27 – 30 April 1987. pp. 430 - 439.

Dawit Abate, 2007. Effect of vetch (*Vicia Dasycarpa, L*.) and alfalfa (*Medicago Sativa* ‘Hunter River’) hay supplementation on feed intake, digestibility and body weight change of Arsi Bale sheep fed a basal diet of urea treated barley straw. MSc. Thesis, Haramaya University, Dire Dewa, Ethiopia. 103pp.

Dawit Abate, Belete, S., Wegi, T., Usman, S., Wamatu, J. and A. Duncan, 2012. Characterization of the livestock production systems and the potential of feed-based interventions for improving livestock productivity in Sinana district, Bale Highlands, Ethiopia. International Livestock Research Institute, Nairobi, Kenya

Dejene, A., 2003. Integrated natural resource management to enhance food security: the case for community-based approaches in Ethiopia. Working Paper No 16. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. Document. Ministry of Agriculture/ AFRDRD/AFRDT Food and Agriculture Organization/SSFF. Addis Ababa, Ethiopia.

Dereje Fekadu, Seyoum Bediye and Zinash Sileshi, 2010. Characterizing and predicting chemical composition and in vitro digestibility of crop residue using near infrared reflectance spectroscopy (NIRS). Livestock research for rural development, 22(2).

Deshbhratar P.B., P.K. Singh, A.P. Jambhulkar and D.S. Ramteke, 2010. Effect of suplphur and phosphorus on yield, quality and nutrient status of Pigeon Pea (*Cajanus cajan*). Journal of Environmental Biology: 31(6) 933-937.

Diriba Geleti, Adugna Tolera, Ashenafi Mengistu and Mekonnen H/Mariam., 2011. Effect of variety of maize on yield of grain, residue fractions and the nutritive value of the whole stover. Ethiopian Journal of Applied Science and Technology. 2(2): 91 - 96

Diriba Geleti, Mekonnen Hailemariam, Ashenafi Mengistu and Adugna Tolera, 2013.Nutritive Value of Selected Browse and Herbaceous Forage Legumes Adapted to Medium Altitude Subhumid Areas of Western Oromia, Ethiopia. Global Veterinaria 11 (6): 809-816.

Dotaniya M.L., K.K. Pingoliya, M. Lata, R.Verma, K.L. Regar, P. Deewan and C.K. Dotaniya, 2014. Review on the role of phosphorus in chickpea (*Cicer arietinum L.)* production. African Journal of Agricultural Research: Vol.9 (51), pp 3736-3743.

Endale Yadessa, 2015. Assessment of feed resources and determination of mineral status of livestock feed in Meta Robi District,West Shewa Zone, Oromia Regional State, Ethiopia. MSc Thesis, Ambo University. Ambo, Ethiopia. 143pp

Ermias Belete, 2014. On- Farm Performance Evaluation of Dorper Sheep Breed Crosses In Wolaita and Siltie Zones, Southern Ethiopia. M.Sc Thesis. Addis Abeba University, Addis Abeba, Ethiopia. 92pp

Ermias Tekletsadik. 2008. The Effect of supplementation with barley bran, linseed meal, and their mixtures on the performance of Arsi Bale sheep fed a basal diet of faba bean haulms. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

ERSS (Ethiopia Rural Socioeconomic Survey), 2013. Survey report. Central Statistical Agency and the World Bank. May 7th, 2013

Evitayani1, L., Warly, A., Fariani, T., Ichinohe and T., Fujihara.2004. Study on Nutritive Value of Tropical Forages in North Sumatra, Indonesia. *Asian-Australian Journal of Animal Science. 17(11): 1518-1523.*

FAO (Food and Agricultural Organization), 1987. Assistance to land use planning in Ethiopia. Economic analysis of land use. UNDP/FAO Technical Report No. 8, Food and Agricultural Organization of the United Nations, Rome, Italy.

Fekadu, D. 2009. Characterizing farming practices from three regions of Ethiopia on which *Enset (Ensete ventricosum)* is widely profited as a multipurpose crop plant. Livestock Research for Rural Development 21 (12). http://www.lrrd.org/lrrd21/12/feka21213.htm.

Funte S., T. Negesse and G. Legesse, 2010. Feed resources and their management systems in Ethiopia highlands; The case of Umbulo Wacho Watershed in Southern Ethiopia. Tropical and Subtropical Agro-ecosystems, 12:47-56.

Gepts P., William D., Beavis E., Charles B., Randy C., Shoemaker H., Thomas S., Norman F., and Nevin D. Y., 2005. Legumes as a model plant family. Genomics for Food and Feed Report of the Cross-Legume Advances through Genomics Conference Plant Physiol. 2005 Apr; 137(4): 1228–1235.

Getachew Asamenew, Haile Beyene, Werkneh Nigatu and Gezahegn Ayele, 1993b. A survey of farming systems of vertisol areas of the Ethiopian highlands. In: Tekalign Mamo, Abiye Astatke, K.L. Srivastra and Asgelil Dibabe (eds.) Improved management of vertisols for sustainable crop-livestock production in the Ethiopian highlands. Synthesis Report 1986-92. Technical committee of the joint vertisol project, Addis Ababa, Ethiopia. p. 29-49.

Getachew Asamenew, Zerbini, E. and Abate T., 1993a. Crop- livestock interaction and implications for animal traction research in the Ethiopian highlands. Proceedings of the 4th National Livestock Improvement Conference (NLIC) Held in Addis Ababa, Ethiopia, 13- 15 November 1991. Pp. 29- 36.

Getachew E, 2002. An assessment of feed resources, their management and impact on livestock productivity in the Ginchi watershed area. MSc. Thesis. Alemaya University of agriculture, Alemaya.

Gezu Tadesse, Haftu Kebede and Sefa Salo, 2014. Feed resources and constraints for cattle fattening in Lemo and Soro woredas, Hadya zone, Southern Ethiopia. Global Journal of Animal Science, Livestock Production and Animal Breeding, Vol. 2 (4), pp. 119-125

Giller, K. E. 2001. Nitrogen fixation in tropical cropping systems: Cabi. Wallingford. Hardy, W., and R. Burns. 1968. Biological nitrogen fixation. *Annual review of biochemistry* 37 (1):331-358.

Gizawy N.Kh.B. E and S.A.S. Mehasen, 2009. Response of faba bean to bio, mineral phosphorus fertilizers and foliar application with zinc. World Applied Sciences Journal 6 (10): 1359-1365.

Golshani A. A., N. Maheri-Sis, A. Baradaran-Hasanzadeh, A. Asadi-Dizaji, A. Mirzaei-Aghsaghali, and J. Dolgari-Sharaf, 2012. Determining nutrients degradation kinetics of chickpea (*Cicer arietinum*) straw using nylon bag technique in sheep. Open Vet J.; 2(1): 54–57.

Graham P. H. and Vance C. P., 2003. Legumes: Importance and Constraints to Greater Use. Plant Physiol. Vol. 131. www.plantphysiol.org/cgi/doi/10.1104/pp.017004.

Graham P.H. and Vance C.P., 2003. Legumes. Importance and constraints to greater use. Plant Physiology, 131:872-877.

Habbasha El., M. Hozayn and M.A. Khalafallah, 2007. Integration effect between phosphorus levels and bio-fertilizers on quality and quantity yield of faba bean (*Vicia faba L.)* in newly cultivated sandy soils. Research Journal of Agriculture and Biological Sciences, 3(6): 966-971, 2

Hart, R., and McDowell, R.E., 1985. Crop-livestock interactions as determinants of crop and livestock production. Cornell International Agriculture Mimeo 107, Cornell University, Ithaca, NY.

Hassen B., 2013. Factors affecting the adoption and intensity of use of improved forages in North East Highlands of Ethiopia. American Journal of Experimental Agriculture 4(1): 12-27.

Ibsa Aliyi, 2013. Agronomic and symbiotic characteristics of chickpea, *Cicer arietinum* (L.), as influenced by *Rhizobium* inoculation and phosphorus fertilization under farming systems of Wolaita area, Ethiopia. MSc Thesis, Wageningen University, Wageningen, Netherland. 84pp

Jahnke, H. E., 1982. Livestock Production Systems and Livestock Development in Tropical Africa. Kieler Wissenschaftsverlag Vauk. Kiel, Germany.

Jansman, A. J., M. W. Verstegen, J. Huisman and J. W. Van den berg, 1995. Effects of hulls of faba beans (Vicia faba L.) with a low or high content of condensed tannins on the apparent ileal and fecal digestibility of nutrients and the excretion of endogenous protein in ileal digesta and feces of pigs. 121p.

Jufare, A. T. 2008. Livelihood Adaptation, Risks and Vulnerability in Rural Wolaita, Ethiopia, Noragric, Department of International Environment and Development Studies, Norwegian University of Life Sciences.

Karami Morteza, 2015. The Nutritive Value and *In-Vitro* Digestibility of Legume Straws as Animal's Diet. Am. Adv. J. Biol. Sci.; 1 (2), 63-71.

Kellems, R.O. and Church, D.C. 1998. Livestock feeds and feeding, 4th edition, Prentice-Hall, Inc., New Jersey, USA.

Khaim S., M.A.H Chowdhury and B.K. Saha, 2013. Organic and inorganic fertilization on the yield and quality of soybean. J. Bangladhes Agril Univ. 11(1): 23–28

Levene H., 1960. In contributions to probability and statistics: Essays in Honor of Harold Hotelling, I. Olkin *et al*., eds., Stanford University Press, pp. 278-292

Lopez S., David R. D., Javier F. G., Dhanoa M.S., Dijkstra J. and James F., 2005. Assessment of nutritive value of cereal and legume straws based on chemical composition and *in vitro* digestibility. Journal of the Science of Food and Agriculture. **85**:1550–1557

Lulseged Gebrehiwot and Alemu, T., 1985. Pasture research and development in Ethiopia. In: J.A. Kategile (ed) pasture improvement research in eastern and southern Africa. Proceedings of a work shop held in Harare, Zimbabwe, 17-21 sept.1984. IDRC, Ottawa, Ontario. pp77-91.

Lulseged Gebrehiwot and Jemal Mohammed, 1989. The potential of crop residues, particularly wheat straw as livestock feed in Ethiopia.

Maheri-Sis N., B. Abdollahi-Ziveh, R. Salamatdoustnobar, A. Ahmadzadeh, A. Aghajanzadeh-Golshani and M. Mohebbizadeh, 2011. Determining Nutritive Value of Soybean Straw for Ruminants Using Nylon Bags Technique. Pakistan Journal of Nutrition 10 (9): 838-841; ISSN 1680-5194.

Malede Birhan and Takele Adugna, 2014. Livestock feed resources assessment, constraints and improvement strategies in Ethiopia. Middle-East Journal of Scientific Research 21 (4): 616-622.

Marenya P., Christopher B. B. and Trudi G. 2008. Farmers' perceptions of soil fertility and fertilizer yield response in Kenya. https://www.researchgate.net/publication/228310787

Mekdes Abera, 2011. Analysis of Technical Efficiency of Lentil *(Lens Culinaris Medikus)* Production: The Case of Gimbichu District, Eastern Shewa Zone of Oromia, Ethiopia. M.Sc. Thesis. Haramaya University. Dire-Dewa, Ethiopia.

Mergia Abera, Adugna Tolera and Getnet Assefa, 2014. Feed Resource Assessment and Utilization in Baresa Watershed, Ethiopia. International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Volume 3 Issue 2, www.ijsr.net

Mohamed Saleem M A and von Kaufmann R. 1985. Evaluation of stylosanthes for forage improvement in the sub-humid zone of West Africa. Effect of phosphorus application on the productivity and quality of three stylosanthes cultivars.

Mohammed-Saleem, M. A. and Abate Tedla, 1995. Feed improvement to support intensification of ruminant production systems in the Ethiopian Highlands. pp. 296-306. In: Proceedings of the 3rd Annual Conference of the Ethiopian Society of Animal Production. Addis Ababa, Ethiopia, 27-29 April 1995.

Muluken Minta, 2006. Effect of *Rhizobium* inoculation on nodulation, nitrogen fixation and yield of some annual forage legumes (*Vicia spp*.) on Nitisols and Vertisols of Central Highlands of Ethiopia. MSc. Thesis, Alemeya University, Dire Dewa. 102pp

Ndlovu Tshepo John, 2015. Effect of *Rhizobium Phaseoli* Inoculation and Phosphorus Application an Nodulation, Growth and Yield Components of Two Drybean (*Phaseolus Vulgaris*) Cultivars . MSc Mini- Dissertation. University of Limpopo, South Africa. 85pp

Novoa, R., and R. Loomis. 1981. Nitrogen and plant production. *Plant and Soil* 58 (1):177- 204.

Nsahlai I.V. and Umunna N.N., 1996. Comparison between reconstituted sheep faeces and rumen fluid inocula and between *in vitro* and *in sacco* digestibility methods as predictors of intake and *in vivo* digestibility. Journal of agricultural science 126 (2): 235-248

Owen, E. and Jayasuriya, M.C.N. 1989. Use of crop residues as animal feeds in developing countries: a review. *Research and Development in Agriculture*, 6(3): 129-138.

Peoples, M.B., A.W. Faizah, B. Rerkasem and D.F. Herridge, 1989. Methods for evaluating nitrogen fixation by nodulated legumes in the field. ACIAR monograph. No. 11, ACIAR, Canberra, Australia. pp. 76.

Powell, J.M., Pearson, R.A. and Hiernaux, P.H. 2004. Crop-livestock interactions in the west African drylands. Agronomy Journal, 96, 469-483

Rahman M.M, Bhuiyan M.M.H, Sutradhar G.N.C and Paul A.K, 2008. Effect of Phosphorus , Molybdenum and Rhizobium inoculation on yield and yield attributes of mungbean. International Journal of sustainable Crop Production. 3(6): 26-33

Reddy B.V.S., P. Sanjana Reddy, F. Bidinger, and M. Blu¨mmel, 2003. Crop management factors influencing yield and quality of crop residues. Field Crops Research 84 (2003) 57–77.

Ronner E., A.C. Franke, B. Vanlauwe, M. Dianda, E. Edeh, B. Ukem, A. Bala, J. van Heerwaarden, and K.E. Giller, 2015. Understanding variability in soybean yield and response to P-fertilizer and *Rhizobium* inoculants on farmers' fields in Northern Nigeria. Field Crops Research 186 (2016) 133-145.

Samual Menbere, 2014. Livestock feeds and feeding system in *Enset (Ensete ventricosum)* dominated mixed farming system of Southern Ethiopia. Online Journal of Animal and Feed Research. Vol, 4 (6); 150-158pp.

Sannasgala K., and Jayasuriya M.C.N., 1987. The influence of plant fractions on the digestibility of rice straw. Biol. Wastes 20, 153-156

Seyoum Bediye and Fekede Feyisaa, 2008. The status of animal feeds and nutrition in the West Shewa Zone of Oromiya, Ethiopia, PP. 27-49. In: Proceedings of the Workshop 'Indigenous Tree and Shrub Species for Environmental Protection and Agricultural Productivity', November 7-9, 2006, Holetta Agricultural Research Centre, Ethiopia. Series on Conference and Workshop Proceedings of KEF (Commission for Development Studies at the Austrian Academy of Sciences): 2008/1.

Seyoum Bediye and Fekede Feyissa, 2003. The status of animal feeds and nutrition in the West Shewa Zone of Oromiya, Ethiopia. http://www.musiklexikon.ac.at:8000/6131-8inhalt/kindu%20proceedings_027_049_theme1.pdf

Seyoum Bediye and Zinash Sileshi, 1989. The composition of Ethiopian feeds. IAR. Research reports. IAR (Institute of Agricultural Research), Addis Ababa, Ethiopia. 34p.

Seyoum Bediye, Getinet Aseffa, Abate Tedla, & Dereje Fikadu, 2001. Present status and future direction in feed resources and nutrition research targeted for wheat based crop livestock production system in Ethiopia. In: P. C Wall (ed.). Wheat and Weed: Food and Feed. Proceedings of Two Stakeholder Workshops. CIMMYT, Mexico City. Improving the Productivity of Crop Livestock Production in Wheat-based Farming Systems in Ethiopia, Addis Ababa, Ethiopia, 10 - 11 October 2000. pp. 207 - 226.

Singh, G.P. and Oosting, S.J. 1992. A Model for describing the Energy Value of Straws. Indian Dairyman XLIV, 44: 322-327.

Sisay Belete, Teklu Wegi, Dawit Abate, Sultan Usman and Adugna Tolera, 2012. Application of TechFit to prioritize feed technologies in Sinana District of Bale Highlands, Southeastern Ethiopia. International Livestock Research Institute. Nairobi, Kenya.

Solomon Bogale, 2004. Assessment of livestock production system and feed resource base in Sinana Dinsho district of Bale Highlands, Southeast Oromia. MSc. Thesis. Alemaya University, Alemaya. 135 pp

Solomon Bogale, Solomon M., and Alemu Y., 2008. Potential use of crop residue as livestock feed resources under smallholder farmers condition in Bale highlands of Ethiopia. Tropical and Subtropical Agroecosystmes, Vol.8. Pp 1007-114.

Solomon Bogale, Solomon Melaku and Alemu Yami, 2009. The interdependence of crop-livestock production sectors: the case of Sinana-dinsho district in Bale highlands of Ethiopia. Tropical and Subtropical Agroecosystems. Vol 42(2).

Solomon Zewdu, Binyam Kassa, Bilatu Agza, Ferede Alemu and Gadisa Muleta. 2014. Smallholder cattle production systems in Metekel zone, northwest Ethiopia. Research Journal of Agriculture and Environmental Management. Vol. 3(2), pp. 151-157, http://www.apexjournal.org.

Sundstøl, F and E. Owen, 1984. Straw and other fibrous by-products as feed. Elsevier, Amsterdam Science Pub. Com., New York, Tokyo. 604pp

Tadesse Amsalu and Solomon Addisu, 2014. Assessment of grazing land and livestock feed balance in Gummara-Rib Watershed, Ethiopia. Curr.Agri.Res.Jour., Vol.2(2), 144-122.

Tagore G. S, S K Sharma and S. K. Shah, 2014. Effect of microbial inoculants on nutrient uptake, yield and quality of chickpea genotypes. Int.J.Agric.Sc & Vet.Med. Vol.2, No. 2.

Tagore, G. S, Namdeo S. L., Sharma S. K. and Narendra K., 2013. Effect of *Rhizobium* and Phosphate Solubilizing Bacterial Inoculants on Symbiotic Traits, Nodule Leghemoglobin, and Yield of Chickpea Genotypes. International Journal of Agronomy, http://dx.doi.org/10.1155/2013/581627

Tairo E.V. and P.A. Ndakidemi, 2013. Possible benefits of Rhizobial inocualationa and phosphorus supplementation on nutrition, growth and economic sustainabltiy in grain legumes. American Journal of Research Communication. Vol 1(12); www.usa-journals.com

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

Teklu Wegi, 2016. Effects of feeding different varieties of faba bean (*Vicia faba l.*) straws with concentrate on feed intake, digestibility, body weight gain and carcass characteristics of Arsi-Bale Sheep. MSc Thesis. Haramaya Universtiy, Haramaya, Ethiopia. 85pp

Tena Alemu, 2016. Variability in food-feed traits in chickpea (*Cicer Arietinum*) *Varieties*. MSc Thesis. Hawassa University, Hawassa, Ethiopia. 110pp

Tesfaye Alemu and N. K.R. Musimba, 2003. Study on the chemical composition, intake and digestibility of maize stover, tef straw and haricot bean haulms in Adami Tulu District, Ethiopia. Kasetsart J. (Nat. Sci.) 37:401–407.

Tesfaye Fituma, 2015. Effect of *Bradyrhizobium* inoculation and phosphorus rate on nodulation, yield and yield related traits of soybean intercropped with sugarcane in Metahara Sugar Estate, Central Rift Valley of Ethiopia. M.Sc. Thesis. Haramaya University, Ethiopia. 88pp

Tilahun Amede, 2003. Pathways for fitting legumes into the farming systems of East African Highlands: A Dual Approach. In Waddington, S. (ed), 2003. Grain legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress. Soil Fert Net and CIMMYT-Zimbabwe, Hararre, Pp, 21-30.

Tsedeke Kocho, 2007. Production and marketing systems of sheep and goats an Alaba, Southern Ethiopia MSc Thesis, Hawassa University, Hawassa, Ethiopia. 159pp

Valbuena D., S. Homann-Kee Tui, O. Erenstein, N. Teufel, A. Duncan, T. Abdoulaye, B. Swain, K. Mekonnen, I. Germaine, B. Gérard. 2015. Identifying determinants, pressures and trade-offs of crop residue use in mixed smallholder farms in Sub-Saharan Africa and South Asia. Agricultural Systems 134 (2015) 107–118. http://creativecommons.org/licenses/by-nc-sa/3.0

Van Soest, P.J. 1994. Nutritional Ecology of Ruminants, 2nd edition. Cornell University press. London.

Vance C.P, Graham P.H, and Allan D.L., 2000. Biological nitrogen fixation. Phosphorus: a critical future need. In F.O Pedrosa, M. Hungria, M.G Yates, W.E Newton, eds, Nitrogen Fixation: From Molecules to Crop Productivity. Kluwer Academic Publishers, Dordrecht, the Netherlands, pp 506–514.

Wang T.L, Domoney C, Hedley CL, Casey R, and Grusak MA (2003). Can we improve the nutritional quality of legume seeds? Plant Physiol 131**:** 886–891.

Williams, T.O., Fernandez-Rivera, S., Kelley, T.G., 1997. The influence of socio-economic factors on the availability and utilization of crop residues as animal feeds. In: Renard, C.(Ed.), Crop residues in sustainable mixed crop/livestock farming systems. CAB International, ICRISAT, ILRI, Wallingfor, pp.25-39.

Yagoub S. O, W. M. A. Ahmed, and A. A. Mariod, (2012). Effect of Urea, NPK and Compost on growth and yield of soybean (Glycinemax L.), in Semi-Arid Region of Sudan. International Scholarly Research Network. ISRN Agronomy.

Yakubu H., J. D. Kwari and M.K. Sandabe, 2010. Effect of phosphorus fertilizer on nitrogen fixation by some grain legume varieties in Sudano – Sahelian Zone of North Eastern Nigeria. Nigerian Journal of Basic and Applied Science, 18(1):19-26.

Yayneshet Tesfaye, 2010. Ethiopia Sanitary & Phytosanitary Standards and Livestock and Meat marketing Program (SPS-LMM) Texas A&M University System: Feed Resources

Availability in Tigray Region, Northern Ethiopia, for Production of Export Quality Meat and Livestock.

Yetimwork Gebremeskel, Awet E. and Solomon M., 2011. Effect of selected faba bean (*Vicia Faba*) varietal difference on straw DM yield, chemical composition and nutritional quality. Journal of the Drylands 4(2): 333-340

Zarei I., Y. Sohrabi, G. R. Heidari, A. Jalilian and K. Mohammadi, 2012. Effects of biofertilizers on grain yield and protein content of two soybean (*Glycine max* L.) cultivars. African Journal of Biotechnology Vol. 11(27), pp. 7028-7037.

Zinash Sileshi and Seyoum Bediye, 1989. Utilization of feed resources and feeding systems in the central zone of Ethiopia. pp. 129 – 134. Proceedings of the 3rd National Livestock Improvement Conference (NLIC). Institute of Agricultural Research (IAR), Addis Ababa. IAR/NLIC Proceedings, Addis Ababa, Ethiopia, 24 - 26 May 1989.

8. APPENDIXES

8.1. Appendix I: Survey Questionnaires

Name of enumerator: _____________ **Date of interview: ________________**

1. General information

Region: ____________________ Zone: _________________________

Woreda/district: ______________ *Kebele*/PA: ___________________

Name of respondent: __________ Sex: ___________

Age: _________ Educational status: ___________

Participate in N2Africa package Yes ☐ No ☐

2. **Livestock holding:**

Livestock categories	**Number**
Oxen	
Cows	
Bulls	
Heifers	
Calves	
Sheep	
Goats	
Horses	
Mules	
Donkeys	

3. Land holding in hectare and use pattern (if local unit used please indicate)
   a. Total land holding__________
   b. Total land cultivated _________
   c. Land allocated for pulse crops __________
   d. Land allocated for grazing __________
   e. Land allocated for cultivated fodders _____
4. What are the pulse crops (grain legumes) you are producing currently? _________________

   ____
5. Do you use fertilizers on pulse crops (grain legumes)? (Mark with ✓) Yes ☐ No ☐
6. If your answer is yes for question number 5, which fertilizers? ___________________
7. Do you use inoculants on grain legumes (pulse crops)? (Mark with ✓) Yes ☐ No ☐
8. What are the uses/functions of grain legume straws (with ranking of purpose of use if possible)
   a. ____________________________________
   b. ____________________________________
   c. ____________________________________
   d. ____________________________________
9. Your main source of feed for your livestock (with ranking)
   a. Grazing pasture ____

b. Stubble grazing _____
c. Cut-and carry forages _____
d. Cereal residues _______
e. Legume residues ______
f. Hay ___________
g. Others (e.g. By products) ______

10. Do you face feed shortages (Mark with ✓)? Yes ☐ No ☐

At what time of the year? __________

11. How do you cope with the feed shortage ____

12. What is the trend of legume straw use as feed in your case? (Mark with ✓)

a. Increasing _____ c. No change______
b. Decreasing _____ d. No idea _________

13. If your answer is increasing for question number 12, what are the reasons for that?

a. Increased annual production of straw_____
b. Improved awareness on nutritional advantages_____
c. Feed shortage and Lack of other options________
d. Others (specify)___________________________

14. Do you apply any treatment and processing on the legume straw before feeding? (Mark with ✓) Yes ☐ No ☐

15. List treatment methods used and reasons for treatment.

No.	Method of straw treatment employed	Reason for treatment
1		
2		
3		

16. How legume straw is used for livestock feeding? (Mark with ✓)

a. Sole ______ c. Mixed with other supplements ____
b. Mixed with cereal straws ______ d. Others(specify)___________

17. When do you use legume straw for animal feeding? (Mark with ✓)

a. Throughout the year__________
b. During dry season when feed is a critical problem______

c. During wet season as supplement_________

d. Others (specify) _____________________

18. What is the storage method you used for legume straw for later use?

a.__________________

b.__________________

c.__________________

d.__________________

19. Do you think application of fertilizer (like DAP, NPS) and inoculants on grain legumes can affect:

I. Straw yield? Yes ☐ No ☐

II. Straw quality? Yes ☐ No ☐

20. Do you observe varietal difference in the quality of grain legume residues? Yes ☐ No ☐

21. What is the effect of fertilizer and inoculants application on yield and quality of grain legume straws? (Mark with ✓)

I. Straw yield a. Increased ____ b. Decreased ____ c. no change_____

II. Straw quality a. Improved ____ b. Decreased ____ c. no change_____

8.2. Appendix II: Analysis of Variance

Appendix Table 1: Mean squares of yield components from combined analysis of variances for faba bean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
Grain yield	4.6082^{ns}	4.4683	0.3963*	0.1691^{ns}	0.1417	2.72	13.81	0.94
Haulm yield	4.4873^{ns}	7.8316	2.0332*	0.7227^{ns}	0.6005	3.10	24.96	0.85
Harvest index	0.04797^{ns}	0.0225	0.0026^{ns}	0.0056^{ns}	0.0050	0.45	15.94	0.75

#=error for location, Trt=treatment, CV=coefficient of variance, * significant at $P<0.05$

Appendix Table 2: Mean squares of yield components from combined analysis of variances for chickpea grown wit application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
Grain yield	1.1448^{ns}	0.776	1.1991***	0.1303^{ns}	0.0671	1.82	14.25	0.87
Haulm yield	12.8744***	0.857	0.1661^{ns}	0.2648^{ns}	0.1538	2.37	16.58	0.87
Harvest index	0.2120***	00047	0.0108*	0.0015^{ns}	0.0053	0.42	17.43	0.72

#=error for location, Trt=treatment, CV=coefficient of variance, * significant at P<0.05, *** significant at P <0.001

Appendix Table 3: Mean squares of yield components from combined analysis of variances for haricot bean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
Grain yield	1.0220^{ns}	0.6027	0.4240*	0.6040**	0.1820	1.78	23.97	0.70
Haulm yield	1.0121^{ns}	0.6401	0.4761*	0.4893**	0.1259	1.64	21.68	0.77
Harvest index	0.05947*	0.0138	0.0165*	0.0123**	0.0040	0.50	12.80	0.75

#=error for location, Trt=treatment, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01

Appendix Table 4: Mean squares of yield components from combined analysis of variances for soybean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error[#]	Trt	Trt*Location	Error			
Grain yield	3.6782^{ns}	5.2350	2.2177^{*}	0.3055^{ns}	0.6256	2.22	35.68	0.83
Haulm yield	24.6887^{*}	7.0273	5.2214^{**}	1.0662^{ns}	0.8205	2.69	33.72	0.92
Harvest index	0.4849^{*}	0.0952	0.0028^{ns}	0.01388^{ns}	0.0112	0.49	21.34	0.93

[#]=error for location, Trt=treatment, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01

Appendix Table 5: Mean squares of haulm quality parameters from combined analysis of variances for faba bean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error[#]	Trt	Trt*Location	Error			
Ash	84.2341^{**}	5.2700	2.2889^{ns}	2.3407^{ns}	1.6343	7.50	17.04	0.89
CP	10.4340^{ns}	4.7372	3.8174^{*}	3.2099^{*}	1.0111	6.15	16.35	0.82
NDF	918.8577^{**}	68.7145	92.9141^{*}	46.7747^{ns}	22.7075	66.27	7.19	0.88
ADF	680.4608^{**}	56.1218	87.0134^{*}	36.6246^{ns}	21.9269	60.07	7.79	0.85
ADL	44.1576^{**}	3.3377	2.4212^{*}	1.0233^{ns}	0.7761	12.80	6.88	0.90
TIVOMD	203.2856^{*}	28.6328	41.6820^{*}	25.7718^{ns}	13.5973	45.77	8.06	0.79
ME	4.2747^{**}	0.5554	0.8095^{*}	0.4666^{ns}	0.26473	6.68	7.70	0.79

[#]=error for location, Trt=treatment, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, TIVOMD= true in vitro organic matter digestibility, ME=metabolizable energy, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01

Appendix Table 6: Mean squares of haulm quality parameters from combined analysis of variances for chickpea grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error[#]	Trt	Trt*Location	Error			
Ash	23.7478***	1.9571	0.3269ns	0.3605ns	1.0813	6.75	15.41	0.68
CP	85.1523***	2.3615	5.3698***	0.8754***	0.2308	3.72	12.91	0.97
NDF	316.3492***	14.8292	12.2292ns	4.5195ns	8.6602	62.95	4.67	0.76
ADF	233.9216***	11.8850	18.6765ns	5.7758ns	7.4563	50.33	5.42	0.74
ADL	6.9072**	1.0552	0.2604ns	0.2469ns	0.3495	10.10	5.37	0.71
IVOMD	81.9712***	9.4254	24.4540**	6.9809ns	4.9943	46.47	4.81	0.69
ME	16.9798***	0.1710	0.6404***	0.1886*	0.0938	7.16	4.29	0.93

[#]=error for location, Trt=treatment, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, IVOMD= true in vitro organic matter digestibility, ME=metabolizable energy, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

Appendix Table 7: Mean squares of haulm quality parameters from combined analysis of variances for haricot bean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
Ash	38.4086***	3.4411	3.6342*	0.9415ns	1.1239	7.99	13.27	0.83
CP	68.8187***	4.6336	7.0343**	3.0893*	1.4380	6.75	17.76	0.89
NDF	338.2304***	14.6939	25.6773*	5.6832ns	6.8972	69.13	3.80	0.86
ADF	227.8739***	17.5868	28.7064*	6.6110ns	7.4637	56.29	4.83	0.82
ADL	34.8138***	1.5289	0.9337ns	0.8170ns	0.6934	8.22	10.13	0.87
IVOMD	260.0714***	21.6708	22.0253*	10.4267ns	6.4140	56.52	4.48	0.86
ME	0.5102**	0.0894	0.1414*	0.0642ns	0.0432	8.63	2.41	0.72

#=error for location, Trt=treatment, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, IVOMD= true in vitro organic matter digestibility, ME=metabolizable energy, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

Appendix Table 8: Mean square of haulm quality components from combined analysis of variances for soybean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
Ash	8.1864^{ns}	7.5513	0.2448^{ns}	1.0010^{ns}	0.5418	5.89	12.50	0.90
CP	40.8954^{ns}	13.4625	15.7737***	2.1611*	0.9475	5.70	17.08	0.94
NDF	295.0421*	67.4393	15.1102*	2.6702^{ns}	4.9674	75.30	2.96	0.94
ADF	346.2954*	67.9770	19.7285*	6.1576^{ns}	5.5796	58.05	4.07	0.95
ADL	23.0519*	6.8126	1.5096**	0.2635^{ns}	0.2233	10.79	4.38	0.97
IVOMD	57.9556^{ns}	40.2466	7.7819*	5.6867**	1.9412	49.94	2.79	0.94
ME	1.2595**	0.2338	0.0388^{ns}	0.0548**	0.0182	8.78	1.53	0.95

#=error for location, Trt=treatment, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, IVOMD= true in vitro organic matter digestibility, ME=metabolizable energy, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

Appendix Table 9: Mean square of grain quality components from combined analysis of variances for chickpea grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
TSW	47946.0111***	1043.2651	106.1950ns	157.2959ns	126.2819	281.53	3.99	0.95
Ash	0.2475*	0.0527	0.0489ns	0.0460ns	0.0346	3.74	4.97	0.52
CP	55.1148***	3.9272	0.6662ns	0.8476ns	0.8830	19.88	4.73	0.82
ME	0.8491***	0.0511	0.0063ns	0.0151ns	0.0095	10.48	0.93	0.86
IVOMD	46.4045***	3.4912	0.3472ns	0.7819ns	0.5981	71.95	1.07	0.85

#=error for location, Trt=treatment, TSW=thousand seed weight, CP=crude protein, ME=metabolizable energy, IVOMD= true *in vitro* organic matter digestibility, CV= coefficient of variance, * significant at P<0.05, *** significant at P <0.001

Appendix Table 10: Mean square of grain quality components from combined analysis of variances for haricot bean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
TSW	12286.0973***	1221.4562	560.1641***	55.0978ns	68.0507	205.22	4.02	0.96
Ash	3.0199***	0.1724	0.0187ns	0.0432ns	0.0219	5.21	2.84	0.94
CP	515.8332***	13.5661	4.1885*	3.1167**	0.9927	27.26	3.65	0.98
ME	2.9347***	0.0744	0.0410**	0.0177ns	0.0094	11.92	0.81	0.97
IVOMD	264.8274***	7.0583	3.1190**	1.5976*	0.6861	82.60	1.00	0.97

#=error for location, Trt=treatment, TSW=thousand seed weight, CP=crude protein, ME=metabolizable energy, IVOMD= true *in vitro* organic matter digestibility, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

Appendix Table 11: Mean square of grain quality components from combined analysis of variances for soybean grown with application of P fertilizer and inoculants at different locations

Traits	Source of variations					Mean	CV (%)	R^2
	Location	Error#	Trt	Trt*Location	Error			
TSW	1614.5769^{ns}	1154.3860	274.2115^{ns}	458.1477**	132.6313	142.76	8.07	0.85
Ash	0.2465^{ns}	0.3685	0.2258**	0.0856*	0.0361	5.96	3.19	0.85
CP	33.2874^{ns}	42.5233	42.4015***	12.8553*	5.1634	41.55	5.47	0.84
ME	0.7431^{ns}	1.0942	1.2740***	0.3391*	0.1449	9.88	3.85	0.83
TIVOMD	45.3636^{ns}	63.8729	71.3065***	19.6285*	8.2064	76.24	3.76	0.83

#=error for location, Trt=treatment, TSW=thousand seed weight, CP=crude protein, ME=metabolizable energy, IVOMD= true *in vitro* organic matter digestibility, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

Appendix Table 12: Mean squares of grain essential amino acid parameters from combined analysis of variances for chickpea growth with application of P fertilizer and inoculants at different locations

Source of variations	Cys	Hist	Isol	Leu	Lys	Methi	Phen	Threo	Tryp	Tyro	Val	Total Amino acid
Location	0.0049***	0.0325***	0.0293**	0.1719***	0.0203ns	0.0051***	0.0852***	0.0375***	0.0050**	0.0173**	0.0787***	23.2279***
Error#	0.0003	0.0009	0.0045	0.0053	0.0070	0.0002	0.0063	0.0022	0.0005	0.0019	0.0069	1.7930
Trt	0.0001	0.0002	0.0008	0.0010	0.0012	0.00016	0.0007	0.0005	0.0001	0.0008	0.0013	0.3487
Trt*Location	0.0001	0.0003	0.0008	0.0036	0.0021	0.00017	0.0022	0.0004	0.00003	0.0005	0.0008	0.4093
Error	0.0001	0.0004	0.0011	0.0021	0.0021	0.00008	0.0014	0.0007	0.0002	0.0006	0.0014	0.3920
Mean	0.31	0.78	0.66	1.69	1.27	0.18	1.01	0.72	0.18	0.53	0.71	17.46
CV (%)	3.55	2.52	4.91	2.72	3.63	5.097	3.73	3.66	7.32	4.58	5.26	3.58
R^2	0.73	0.83	0.74	0.82	0.63	0.79	0.81	0.78	0.70	0.72	0.81	0.81

#=error for location, Cyst= cystine, Hist= histidine, Isol- isoleucine, Leu= leucine, Lys= lysine, Methi= methionine, Phen= phenylalanine, Threo= threonine, Tryp= tryptophane, Tyro= tyrosine, Val= Valine, Trt=treatment, CV=coefficient of variance, **significant at P <0.01, *** significant at P <0.001

Appendix Table 13: Mean square of grain essential amino acid parameters from combined analysis of variances for haricot bean grown with application of P fertilizer and inoculants at different locations

Source of variations	Cys	Hist	Isol	Leu	Lys	Methi	Phen	Threo	Tryp	Tyro	Val	Total Amino acid
Location	0.03409***	0.12179***	0.652537***	1.27057***	0.62888***	0.04625***	1.14738***	0.39524***	0.06297***	0.35764***	0.78966***	282.0206***
Error#	0.00065	0.00327	0.01797	0.03415	0.01407	0.00142	0.03195	0.0096	0.00163	0.01016	0.02138	7.10834
Trt	0.00044*	0.00188**	0.00585*	0.01819**	0.00273	0.00045*	0.00816*	0.00408*	0.00066*	0.00275*	0.00812**	3.1479**
Trt*Location	0.00022	0.00088*	0.0060**	0.00970	0.00513	0.00056**	0.0075**	0.00368**	0.00050**	0.00301***	0.00536**	2.1219**
Error	0.00014	0.00042	0.00171	0.00423	0.00268	0.00015	0.00265	0.00106	0.00016	0.00078	0.00162	0.61436
Mean	0.40	0.932	0.84	1.93	1.53	0.25	1.34	0.93	0.26	0.67	1.07	22.66
CV (%)	3.03	2.19	4.94	3.37	3.38	4.87	3.84	3.49	4.88	4.17	3.76	3.46
R^2	0.96	0.97	0.97	0.97	0.96	0.97	0.98	0.97	0.97	0.98	0.98	0.98

#=error for location, Cyst= cystine, Hist= histidine, Isol- isoleucine, Leu= leucine, Lys= lysine, Methi= methionine, Phen= phenylalanine, Threo= threonine, Tryp= tryptophane, Tyro= tyrosine, Val= Valine, Trt=treatment, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

Appendix Table 14: Mean squares of grain essential amino acid parameters from combined analysis of variances for soybean grown with application of P fertilizer and inoculants at different locations

Source of variations	Cys	Hist	Isol	Leu	Lys	Methi	Phen	Threo	Tryp	Tyro	Val	Total Amino acid
Location	0.00321	0.03097	0.0695	0.2174	0.06018	0.00552	0.0967	0.0367	0.00606	0.05351	0.09531	33.53609
Error #	0.00451	0.02834	0.07473	0.16934	0.09084	0.00671	0.11401	0.05740	0.00859	0.044174	0.10918	40.47175
Trt	0.00442***	0.03583***	0.08123***	0.22584***	0.07552***	0.006026***	0.13743***	0.05626***	0.00719***	0.04777***	0.09530***	46.44101***
Trt*Location	0.00099*	0.00888*	0.02393	0.06406*	0.0219	0.00224*	0.03702*	0.01563*	0.00215	0.01402*	0.02912*	12.48576*
Error	0.00042	0.00355	0.00927	0.02484	0.01106	0.00086	0.01504	0.00625*	0.00084	0.00549	0.01166	5.0776
Mean	0.50	1.03	1.64	2.76	2.10	0.38	1.88	1.39	0.46	1.33	1.77	35.11
CV (%)	4.07	5.77	5.86	5.71	5.01	7.56	6.53	5.68	6.31	5.57	6.09	6.42
R^2	0.86	0.85	0.84	0.84	0.83	0.83	0.84	0.84	0.86	0.85	0.85	0.84

#=error for location, Cyst= cystine, Hist= histidine, Isol- isoleucine, Leu= leucine, Lys= lysine, Methi= methionine, Phen= phenylalanine, Threo= threonine, Tryp= tryptophane, Tyro= tyrosine, Val= Valine, Trt=treatment, CV=coefficient of variance, * significant at P<0.05, **significant at P <0.01, *** significant at P <0.001

BIOGRAPHICAL SKECH

The author, Mr. Sisay Belete was born on February, 12, 1987 in Ada'a district, East Shewa Zone, Ethiopia. He attended his education at Bole Primary School (grade 1-8), Ada'a Model Secondary School (grade 9-10) and Bishoftu Preparatory School (grade 11-12) at Bishoftu town from September 1994 to July, 2006. He then joined the then Jimma University, Ambo College in November, 2006 and awarded BSc degree in Animal Production in July, 2009. After graduation, he employed by Oromia Agricultural Research Institute and Joined Sinana Agricultural Research Center, Feed Resource and Range Land Improvement case team as Junior Researcher in October, 2009 and worked there for three years.

After three years of service, he left Oromia Agricultural Research Institute and he was then employed by Ambo University in January 2013. In this organization, he served as Assistant Graduate from January 2013 to September, 2014. In October 2014, he joined School of Graduate Studies at Hawassa University to pursue his graduate study in Animal Nutrition.