EVALUATION OF SELECTED GRAIN LEGUMES FOR SOIL FERTILITY IMPROVEMENT IN THE CEREAL BASED CROPPING SYSTEMS OF SOUTHWEST ETHIOPIA

M.Sc. THESIS

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By

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M.Sc. Thesis

Submitted to the Department of Natural Resource Management, College of Agriculture and Veterinary Medicine Jimma University, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Soil Science

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Decision/suggestion of department Graduated Council (DGC)

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DEDICATION

To God almighty and Jesus Christ his only begotten son, for nothing is impossible with God and to My Father Chernet Madolo and My mother, Birknesh Serato, for her all-rounded and unconditional support in my life.

DECLARATION

This thesis is my original work it has never been submitted in any form to other university, it has never been published nor submitted for any journal by another person, and all sources of materials used for the thesis have been duly acknowledged.

Name: Mulatu Chernet

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BIBLOGRAPHY

The Author Mr. Mulatu Chernet was born in Hadiya zone, SNNP Regional State , Ethiopia on 21th of April 1989. He started his elementary education in 1996 at W/Hana elementary school in Hosanna. Secondary education at Wachamo high school in 2006 and preparatory education at Wachamo preparatory school from 2007-2008. After preparatory, he was joined Dilla University and graduated with BSc in Land Resource Management in 2011. From 2012-2013, he worked at Habicho town Municipality office, SNNP region, Ethiopia as the coordinator of Land Information System (LIS)/Cadastre. In 2014, he joined the school of graduate studies of Jimma University College of Agriculture and Veterinary Medicine, (JUCAVM) to study his MSc degree in soil science.

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LIST OF ABBREVIATION

AHI	African Highlands Initiative
BNF	Biological Nitrogen Fixation
CEC	Cation Exchange Capacity
ECSA	Eastern, Central and Southern Africa
FAO	Food and Agricultural Organization of the United Nations
GPS	Geographic Positioning System
IPNM	Integrated Plant Nutrient Management
ISSS	International Soil Science Society
Kg	Kilogram
LSD	Least Significant Difference
MoA	Ministry of Agriculture
TN	Total Nitrogen
Ndfa	Nitrogen derived from atmosphere
NN	Number of Nodule
OM	Organic Matter
P	Available Phosphorus
RDW	Root Dry Weight
SAS	Statistical Analysis System
SDW	Shoot Dry Weight
SOC	Soil Organic Matter
SWE	South West Ethiopia
USDA	United States Department of Agriculture

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ABSTRACT

Decline in soil fertility has become a serious problem in Sub Saharan Africa (SSA) region. It affects all spheres of social and economic life in the region. Among the countries in SSA, Ethiopia has the highest rates of nutrient (N and P) depletions mainly due to the low nutrient input and high biomass removal. An experiment was conducted to determine the effects of selected grain legumes (faba bean and soybean) on soil fertility improvement. Soil samples were collected in a transect walk from Dedo and Tiro-Afeta districts of south western Oromia Regional States, Ethiopia. Six composite soil samples from each transect (based on elevation) were collected at the depth of (0-30cm). The soil samples were collected from fields that are known to grow continuous cereal-cereal at least for the last three years. A pot experiment was therefore conducted under greenhouse conditions in RCBD with three replication on soils obtained from Dedo and Tiro-Afeta transects. Soil physic-chemical properties were studied before and after sowing. All plant related data from crops were recorded at 75% flowering stage. The effect of different elevation levels showed that soil properties before planting were significantly ($P<0.05$) for all studied parameters. The effect was observed by measuring plant Ht, DMP, NN, ANF, Ndfa, soil N and P contents, pH after planting and N and P contents of plant dry matter for each faba bean and soya bean. The study showed a significant ($P<0.05$) difference and positive correlation between all treatments with soil available P before planting except Ndfa for both crops. Faba beans recorded the highest value for the studied parameters under Dedo soils than soybean for the same parameters. Similarly, soybean recorded the highest value under Tiro-Afeta soils than fababean for the studied parameters. Thus, this study concludes that firstly growing fababean crop on the Dedo soils and soya bean crop on the Tiro-Afeta soils would improve soil fertility quickly and inexpensively thereby crop productivity can be enhanced.

***Keyword**: Faba bean, Soya bean, soil fertility, Ndfa.*

1. INTRODUCTION

Soil nutrient balance studies in Africa show evidence of widespread nutrient mining (Speirs and Olsen, 1992; Bohlool *et al*., 1992; Smaling, 1993; Boddey *et al.*, 1996 and Okalebo *et al.*, 2007). Amount of nutrients annually taken away in the form of harvested crops, crop residues transferred out of fields or lost through leaching, erosion and volatilization are higher than the amount of nutrient inputs through fertilizers, deposition and Biological N_2 fixation (Smaling and Braun, 1996, Bado *et al*., 2004; Ndema *et al.,* 2010).

Legumes are important components of various farming systems, and farmers acknowledge the positive contributions of legumes, the amount of land allocated to grow legumes (food, fodder or cover crops) is relatively small (Tilahun, 2003). In the upper highlands of Eastern Africa above 2700 m a.s.l, e.g. Ethiopian highlands, only few legumes are integrated to the system (Amede *et al*., 2001). It is only lentils as a food legume and natural medicines and trifolum as feed legumes, whereby the proportion of legumes in the system is < 2%. In the mid-highlands of East Africa 1000-2200 m a.s.l (both in the cereal-based and perennial-based systems) intermediate and break crops (Eyasu, 2002).

Grain legumes are important components of the farming systems of the East African highlands as they are the sole protein sources for animals and humans (Amede *et al*., 2001). In Ethiopia, legumes are grown in rotation with cereals mainly because, besides restoring soil fertility, they also accompany the staple cereals in the local dishes. However, as farmers export both grain yield and Stover from the field, the amount of legume residue left to the soil is too small to have a profound effect on restoration of soil fertility (Amede and Kirby, 2010).

In 1999 and 2000, researchers of the African Highlands Initiative (AHI) conducted farmer's participatory research on maize varieties in Southern Ethiopia, Areka, by applying different inorganic sources of fertilizers (Amede and Kirby, 2010). Although the soil is an Eutric Nitisol deficient in nitrogen and phosphorus (Waigel, 1996), high level application of inorganic N and P did not improve maize yield. The land is highly nutrient and organic matter are totally depleted. Lack of response to inorganic fertilizers because of low soil organic matter content was also reported elsewhere (Swift and Woomer, 1993).

Nitrogen (N) is thought to be the nutrient that mostly limited in tropical agricultural production (Rufino *et al.*, 2006). As an alternative to N inputs from fertilizer or manure, intensification of nitrogen-fixing legumes is often promoted to increase productivity of cereal-based cropping systems in developing countries. They have the potential to increase the N content of the soil and thereby subsequent cereal yields. At the same time sustainability of soil will be improved by diversifying the cereal dominated cropping with legumes rotations (Vanlauwe and Giller, 2006). Furthermore, crop diversification, in the form of rotation or intercropping, with edible grain legumes could be an option.

Improving N fertilizer efficiency and exploitation of biologically fixed N (BNF) are thus of great importance for long-term sustainability of crop production in agro-ecosystems (Unkovich *et al*., 2008). The global high price for N fertilizer and the overall environmental impact of excessive fertilizer use (Chianu *et al*., 2011; Fan *et al*., 2006) warrant a growing interest in legume BNF, especially for smallholder farmers in the tropics. The use of legume–cereal crop rotation systems, particularly with faba beans, has proven to be an efficient cultivation method to reduce N fertilizer use in tropical highlands (Amanuel *et al*., 2000; Maidl *et al*., 1996), and is thus a sustainable option for agricultural intensification. The beneficial effect of the incorporation of legumes into cereal-based cropping systems with regard to N input through N_2 fixation is well established (Vance, 2001). There is also ample evidence that the positive rotational effect of legumes on subsequent cereals goes well beyond this N effect (Horst and Haerdter, 1994; Bagayoko *et al*., 2000; Bergerou *et al*., 2004).

Many soils in the humid area with high levels of iron (Fe) and aluminum (Al) oxides have high phosphorus sorption capacity leading to low P availability to plants (Eswaran *et al*., 1997; Menzies and Gillman 1997; Vitousek and Farrington 1997). On humid tropical soils, P is the most limiting nutrient for crop production (Ssali *et al*., 1996). However, many plants possess specific mechanisms that allow them to acquire available P more efficiently or mobilize less available soil-P pools (Horst and Kamh, 2004; Lynch and Ho, 2005; Raghothama and Karthikeyan, 2005; Shenoy and Kalagudi, 2005).

In most soils, the transport of P to the root is the main limiting factor for P acquisition rather than root P uptake (Barber, 1995; Jungk and Claassen, 1997). Therefore, enhancing P transport and soil/root contact through lateral root formation (Lynch *et al.*, 1997; Manske *et* *al*., 2000) and reduced root diameter (Fohse *et al*., 1991), or establishing a symbiosis with arbuscular mycorrhizal fungi which allows plant access to soil P up to several cm away from the root (George *et al*., 1995; Li *et al*., 1997) will improve soil-P acquisition by plants. The release of H^+ or OH) (Gahoonia *et al.*, 1992), organic acid anions (Kirk, 1999; Gerke *et al*., 2000), the increase of reduction capacity (Holford and Patrick, 1979), and rhizosphere phosphatase activity (Tarafdar and Jungk, 1987) will allow the plant to access poorly available inorganic and organic soil-P fractions and thus increase the pool of soil/fertilizer P which contributes to plant P nutrition. In low-input cropping systems of the farmers usually do not apply P fertilizers to their crops due to the cost of P fertilizer needed for meaningful management of the high P-fixing soils.

Therefore, the incorporation into a rotation of legumes plants those are efficient at acquiring P from less available sources and/or in combination with cheaper sources of P such as phosphate rock (PR). This has been previously shown for leguminous cover crops (Gardner and Boundy, 1983; Horst *et al*., 2001; Kamh *et al*., 2002; Vanlauwe *et al*., 2000a, 2000b). In addition to a possible improvement of the P use and N supply to cereals grown in rotation (Carsky *et al*., 1997; Peoples and Craswell, 1992), enhancement of soil physical properties and detoxification of aluminum (Al) have been found to contribute to a positive rotational effect of legumes (Bagayoko *et al*., 2000; Horst and Haerdter, 1994).

Most Ethiopian soils are deficient in nutrients, especially nitrogen and phosphorus and fertilizer application has increased yields of crops (Asnakew *et al*., 1991). Besides, in modern agriculture, the replenishment of soil nitrogen by extensive application of chemical fertilizers has several negative environmental impacts (Peoples *et al*., 1995). Hence, it is important to understand these constraints and develop low cost techniques that focus on development of appropriate Integrated Plant Nutrient Management (IPNM) for the Ethiopian highlands. In Ethiopia, declining soil fertility requires approaches that include, but go beyond application of chemical fertilizers (Beyene, 1988; IFPRI, 2010). Bio-fertilizer as an alternative to commercial fertilizer N for pulses is gaining priority due to its economic and ecological benefits (Beyene, 1988; Hailemariam and Tsige, 2006; Wijnands *et al*., 2011; Jensen *et al.*, 2012). Biological nitrogen fixation (BNF) is a renewable source of nitrogen to replace inorganic nitrogen fertilizer (Beyene, 1988; Bejiga, 2004).

The faba bean *(Vicia faba L.)* is a long-day plant with optimal performance in good-structured clay or loam soils with pH 6.5-9 and temperatures between 18 and 27 °C (Jensen *et al*., 2009; Link *et al*., 2010). Faba bean is the major grain legume for food in Ethiopia, especially important in the southwestern highlands (Agegnehu *et al*., 2006), where it occupies about 17902 hectares with an annual production of around 0.20 million tons (CSA, 2008). This legume has attracted attention due to its demand as export crop and is now one of the leading pulses in Ethiopia (Agegnehu and Tsigie, 2004). Faba bean has the capacity to mobilize soil phosphorus by secretion of acids from its rhizosphere, and is therefore of important value in low-input crop rotation systems (Nuruzzaman *et al*., 2005).

The benefits of soybean (*Glycine max* L.) over other grain legumes commonly grown by smallholders, include lower susceptibility to pests and disease (Giller *et al*., 2011; Mpepereki *et al*., 2000), better grain storage quality, and a large leaf biomass which gives a soil fertility benefit to subsequent crops (Mpepereki *et al*., 2000). Besides, soybean was identified as the crop with a potential to address the need for diversifying the cropping systems, which could assist in overcoming the pervading soil fertility constraints and could provide smallholder farmers with an opportunity to earn income while also addressing the nutritional security of households (Giller *et al*., 2011). Furthermore, soybean has a major potential to benefit smallholder farmers where soil fertility is extensively depleted due to a combination of increasing population, poverty and inherently poor soil (Vanlauwe and Giller, 2006).

Dedo and Tiro-Afeta, located south west part of Ethiopia are known for cereal crop production. The major problems in the area are constant drain of nutrients from the soil through grain harvest and due to farmers removal of crop residue from the field to use the residue as animal feed or as a source of energy. Cereal-mono cropping system leads to increasing soil nutrient degradation, and aggravate the downward spiral of soil fertility loss in the study areas. Indeed, low productivity, poor response of crops to chemical fertilizers and high cost of chemical fertilizers are major problems of the study areas. Therefore, taking the above problems into consideration, scientific studies on the effects of Fababean and soya bean contribution in Integrated Soil Fertility Management for soil fertility and crop yield improvement is essential and may be important for police maker, academic purpose, research institution and rural communities.

1.1. Objective of the study

1.1.1. General objective

The general objective of the study is to identify the effects of grain legumes on soil fertility improvement in the cereal based cropping systems of South West Ethiopia (SWE)

1.1.2. Specific Objective

- To determine both above and below ground biomass production potential of selected grain legumes
- To assess the effect of the selected grain legumes on soil chemical properties
- To evaluate N and P contribution potentials of the selected grain legumes

2. LITERATURE REVIEW

2.1. Concepts of grain legume Nitrogen fixation

Legume crops plays a great role in soil fertility management in the cereal based cropping systems of Ethiopian highlands as it fixes substantial atmospheric nitrogen (Amanuel *et al*., 2000). The amount of nitrogen fixed in the roots of grain legumes has been estimated at 150-200 kg/ha, most of which is removed in the grain of the crop (Fisher, 1996).

Legumes are also known to increase soil fertility through various mechanisms. High quality legume fodder produces also high quality manure that could improve soil fertility (Fustec *et al*., 2010). Legumes can also boost the nitrogen stock of the soil through nitrogen fixation and nutrient release from their organic residues. Some legumes also release root exudates that may increase the availability of unavailable/fixed nutrients, e.g. phosphorus, through changing the rhizosphere pH and increased activity of the rhizosphere biota (Tilahun, 2003).

The ability of legumes to fix atmospheric nitrogen is perhaps the most notable aspect that sets them apart from other plants (Lunnan, 1989; Fujita *et al*., 1992; Karlen *et al*., 1994; Adu-Gyamfi *et al*., 2007). In addition, legumes can provide a wide range of important soil quality benefits. Soil quality benefits of legumes include: increasing soil organic matter, improving soil porosity, recycling nutrients, improving soil structure, decreasing soil acidity by increasing pH, diversifying the microscopic life in the soil, and breaking disease build-up and weed problems of grass-type crops (Peoples and Crasswell, 1992; Bowren *et al*., 1995; Varvel, 2000).

2.2. Residual effects of legumes cereal rotation on soil fertility

Soil fertility benefits of legume diversification depend on the legume-cereal ratio, the duration of legume biomass production and residue management (CSA, 2004; Rachel *et al.,* 2007; Rahman *et al*., 2009). Edible legumes are usually harvested, and their leaves used as a vegetable or for forage thereby reducing nutrient input to the soil. The N benefit of including a grain legume in a rotation has been widely debated; it is estimated at 0–190 kg N ha^{-1} for short or medium-duration soybean and generally higher for a longer-duration legume that grows for about 180 days (Giller and Cadisch, 1995; Hardarson and Atkins, 2003).

Long-season legumes are biologically superior at fixing significant amounts of N, enhancing P availability and yields of subsequent cereal crops, compared to short-duration legumes. The trade-off is that short-duration varieties tend to have the highest yield potential, while contributing fewer nutrients for soil enhancement (Giller and Cadisch, 1995). Farmers may be interested in access to both types of legumes (Kitch *et al*., 1998).

Use of rotational systems involving legumes for nitrogen fixation benefits is gaining importance throughout the region because of economic and sustainability considerations. The beneficial effect of legumes on succeeding crops is normally exclusively attributed to the increased soil N as a result of N_2 fixation (Bationo *et al*., 2003).

Legumes are commonly grown in rotation with cereals in the cereal-dominated highlands. Traditionally, the major cereals like teff (*Eragrostis Abyssinian*), wheat or barley is grown in rotation with pulse crops. Faba beans, common bean and soybean are grown following wheat or teff. Farmers rotate cereals with pulse crops for dual objectives. Firstly, legumes can restore soil fertility through N-fixation and residual effects (Tilahun and Kirkby, 2004). Secondly, legumes can break the cycle of host-specific pests and diseases, which otherwise will remain in soil dormant and revive whenever the true host comes into contact. (Jung *et al*., 1989) compared the after-effect of faba bean, red desmodium and alfalfa on the yield and nitrogen budget of the succeeding wheat in central Ethiopia. They found out that winter wheat grown after legumes took up 118, 47 and 65 Kg N/ha after faba beans, red desmodium and alfalfa, respectively. The amount of nitrogen recovered by wheat was only 24 - 44% of the potentially available nitrogen. The rest N was lost by leaching, which could have been recovered if a crop was grown in association with or immediately after the legumes are harvested (Getnet *et al*., 2002).

The commonly observed residual effects of the inclusion of a legume crop in a cropping system on a subsequent cereal crop can be due to many processes. First there is the possible positive effect due to the net N input in the soil from biological N fixation (provided the quantity of N fixed is larger than the quantity of N exported in grains or crop residues) and or due to the N-sparing effect (Giller, 2001). Residual effects can also be due to reduction of the weed seed bank including parasitic weeds (Carsky *et al.*, 2000), possible P mobilization and transfer of P to the subsequent cereal changes of population structure of soil fauna and soil microbes (e.g. mycorrhizal fungi (Bagayoko *et al*., 2000), or pathogenic organisms such as nematodes (Bagayoko *et al*., 2000; Alvey *et al*., 2001; Diels and Dercon, 2006).

Accumulated organic matter also improves the chemical properties of the soil, increasing cation exchange capacity and slowing down leaching. Medium-and long term effects on soil nutrient supply are also possible. After the first season the rate of nutrient release from a single application of organic matter is likely to be small, but with the accumulation of organic matter the total nutrient release from slowly turning over materials can become significant (Rowe and Giller, 2002; Peoples *et al.,* 2009).

Organic inputs from legumes could increase crop yield through improved nutrient supply/availability and/or improved soil-water holding capacity. Moreover, legumes offer other benefits such as providing cover to reduce soil erosion, maintenance and improvement of soil physical properties, increasing soil organic matter, cation exchange capacity, microbial activity and reduction of soil temperature (Tarwali *et al.*, 1987; Abayomi *et al.*, 2001) and weed suppression (Versteeg *et al.*, 1998).

2.3. The effect of grain legumes on selected soil chemical properties

Many soil fertility characteristics (including organic matter content, pH, cation exchange capacity, phosphate sorption, and phosphorus availability) show significant altitudinal variations (Jobbagy and Jackson, 2000). Since, crop production and soil managements differ with kind of soil and their Physico-chemical behavior (Mani, 1990; Sharma *et al.*, 2006). Several factors related to soil fertility limit agricultural production. Many factors such as soil type, farmer's practices, crop residues and mineral fertilizers management influence crop yields (Bado *et al.*, 2004). Among those factors, the texture and the chemical composition of soils remain a major constraint to crop production in large scale in tropical regions (Ndema *et al.,* 2010).

The production of grain legumes is affected by the texture of soil and organic matter content richness (Nyabyenda, 2005). The influence of soil texture on organic matter decomposition indicate that the rate of decomposition and net mineralization depend on the accessibility of organic substrates to soils organisms (Hassink, 1992). Changing the texture through sand amendments increased the bulk densities of the soil (Jobbagy and Jackson, 2000). Clay particles are believed to protect some of the more easily decomposable organic compounds from rapid microbial breakdown through encrustation and entrapment (Tisdall and Oades, 1982). The protective action by clays against organic matter degradation through the formation of complexes between metal ions associated with large clay surfaces and high CEC explains the effect of soil texture on organic matter decomposition (Giller *et al*., 1997). Fine textured soils (clays) often contain higher amounts of organic matter than sandy soils (Jobbagy and Jackson, 2000).

2.4. Biological nitrogen fixation (BNF) by legume crops

(Biological Nitrogen Fixation) BNF is a natural process in legume crops, where atmospheric dinitrogen (N_2) is fixed into ammonia (NH_3) in plant root nodules by a symbiotic form of rhizobia, a gram-negative Proteobacteria. The plant assimilates this NH_3 into proteins, nucleic acids and other nitrogenous compounds (Strodtman and Emerich, 2009). BNF is important in terms of saving fertilizer costs and hereby reducing costs for crop production and avoiding ground water pollution; enhancing protein production and thus improving nutrition status of the people; fixing N_2 for succeeding crops and contributing to improved soil fertility (Hardarson, 1993).

Biological Nitrogen Fixation, which enables legumes to depend on atmospheric nitrogen (N), is important in legume-based cropping systems when fertilizer-N is limited (Fujita and Ofosu-Budu, 1996), particularly in SSA where nitrogen annual depletion was recorded at all levels at rates of 22 kg ha^{-1} (Smaling *et al.,* 1997) and mineral-N fertilization is neither available nor affordable to smallholder farmers (Jama *et al.,* 2000). BNF contributes N for legume growth and grain production under different environmental and soil conditions. In addition, the soil may be replenished with N through decomposition of legume residues (Fujita and Ofosu-Budu, 1996). Legumes species commonly used for provision of grain and green manure have potential to fix between 100 and 300 kg N ha^{-1} (Giller, 2001).

Nitrogen fixation can contribute directly to agricultural production by providing the N of the leafy vegetative parts, pods, seeds and tubers of plants used as feed for livestock or harvested for human consumption. Nitrogen fixation is also a major source of N for agricultural soils via the N- rich residues that remain following plant harvest or grazing (Unkovich *et al.,* 2008).

Symbiotic relationships between legumes and rhizobia are responsible for the largest contributions of fixed N to farming systems (Giller, 2001). Establishment of effective N_2-fixing symbioses between legumes and their N_2-fixing bacteria (rhizobia) is dependent upon many environmental factors and can be greatly influenced by farm management practices (Peoples *et al.,* 1995). One of the most factors limiting a legume's ability to fix N_2 is the absence of sufficient numbers of effective rhizobia in the soil. Fortunately, strains of rhizobia can be introduced into soil relatively simply by inoculation and, in many countries, this has been practiced successfully on a commercial scale for many years (Unkovich *et al.*, 2008). However, research had demonstrated that nutritional deficiencies induced by poor supply of available phosphorus commonly restrict legume growth and N_2-fixation (Giller and Cadisch, 1995).

The fixed N contributes to productivity both directly, where the fixed N is harvested in grain or other food for human or animal consumption, or indirectly, by contributing to the maintenance or enhancement of soil fertility in the agriculture system by adding N to the soil (Giller and Cadisch, 1995). The ability of legumes to improve soil fertility has been explored by several researchers (Snapp and Silim, 2002). Biological N_2-fixation is an important option for improving the soil N balance in smallholder farming systems (Giller, 2001). Beneficial effects of legumes on soil fertility as well as subsequent cereal crops are well documented (Peoples and Craswell, 1992; Wortmann *et al.*, 1994). Although the benefits of legume N fixation to the system have been reported, N fixation differs from one legume to another and in some cases N_2-fixation by legumes cannot compensate for the N removed through the produce. Grain legumes have been reported to contribute to soil fertility N enrichment when the percentage of N derived from fixation is greater than or equal to the nitrogen harvest index (NHI) of that legume and when the stover is incorporated (Giller *et al.,* 1994; Toomsan *et al*., 1995).

The amount of nitrogen fixed varies according to the legume species and variety. Within a species the amount of nitrogen fixed is directly related to (dry matter) yield. Most grain legumes including soybean can obtain between 50 and 80 % of their nitrogen concentration requirements through biological fixation, but some, like fababean will fix up to 90 % (Solomon *et al.,* 2012). Among the family of the Leguminosae (Fabaceae), *Vicia faba L.* is one of the best N_2 fixers (Amanuel *et al.*, 2000; Jensen *et al.*, 2009), fixing an amount of atmospheric nitrogen in the range of 165 to 240 kg N ha^{-1}. Lopez-Bellido *et al.* (2006) reported that up to 96% of the N taken up by the faba bean was derived from the atmosphere (%Ndfa, percentage nitrogen derived from atmosphere).

2.4.1. Nodulation potential in grain legume crops

The legume-rhizobia symbiosis is highly specific (Marel *et al*., 1996 and Denarie *et al*., 1992) and depends on complex signaling processes between the host plant and rhizobia partner. Symbiotic N fixation between legumes and rhizobia takes place in plant-derived root organs called nodules, and competent nodulation is critical for efficient BNF. Molecular dialog or signal exchange between the legume and Rhizobium (Denarie *et al*., 1992) is a complex process that involves both the legume symbiotic (sym) genes and the rhizobia nodulation (nod) genes. In the beginning of the signaling process, legumes exude flavonoid compounds into the rhizosphere, which then trigger soil dwelling rhizobia to release highly specific reverse signal molecules, nod factors, only comprehended by specific legume species (Cooper, 2004) to initiate nodule formation. Rhizobia strains have a defined group of legumes species, or host range, with which they can nodulate, and in parallel, legumes select for specific rhizobia partner species (Denarie *et al*., 1992). For example, Rhizobium leguminosarum biovar viciae (Rlv) nodulates plant species belonging only to tribe viciae, which includes the genera Vicia, Pisum, Lathyrus, and Lens.

Soybean is primarily nodulated by *Bradyrhizobia spp*., however some Rhizobium species also nodulate soybean hosts (Yamato *et al*., 1997). Specificity can be variable among legumes and rhizobia, with some legume species such as Phaseolus vulgaris known to associate with a wide range of rhizobia (Andrade, 2002). Nodulation, defined here as the number of nodules formed and the total nodule mass contained on a plant, is most related to soil rhizobial population size, with high nodulation occurring where compatible rhizobial population is high (Patrick and Lowther, 1995).

While nodulation success is vital to BNF efficiency, excessive nodule formation without an associated increase in N fixed can be detrimental to plant growth as this process is energy driven and uses a large percentage of the host plant’s photosynthetic production to fuel the fixation of N. Hence, most legume hosts have a mechanism to control the number of nodules and zone of nodule development called auto regulation of nodulation (Oka and Kawaguchi, 2006). Legume hosts that lack this regulatory system are characterized by excessive nodule numbers and are said to be hypernodulating mutants (Ferguson *et al*., 2010).

Soil properties have been shown to affect legume nodulation either by impacting rhizobia population sizes and diversity, or interfering directly with the process of nodule formation. Soil acidity has been reported by several researchers as one of the main factors influencing rhizobial population size (Lapinskas, 2007), with extremely low population sizes of 10 cells g^{-1} soil or less being observed in cropped un limed acidic soils (Coventry and Hirth, 1992).

2.5. Phosphorus benefits of legumes

Phosphorus is one of the most important elements that significantly affect plant growth and metabolism thus its deficiency limits legume production in most agriculture soils (Abel *et al.*, 2002). Phosphorus plays key roles in many plant processes such as energy metabolism, nitrogen fixation, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation. It influences nodule development through its basic functions as an energy source. However, the element is generally deficient and limits biological nitrogen fixation in highly weathered tropical soils (Nyemba, 1986; Tsvetkova and Georgiev, 2003; Kumaga and Ofori, 2004).

The use of legumes in rotations may enhance P availability and yields of the subsequent cereal crop (Vanlauwe *et al*., 2000a; Horst *et al*., 2001). P efficient legumes such as white lupin (*Lupinus albus*) and pigeon pea (*Cajanus Cajan*) are characterized by rhizosphere processes (acidification of the rhizosphere and/or excretion of organic acids) that allow these species to mobilize P from sparingly soluble P pools (Braum and Helmke, 1995; Hocking *et al*., 1997; Bloem and Barnard, 2001). The P is taken up by the legume and partly returns to the soil through the residues as a high quality organic P source for the subsequent cereal crop.

When trying to establish legumes, the most common problem is shortage of phosphorus. In highly acid soils liming or adding animal manure can raise the pH and increase the availability of phosphorus. Legumes are mobilize more P from poorly soluble P compared to non-legumes (Kamh *et al*., 1999; Nuruzzaman *et al*., 2005). A greenhouse study found that several legumes showed less response to increasing P fertilizer addition than cereals due to the capability of the legumes to utilize native soil P (Bolland *et al*., 1999). Legumes increase growth and P uptake of the following cereal (Carsky *et al*., 2001; Nuruzzaman *et al*., 2005). It is suggested that the positive pre-crop effect of legumes on cereals is due to P mobilization or P release from legume residues. In most soils, however, the only option is adding phosphorus. Adding plant residues or animal manures will help provide some phosphorus, but mineral fertilizers are by far the most effective means. When sowing grain legumes or green manures, adding small amounts of phosphorus (20 to 30 kg ha^{-1}) (Swaminathan, 2003).

In Ethiopia, the highlands are dominated by acid P-fixing soils like Nitisols and occur widely in Ethiopian highlands where rainfall intensity is high and P fixation due to high Fe and Al content of these soils makes is the major problem. The use of legumes in rotations may enhance P availability and crop yields of the subsequent cereal crop (Barrios *et al*., 1998). Legumes can increase the growth and P (phosphorus) uptake of the following cereals which may be related to mobilization of P during the growth of the legumes (Hasnuri *et al*., 2010). The P is taken up by the legume and partly returns to the soil through the residues as a high quality organic P source for the subsequent cereal crop. Grain legume crops may improve P availability for crops grown in rotation with them, and this may be one of the reasons why they are becoming increasingly important in agriculture (Siddique and Skyes, 1997).

Like nitrogen, phosphorus is an essential element in plants and is required particularly to support energy transfer within cells. Much of the phosphorus in the plant is in inorganic form and readily reacts in the sequence of events resulting in energy transfer (Bieleski, 1973). Abundant inorganic phosphorus can be stored in the vacuoles of cells in substantial excess to provide a phosphorus reserve for late-season plant growth when phosphorus in the soil solution may no longer be available (Lauer *et al.*, 1989 and Lee *et al*., 1990). The lack of vacuoles in young leaf cells to supply stored phosphorus causes the development of meristems to be especially inhibited by deficient phosphorus uptake (Freeden *et al*., 1989; Rao *et al.*, 1993).

Grain legume species, however, have evolved mechanisms to allow recovery of phosphorus from unavailable forms and some legumes also release root exudates that may increase the availability of unavailable/fixed phosphorus through changing the rhizosphere pH and increased activity of the rhizosphere biota (Tilahun, 2003). For example, when grown on soils with no available phosphorus, (Ae *et al*., 1990) found that grain legume crops thrived for 1 month after sowing while four other crop species died from phosphorus deficiency. A similar experiment with peanut showed it survived for two months after sowing while three other species died (Ae and Shen, 2002).

There appear mechanisms that can be employed by grain legumes to release unavailable phosphorus in the soil for recovery by the plants. One mechanism is the exudation of organic acids from legume roots. Several organic acids are exuded with citrate being predominant among common bean (Shen *et al*., 2002), soybean and cowpea (Nwoke *et al*., 2008). Malate is exuded predominately by lupin, field pea, and faba bean and Chickpea was found to exude large amount of citrate and malate (Ohwaki and Hirata, 1992). Other organic acids exuded by grain legumes include oxalate, tartrate and acetate. However, the effectiveness of these organic acids in mobilizing phosphorus is highly dependent on the soil and the soil environment (Jones *et al*., 2003). For example, organic acid mediated solubilization of phosphorus by addition of citrate or oxalate varied widely among 20 contrasting soils (Jones *et al*., 2003).

There appears to be a other mechanism expressed by some grain legumes for recovering phosphorus from unavailable forms. Ae and Shen, (2002) reported an ability of peanut and pigeon pea to recover phosphorus from unavailable forms by a contact reaction between the root surface and the insoluble phosphorus adjacent to the root.

3. MATERIALS AND METHODS

3.1. Description of the study area

The research was conducted in Dedo and Tiro-Afeta district of the Oromia Regional State, South West Ethiopia and located in the Jimma Zone, about 335 km from Addis Ababa. Jimma Zone is found between (1609-3018m a.s.l) of areas (Aticho, 2011). Average day temperatures are about 18.6°C and annual total rainfall ranges between 1592-1275mm, with bimodal distribution (Aticho, 2011). The dominating soils of the region are Nitisols (Alemayehu, 2009). These soils are strongly weathered, well drained and have favorable physical properties for agricultural practices and well recognized as the most productive soils in Ethiopia (Alemayehu, 2009; Aticho, 2011). Main crops cultivated in this region are maize, sorghum, wheat, barley, teff, enset, faba bean and coffee (Amanuel *et al*., 2000; Agegnehu *et al*., 2008).

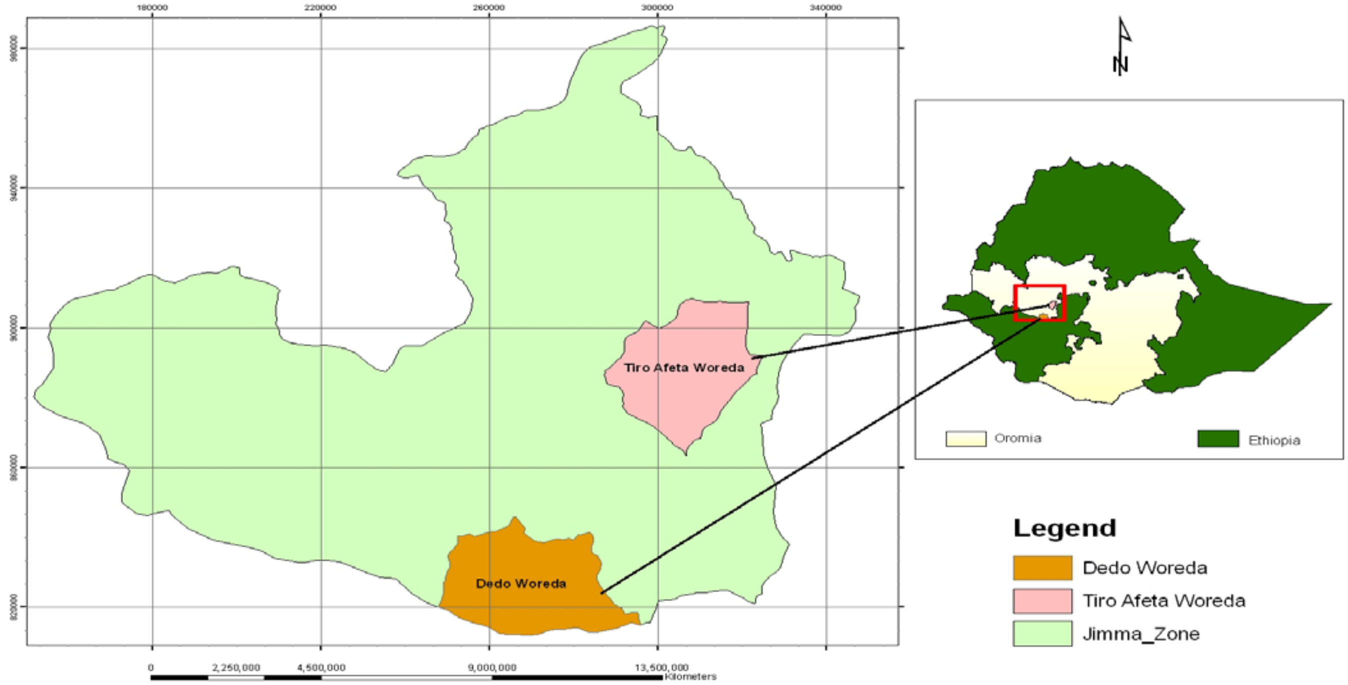

Figure 1: Location Map of the Research Site Dedo and Tiro Afeta Woreda, South West Ethiopia

3.1.1. Dedo district

Dedo is located in South-West Ethiopia between 07°22'- 07° 58' N latitude and 36°21'-36°52' E longitude (BPEDORS, 2000). The district has an average yearly rainfall of 1920mm (data from 1975-2007, cited by Amsalu *et al*., 2014). The mean annual temperature is 20.2°C. Dedo Woreda is located at 18 km South of Jimma town and comprises of a total area of 1459.1 Km^2. Dedo is mountains and the altitude of the Woreda extends between 1600 and 2400m a.s.l. The Woreda consists of 18% highlands, 48% midlands and 34% lowlands (BPEDORS, 2000). The soil was classified as Nitisols (Alemayehu, 2009). The farming practices are characterized by crop-livestock mixed system, cereal grains are the major food crops cultivated whereas, livestock, chat and coffee are the major cash crops of the Woreda.

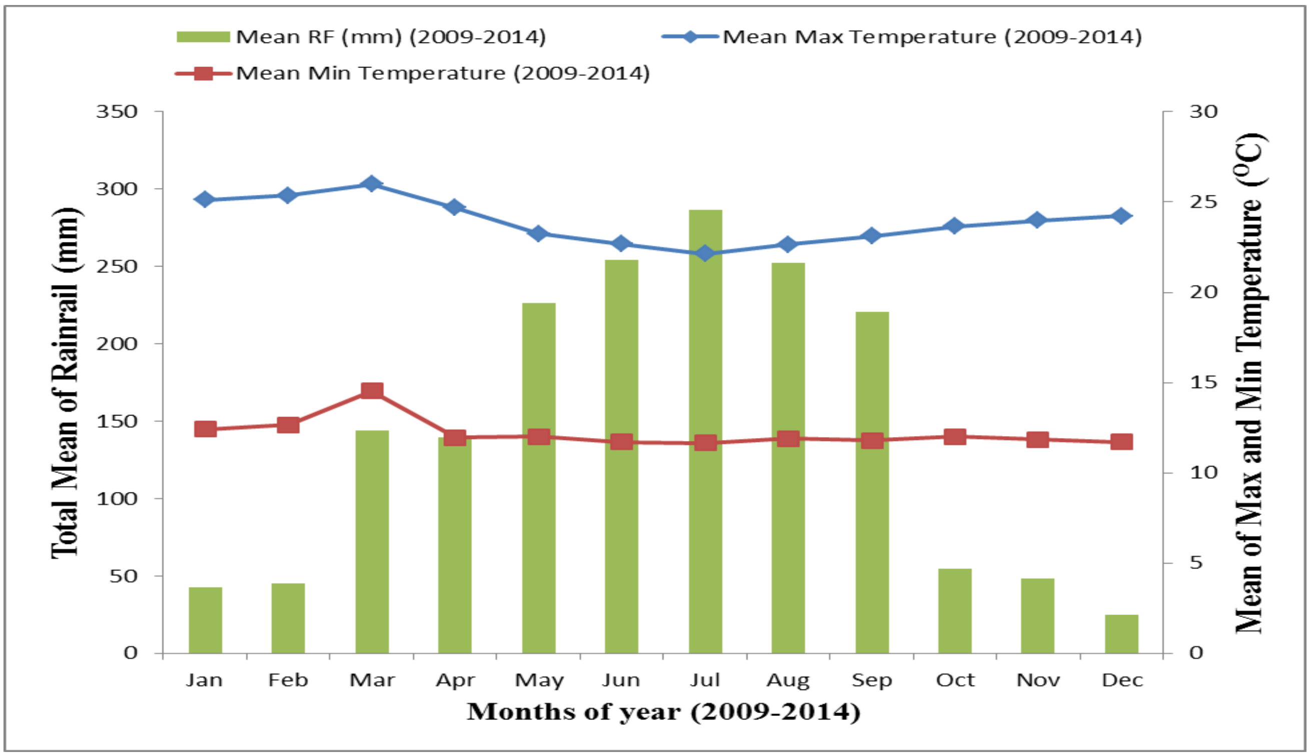

Figure 2: Total monthly rainfall (RF), average minimum (T-min) and maximum (T-max) temperatures of the Dedo.

Most of the rain falls in the months of March–September (Fig. 2). The average minimum and maximum temperature for 2009-2014 between 12.9 and 23.7°C (data from 2009-2014, obtained from the National Meteorology Agency of Jimma branch).

3.1.2. Tiro Afeta district

Tiro Afeta is one of the districts in Jimma Zone of the Oromia Region of Ethiopia. The altitude of this woreda ranges from 1600 to 2300 m a s l and lied between 07° 20'- 07^{o} 45’ N latitude and 034° 25'- 34^{o} 53’ E longitude (BPEDORS, 2000). The district has an average yearly rainfall of 1431.8mm (data from 1982-2007, cited by Amsalu *et al*., 2014). Tiro Afeta is bordered on the south by Omo Nada, on the west by Kersa, on the north by Limmu Kosa, and on the east by Sokoru. A survey of the land in this woreda shows that 26% is arable or cultivable (20.5% was under annual crops), 8.3% pasture, 14% forest, and the remaining 51.7% is considered built-up, degraded or otherwise unusable. The soils in this moderately productive, food self-sufficient area are fertile red and brown clay loam. Agriculture is entirely rain fed. The principal crops grown are maize, sorghum, teff and coffee (BPEDORS, 2000).

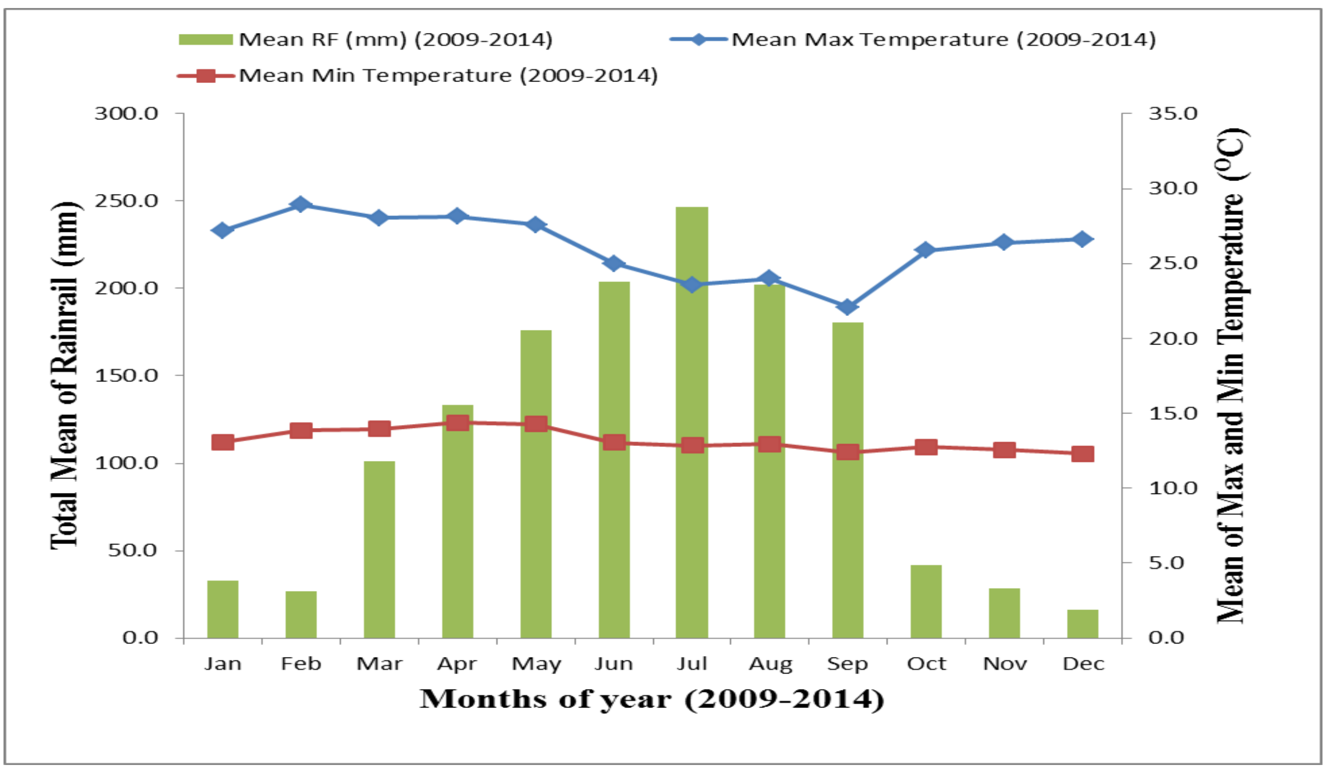

Figure 3: Total monthly rainfall (RF), average minimum (T-min) and maximum (T-max) temperatures of the Tiro afeta district.

Most of the rain falls in the months of April–September (Fig. 3). The average minimum and maximum temperature for 2009-2014 between 13.9 and 25.9^{o}C (data from 2009-2014, obtained from the National Meteorology Agency of Jimma branch).

3.2. Soil Sampling and Collection

Soil samples were collected from the two study sites (Dedo and Tiro-Afeta) based on Elevation and cropping history. The sampled sites were known for continuous cereal production for the last three years that is known to grown continuous cereal-cereal at least for the last three years. A total six composite soil samples were collected by transect walking from both location to another, such as (Location I, Location II and Location III) from each districts (Dedo and Tiro afeta) where cereal crops grown for last three continuous years (Table 1). From different farm plot soils sample collected separately were different Elevation and the sampled sites were recorded by GPS (global positioning system). The selected representative fields were replicated three times, and from each field, fifteen soil sub-samples were collected at depths of 0-30cm by using an Auger. Just before grown to make composite according to (Wilding, 1985) procedure, that represent the experimental area for detailed physicochemical analysis each individual at JUCAVM.

Table 1: Site characteristics of the study area

Sample Sites	Latitude (N)	Longitude (E)	Ranges of altitude	Slope Ranges	Dominant crops for last three consecutive year
Dedo Woreda					
DL1	7^{o}51'- 7^{o}56'	36^{o}49'- 36^{o}52'	Above 2300	moderately	*wheat- barely -wheat*
DL2	7^{o}34'- 7^{o}40'	36^{o}35'- 36^{o}42'	1900-2300	gently	*wheat- barely-wheat*
DL3	7^{o}22'- 7^{o}26'	36^{o}24'- 36^{o}29'	1700-1900	gently	*teff-wheat-teff*
Tiro-Afeta Woreda					
TaL1	7^{o}40'- 7^{o}43'	34^{o}49'- 34^{o}52'	1900-2300	moderately	*maize-teff-sorghum*
TaL2	7^{o}31'- 7^{o}35'	34^{o}37'- 34^{o}41'	1700-1900	gently	*sorghum-teff-sorghum*
TaL3	7^{o}20'- 7^{o}24'	34^{o}26'- 34^{o}31'	1500-1700	gently	*teff-maize- sorghum*

D= Dedo, Ta= Tiro afeta, L= Location, (Moderately= 5-10% & gently= 2-5%) FAO, (2006), N= North and E= East and altitude classification according to (MoA, 2000).

3.3. Soil sample preparation and laboratory analysis before planting

Soil samples were air dried and sieved through a 2 mm for analysis of physicochemical properties except bulk density. Samples were analyzed for selected physical and chemical soil properties at soil laboratory of JUCAVM.

3.3.1. Soil pH

The pH of the samples was measured with 1:2.5 soil-water ratio methods (Reeuwijk, 2002). For the soil-water ratio method, 25 mL of distilled water was added to 10g of soil. The solution was stirred for one minuets and left for 1hr to rest. Then, the soil suspension was stirred and measured by using glass electrode pH meter.

3.3.2. Particle size and Bulk Density

Soil particle size distribution was determined by the Boycouos hydrometric method (Bouyoucos, 1962; Van Reeuwijk, 1992) after destroying OM using hydrogen peroxide (H_2O_2), sodium carbonate (Na_2CO_3) was used as soil dispersing agent and two drops of amyl alcohol was used for foam reduction. The soil textural classes were determined using the International Soil Science Society (ISSS) system (Yong and Warkentin, 1966), triangular guideline.

Bulk density of undisturbed soil sample was determined by core method (FAO, 2007) using core sampler and determining the mass of solids and the water content of the core, by weighing the wet core, drying it to constant weight in an oven at 105°C for 24 hours.

$$Bulk\ Density\left(\frac{g}{cm3}\right)=\frac{W2-W1}{V}$$

Where, W_2 and W_1 are weights of moist and oven dry soils, respectively and V is the volume of the cylindrical core.

3.3.3. Total carbon and nitrogen content

The Soil organic carbon was determined by the Walkley-Black oxidation method with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid solution and titrated with 0.5 N ferrous sulfate solutions (Walkley and Black, 1934) and percent soil OM was obtained by multiplying percent soil OC by a factor of 1.724 (Sahlemedhin and Taye, 2000) following the assumptions that OM is composed of 58% carbon.

$$\textit{Percent of Organic matter (OM)} = 1.724 \times \%\ C$$

Total N of the soil was determined through digestion, distillation and titration procedures of the wet digestion by Semi-micro Kjeldhal method (Bremmer and Mulvancy, 1982) whereby the ammonia evolved was collected in a boric acid solution in the presence of indicators (methyl red and bromocresol green) and titrated with 0.1N H_2SO_4 to pink end color (Sahlemedhin and Taye, 2000).

3.3.4. Available phosphorus

The plant available P fraction in the soil samples was determined using the Bray II method extraction method as described by (Bray and Kurtz, 1945). Thus, 0.2 g of soil was mixed with 14 mL extracting solution Bray, containing 0.03M NH_4F and 0.025 M HCl. The solution was shaken for 1 minute and filtered through Whatman filter paper. The 2 mL of the sample was pipette into a test tube and 8 mL boric acid as well as 2 mL mixed reagent was added. Solutions were left for about 1 hour to develop the blue color. Absorbance was measured at 882nm with a UV/VIS spectrophotometer and plant available P concentrations (mg P kg^{-1} soil) in the soil samples were derived from the calibration curve.

3.4. Experimental lay out

A pot experiment was conducted on soils obtained from fields that are known to grow continuous cereal-cereal at least for the last three years. Grain legumes such as such as faba bean and soya bean were grown on these soils under greenhouse condition without any inorganic and organic fertilizers. A check plot (pot) that contains only cereal crops (wheat for Dedo and teff for Tiro-Afeta) was also included. The experiments were laid out in randomized complete block design (RCBD) with three replications. The reason why RCBD was used is that: The greenhouse that used for this experiment does not have the required facilities to control weather conditions inside. It is simply a screen-house with shelters from its top and sides. This cannot control at least the wind/air movement through the main door. It can avoid the confounding effects wind/air movement through the main door.

3.3.1. Pot experiments in the greenhouse

Seventy eight pots were prepared and given tag for identification purpose. The diameter of each pot was 28cm; radius 14cm and length 32cm. The distance between adjacent pot and blocks was 10cm and 15cm apart, respectively.

$A = \pi r^2$ where, A= Area of pot, r= Radius of pot and D= Diameter

$\boldsymbol{\pi}$ **=** 3.147 and r = 14cm

$A = 44 * 10^{-8}$ ha

A total of 274.56 Kg of bulk soil was collected from both districts (Dedo and Tiro afeta) at different elevations. Of these soil, 3.52 kg was filled in the each pots. From the total of 78 pots, in the 72 pots, the selected grain legumes namely fababean and soybean were sown. But in the rest 6 pots wheat and teff crops were planted. The seeding rate for legumes was four seeds per pot while for cereals 16 seeds for wheat. On June 07/2015, Planting was conducted after 1 week, right from filling of soil in the pots. After 10 days of planting, 1 seedling out of four was removed from each pot. The soil analysis was conducted both before planting and after harvesting.

Where, F= Faba bean grown soil D= Dedo district L= Location

S= Soya bean grown soil T= Tiro-Afeta district r= Replications

Figure 4: Pot experimental layout in the greenhouse

3.4. Plant parameter

3.4.1. Plant height measurement

Two plants from each pot were randomly selected at 75% of flowering stage and tagged. The height measurements for *Vicia faba L.* and *Glycine max L.* was taken at seventh weeks right from planting by using measuring tape. Height measurement was made from the ground level to the topmost point, and the average for each pot was calculated (AOAC, 1990).

Figure 5: Plant height measurements of *Vicia faba L.* and *Glycine max L.* plant

3.4.2. Nodule assessment

Nodule assessment of *Vicia faba L.* and *Glycine max L.* was carried out at 75% of flowering stage, Nodule count was taken from each pot by placing them on a tray (Pal and Saxena, 1975; Desta and Angaw, 1988).

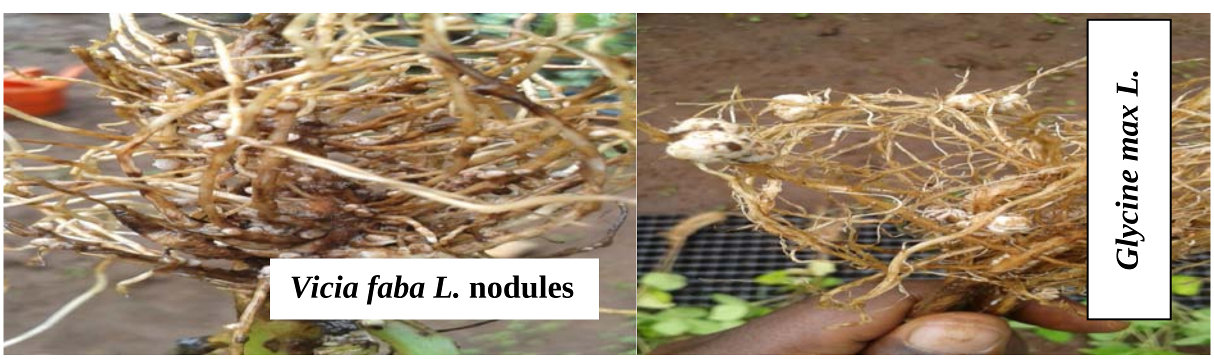

Figure 6: Roots of *Vicia faba L.* and *Glycine max L.* plant for nodule assessment.

3.4.3. Root parameters

A root sample from the experimental pot was taken at 75% flowering stage. From each pots plants was selected and uprooted. Fresh weigh were obtained immediately in the field after harvest using an electronic balance (Fehr *et al*., 1971). All samples were packed in paper bags and labeled, then transported to the soil laboratory of JUCAVM, for oven drying at 70°C for 48 hours after which the dry weighs were recorded and calculated according to (Fehr *et al*., 1971).

% Root dry matter = dry wt. /fresh wt. * 100 (Eq 3.1)

3.4.4. Shoot parameters

A shoot sample from the experimental pot was taken at 75% flowering stage. Fresh weigh were obtained immediately in the field after harvest using an electronic balance. All samples were packed in paper bags and labeled, then transported to the soil laboratory of JUCAVM, for oven drying at 70°C for 48 hours after which the dry weighs were recorded and calculated according to (Fehr *et al*., 1971).

% Shoot dry matter = dry wt. /fresh wt. * 100 (Eq 3.2)

3.5. Laboratory analysis after harvesting

3.5.1. Soil sample preparation and laboratory analysis after harvesting

Soil samples were air dried and sieved through a 2 mm for analysis of chemical properties of the soil from pot experiments. Samples were analyzed for selected chemical soil properties at soil laboratory of JUCAVM to see treatment effects.

The pH of the samples was measured with 1:2.5 soil-water ratio methods (Reeuwijk, 2002). For the soil-water ratio method, 25 mL of distilled water was added to 10g of soil. The solution was stirred for one minuets and left for 1hr to rest. Then, the soil suspension was stirred and measured by using glass electrode.

The soil organic carbon was determined by the Walkley-Black oxidation method with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid solution and titrated with 0.5 N ferrous sulfate solutions (Walkley and Black, 1934).

Total N of the soil was determined through digestion, distillation and titration procedures of the wet digestion by Semi-micro Kjeldhal method (Bremmer and Mulvancy, 1982) whereby the ammonia evolved was collected in a boric acid solution in the presence of indicators (methyl red and bromocresol green) and titrated with 0.1N H_2SO_4 to pink end color (Sahlemedhin and Taye, 2000).

The plant available P fraction in the soil samples was determined using the Bray II method extraction method as described by (Bray and Kurtz, 1945). 0.2 g of soil was mixed with 14 mL extracting solution Bray, containing 0.03M NH_4F and 0.025 M HCl. The solution was shaken for 1 minute and filtered through Whatman filter paper. The 2 mL of the sample was pipette into a test tube and 8 mL boric acid as well as 2 mL mixed reagent was added. Solutions were left for about 1 hour to develop the blue color. Absorbance was measured at 882nm with a UV/VIS spectrophotometer and plant available P concentrations (mg P kg^{-1} soil) in the soil samples were derived from the calibration curve.

3.5.2. Plant sample preparation and laboratory analysis

3.5.2.1. Total nitrogen content of plant tissues

Bulk of plant samples were taken at 75% flowering and oven dried at $70^{o}C$ for 72 hours and then grinded. Plant samples of 0.3 g were ashed in porcelain crucibles for 5 hours at 550°C. Total N was determined through digestion, distillation and titration procedures of the wet digestion by Semi-micro Kjeldhal method (Bremmer and Mulvancy, 1982) whereby the ammonia evolved was collected in a boric acid solution in the presence of indicators (methyl red and bromocresol green) and titrated with 0.1N H_2SO_4 to pink end color (Sahlemedhin and Taye, 2000).

3.5.2.2. Total phosphorus content of plant tissues

Determination of phosphorus was carried out on the digest aliquot obtained through wet digestion by (Chapman and Pratt, 1961; Ryan *et al*., 2001). Plant samples of 0.5 g were ashed in porcelain crucibles for 5 hours at 550°C. The phosphorus in the solution is determined calorimetrically by using molybdate and metavanadate for color development. Plant phosphorus is converted to orthophosphates during digestion. These orthophosphates react with 10ml molybdate and vanadate and give yellow colored unreduced vanado-molybdophosphoric heteropoly complex in acid medium. The yellow color is attributed to a substitution of oxyvanadium and oxymolybdenum radicals for the oxygen of phosphate. The reading is made at 460nm wavelength. The P concentration (PC) was expressed in kg P ha^{-1} dry weight (Khair *et al.*, 2002).

3.6. Estimation of N_2 fixed by legumes

A recommended alternative to the N estimation method is the N difference method in which available soil N levels under both the legume and the reference crop are taken into account. By incorporating the soil N component, soil N transformations over the growing season and respective differences in N uptake from the two crops can be assessed.

The nitrogen difference method was used for calculation of the amount of N_2 fixed by a legume. In this method, the amount of N-fixed obtained through comparison of a legume and a non N_2-fixing reference plant. The N yield of the legume, here the faba bean and soybean are composed of N derived from the soil and N derived from the atmosphere, whereas the N yield of a reference plant is derived from the soil only (Peoples *et al*., 2009). Assuming that the legume assimilates the same amount of soil mineral N as the reference plant, the amount of N_2 fixed can be calculated by subtracting the N yield of the reference plant (Wheat and Teff) from the N yield of the legume from faba bean and soybean:

N_2 fixed = (N yield N_2-fixing plant - N yield reference plant) +
(Soil mineral N under N_2-fixing plant - soil mineral N under reference plant) (Eq 3.3)

Above "equation 3.3" procedure has been suggested to improve the accuracy of the methodology for legumes when the legume and reference plant are may not well matched in terms of soil N uptake (Evans and Taylor, 1987). In this method the difference in postharvest soil mineral N is also determined in the N_2-fixing and reference pots, and added to the difference in total N yield of the two crops.

The difference in total N accumulation between the N_2-fixing and non N_2-fixing plants grown in the same soil is attributed to N_2 fixation. The assumption here is that the non N_2-fixing and N_2-fixing plants extract the same amount of N from the soil (Unkovich *et al*., 2008).

$$\% \text{ Ndfa} = \frac{[\text{Total N in legume} - \text{Total N in reference crop}]}{\text{Total N in legume}} \text{ X } 100 \qquad \text{(Eq 3.4)}$$

Where % Ndfa is the percentage of N_2 derived from the atmosphere

3.7. Statistical Analysis

Both soil physicochemical properties and plant data were subjected to analysis of variance using the general linear model procedure of the statistical analysis system version 9.2 (SAS, 2002). The least significance difference test (LSD) test was used to separate the significances between treatments at 5% probability level. Moreover, simple correlation analysis was executed with the help of (Gomez and Gomez, 1984) to reveal the relationships between selected soil and plant parameters among location.

On the other side, relative change in soil properties was computed as:

$$\text{Relative Change} = \frac{(Pap - Pbp)}{Pbp} X \, 100$$

Where P_{ap} is the soil property measured on the soil after planting and $P_{\mathbf{bp}}$ is the property of soil measured before planting.

4. RESULTS AND DISCUSSION

The first part of this research is reporting the laboratory analysis and characterization experiment of the soils from Dedo and Tiro Afeta. The second part involved a pot experiment. Accordingly, the results of the soil and plant analysis of the pot experiment were discussed of faba bean and soybean grown on soils sampled from Dedo and Tiro-Afeta districts.

4.1. Physico-chemical properties of soil before experiment

4.1.1. Effects of elevation on soil texture and bulk density

According to the soil textural triangle of USDA system the soils of the two sites are classified as clay. This is due to the fact that on the analysis result the highest percentages (61%, 45.6%) and (55%, 41%) of clay values were recorded from both at location 3 of Dedo and Tiro-Afeta locations respectively. On the other hand, the highest value of silt and sand under Dedo location 2 and 1 were (36.6, 18.3) and the lowest value location 3 and 2 (26, 10.3) respectively. Under Tiro-Afeta the highest value of silt and sand was (30, 30) at location 3 and 1, while the lowest values were recorded at location one and three respectively.

All of the soil samples have clay content more than 30%, which is the marginal ranges of total clay requirement for Nitisol (WRB, 2006). The highest percentages of clay was observed at Dedo, while the lowest values were recorded at Tiro-Afeta (Table 2). The clay and sand property were significantly ($P \leq 0.05$) affected by different locations at both Dedo and Tiro-Afeta sites as shown (Table 2). Because of high rain falls the fine particles from the upper elevation can easily detach and transported to the lower elevation positions in the study area. These results agreed with (Roukos *et al*., 2011; Mtambanengwe *et al*., 2004; Jobbagy & Jackson, 2000) significant altitudinal/elevation variations of soil physical properties.

The mean value of bulk density of the soil in the two sites were significantly different ($P < 0.05$) affected by different elevation level. The highest mean (1.31 g/cm^3) value of bulk density was recorded on the Dedo location three and the highest mean (1.5 g/cm^3) under Tiro-Afeta location three might be associated with relatively low content of organic matter and very high clay. The lowest mean (1.14 g/cm^3) value under the Dedo location one and the lowest mean (1.17 g/cm^3) value under the Tiro-Afeta location one as shown (Table 2). The reason for higher soil bulk density on the DL3 as well as in the TaL3 could be due to the very high clay content (Sevgi, 2003; Kidanemariam *et al*., 2012; Shazia *et al*., 2014) and low SOM are low in percent pore space and result in higher Bulk density.

Table 2: SD± and Mean comparison of soil particles and bulk density before planting on Dedo and Tiro afeta.

Locations	% clay	% silt	% sand	STC	BD (g/cm^3)
DL1	45.6 ± 0.5^c	36 ± 1.0^a	18.3 ± 0.5^a	Clay	1.14 ± 0.02^b
DL2	53 ± 1.0^b	36.6 ± 0.5^a	10.3 ± 0.5^b	Clay	1.25 ± 0.03^a
DL3	61 ± 1.7^a	26 ± 2.0^b	13 ± 1.0^c	Clay	1.31 ± 0.01^a
P Value	**	**	**		**
LSD (0.05)	3.16	3.66	1.51		0.05
CV (%)	2.62	4.9	4.8		2.08
TaL1	41 ± 2.6^c	29 ± 1.7^a	30 ± 1.0^a	Clay	1.17 ± 0.03^b
TaL2	46.3 ± 3.7^b	29 ± 4.1^a	24.3 ± 1.5^b	Clay	1.22 ± 0.02^b
TaL3	55 ± 2.6^a	30 ± 1.1^a	14.3 ± 1.5^c	Clay	1.5 ± 0.01^a
P value	**	ns	**		**
LSD (0.05)	3.02	4.89	2.38		0.06
CV (%)	2.77	7.36	4.67		2.05

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Means in a column shows different letters are highly significantly different ($p<0.05$) and similar letters shows non-significant by LSD Test. STC = soil texture class; BD= Bulk density; DL= Dedo location; TaL= Tiro afeta location; LSD= Lattice square design and CV= Coefficient variability.

4.1.2. Soil organic carbon, Organic matter, nitrogen, phosphorus and pH

The organic carbon, organic matter, total nitrogen (TN), plant available phosphorus and pH for soils from Dedo and Tiro-Afeta farm fields were given in (Table 3). The results showed that soil pH_{H2O} varied significantly ($P<0.01$) across locations (Table 3). The pH of the highest mean of Tiro-Afeta soil was lower than the pH of the highest value of Dedo soil. For instance, the highest value (6.22±0.15) and (5.91±0.04) soil pH_{H2O} values were recorded at lower elevation (location 3) for both districts (Table 3). Whilst the lowest value of pH (5.46) and (5.46) were recorded at higher elevation (location 1) with both Dedo and Tiro-Afeta districts, respectively.

Soil pH-H_2O ranged from 5.46 to 6.22 at both transects location one and at Dedo location three respectively. All of the soil samples had pH-H_2O less the critical level (6.5-8.5) given by (Landon, 1991). These low soil pH at the study sites could be attributed to the leaching in to soil profiles even beyond sampling depth through leaching and drain to streams through runoff generated from accelerated erosion. This enhances the activity of Al^{3+} and H^+ in the soil solution, which reduces soil pH and thereby increases soil acidity. The depletion of basic cations in crop harvest, as indicated in their significant reduction, due to continues crop production is another cause for the fall in soil pH (Schumann and Glover, 1999; Nanthi and Mike, 2003). Furthermore, continuous use of ammonium based fertilizers such as diammonium phosphate, $(NH_4)_2HPO_4$, and urea in such cereal based cultivated fields, which upon oxidation by soil microbes produces strong inorganic acids. These strong acids in turn provide H^+ ions to the soil solution that in turn lower soil pH. Acidic nature of Nitisol was also reported by (Yihenew, 2002). Thus, it is pertinent to raise the soil pH through liming to increase crop productivity of the study areas. Generally, the pH values observed that soil pH was significantly affected by upper elevation as compared to lower elevation (Pradhan *et al*., 1996) difference and in the study area were within the ranges of strongly acidic to slightly acid soil reactions as indicated by (Landon, 1991; Tekalign, 1991; Tisdale *et al*., 1993).

Reported by (Mahler *et al*., 1988) the optimal values for pH_{H2O} in soils for legume crop especially faba bean production ranges from 5.7 to 7.2. Soils with a pH_{H2O} lower than 5.6 results in lower grain yields, while soya bean can service lower pH than 5.7. Therefore, Tiro-Afeta soil has thus a pH that is too low for optimal faba bean production. Dedo soil does reach optimal pH values either. It has a pH above the 5.6 border value for good production.

Soil OM content is highly affected by different elevation levels. These elevation variations resulted in highly significant differences ($P < 0.01$) of OM content among the different elevation at both sites (Table 3). The highest value (4.49±0.03) and the lowest value (3.12±0.11) of OM contents were recorded on farm field Dedo location 3 and location 1, respectively, while the highest value (2.61±0.11) and the lowest value (1.12±0.55) of OM contents were recorded on farm field of Tiro-Afeta location 3 and location 1, respectively. The highest OM content was recorded on the lower elevation of Dedo location three and the highest OM contents was recorded on the lower elevation of Tiro afeta location three as shown (table 3) were significantly ($P < 0.05$) different at different elevation. In the higher elevation relatively low soil OM, as compare to both middle and lower elevation of farm land in both sites. In line with the present findings, earlier results suggested that the low accumulation of OM in farm land soils could be due to, the reduction in total organic inputs (litter and crop residues); increased mineralization rates of organic matter caused by tillage and increased wetting-and-drying cycles and the loss by soil erosion (Gregorich *et al*., 1998; Chroth *et al*., 2003). Generally, the OM values observed in the study area are within the ranges of low to medium and/moderate as indicated by (Berhanu, 1980 and Tekalign, 1991).

Soil OC is highly affected by different management practices continues cereal-cereal cropping system and variation in elevation at different location, (Table 3). Organic carbon varied significantly ($P<0.01$) across locations. Organic carbon was recorded of higher value (2.61±0.02) and lowest value (1.81±0.06) for Dedo soils location 3 & 1 respectively. Similarly, the highest value (1.51±0.06) and the OC lowest value (0.65±0.32) were recorded at location 3 and location 1 respectively, of Tiro-Afeta districts.

Organic carbon ranged from 0.65% at Tiro-Afeta location o1 to 2.61% at Dedo location 3 (Table 3). According to (Sanchez *et al*., 1982; Landon, 1991), all of the sampled soils had organic carbon greater than the critical level (0.5-1%) except Tiro afeta location one. High organic carbon than the critical, in Nitisol was also reported by (Mesfin, 1998 and Eylachew, 1999; Wakene and Heluf, 2001; Shimeles *et al.*, 2006).

With increasing elevation the organic carbon content were decreased and the organic carbon status of the soils in lower elevations were higher because of transportation bases and top part of soil particles from upper elevation to lower elevation. OC values for Dedo location 1 and Tiro-Afeta location 3 soil are in the range of values found by (Agegnehu and Fessehaie, 2006), for Nitisols in Ethiopia (1.5-1.8% C). OC values for Dedo location two and three were higher than (Agegnehu and Fessehaie, 2006), but location 3, OC content was lower than values found by (Amanuel *et al*., 2000) for Nitisols in the southeastern Ethiopian highlands (3.0% C). The value of OC at Tiro-Afeta location 1 and 2 were lower than the value found by (Agegnehu and Fessehaie, 2006). The TC values observed in the study area are within the ranges of low to medium and/moderate as indicated by (Tekalign, 1991).

Table 3: SD± and Mean comparison of soil pH, TC, OM, TN and Av.P of Dedo and Tiro afeta districts before planting of grain legumes.

Location	pH (H_2O)	OC (%)	OM (%)	TN (%)	Av.P (mg P kg^{-1})
DL1	5.46±0.06^c	1.81±0.06^c	3.12±0.11^c	0.15±0.01^c	6.7±0.84^b
DL2	5.69±0.13^b	2.07±0.03^b	3.56±0.06^b	0.18±0.00^b	8.8±0.85^b
DL3	6.22±0.15^a	2.61±0.02^a	4.49±0.03^a	0.22±0.01^a	12.2±0.85^a
P Value	**	**	**	**	*
LSD (0.05)	0.14	0.11	0.19	0.01	2.21
CV (%)	1.07	2.32	2.29	3.09	10.5
TaL1	5.46±0.11^c	0.65±0.32^b	1.12±0.55^b	0.05±0.03^b	4.3±0.36^c
TaL2	5.67±0.05^b	1.22±0.06^a	2.11±0.10^a	0.11±0.01^a	5.9±0.9^b
TaL3	5.91±0.04^a	1.51±0.06^a	2.61±0.11^a	0.13±0.01^a	8.9±0.64^a
P Value	**	**	**	**	**
LSD (0.05)	0.15	0.35	0.59	0.03	1.46
CV (%)	1.182	13.6	13.56	15.43	10.07

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Means in a column shows different letters are highly significantly different ($p<0.05$) and similar letters shows non-significant by LSD Test. OC= Organic carbon; OM= Organic matter; TN= Total nitrogen; Av.P= Available phosphorus; DL= Dedo location; TaL= Tiro afeta location; LSD= Lattice square design and CV= Coefficient variability.

Total N content of soils was significantly ($P \leq 0.01$) different at both Dedo and Tiro afeta location affected by different elevation level as shown (Table 3). The average values of total N was highest at location 3, while the lowest value was recorded at location 1 in the Dedo location 3 & location 1 respectively. The highest value (0.13±0.01) and the lowest value (0.05±0.03) recorded under the Tiro-Afeta location 3 & location 1 respectively (Table 3). Total nitrogen ranged from 0.05% at Tiro-Afeta location one to 0.22% at Dedo location three. Based on the classification of (Landon, 1991; Sanchez *et al*, 1982), total nitrogen was found as one of the limited plant nutrient in the study sites. The values of total nitrogen in all soil samples were below the critical level (<1%). The observed nitrogen deficiency in all soil samples could be because of low input of plant residues, nitrogen rich organic materials like manure and compost in cereal based farming systems. As the area receives high rainfall, the nitrogen leaching problem can be another reason for the decline of total nitrogen in cropped fields. Moreover, farmers of the study area do not integrate leguminous plants on their farmlands. Shimeles *et al.* (2006), similar nitrogen contents in the cultivated Nitisol was reported.

Total nitrogen (TN) was almost doubled for Dedo compared to Tiro-Afeta. TN values for Dedo soil were in the range of values found by (Agegnehu and Fessehaie, 2006), for Nitisols in Ethiopia (0.17-0.22% N) and the value of TN to Tiro-Afeta were low. TN values for Dedo and Tiro-Afeta are lower compare to values found by (Amanuel *et al.*, 2000) for Nitisols in the southeastern Ethiopian highlands (0.25% N). The TN values observed in the study area are within the ranges of Low to Medium and/high (0.10-0.25) as indicated by (Tekalign 1991).

Plant available phosphorus, as determined by the Bray method (Bray and Kurtz, 1945) in the Tiro-Afeta soil is relatively low compared to Dedo soil. The available phosphorus was significantly ($P \leq 0.01$) different at different elevations (Tables 3). The content of available P in the Dedo and Tiro afeta at lower elevation level of farm land appeared to be significantly higher than the rest upper two elevation level. Accordingly, the highest (12.2±0.85 mg P kg^{-1}) and the lowest (6.7±0.84 mg P kg-1) available P contents were observed under the Dedo location 3 and location 1, respectively and the highest value (8.9±0.64 mg P kg^{-1}) and the lowest (4.3±0.36 mg P kg^{-1}) available P contents were recorded under the Tiro-Afeta location 3 and location 1, respectively as shown (Table 3).

Available phosphorous ranged from 4.3 mg P kg^{-1} at Tiro-Afeta location 1 to 12.2 mg P kg^{-1} at Dedo location 3 (Table 3). From the soil samples, except Dedo location 3 all available phosphorous below the critical level (10-15 mg P kg^{-1}) given by (Landon, 1991; Sanchez *et al*., 1982). The low level of available phosphorous in the study area might be due to its fixation by Al and Fe, as their presence is expected at the pH values of the soils of the study areas (Tisdale *et al*., 1993). High phosphorous sorption capacity of Nitisol was also reported by (WRB, 2006). The reason for higher P contents at lower elevation might be due to attributed to higher soil organic matter content, the nutrient availability improved through recycling of the biomass back into the soil and high OM decomposition that enhance the amount of available P in the soil at lower elevation level.

According to (Cook, 1967; Cottenie, 1980; Landon, 1991) available soil P level of < 5 mg P kg^{-1} is rated as very low, 5-9 mg P kg^{-1} as low and 10-17 mg P kg^{-1} as medium, 18-25 mg P kg^{-1} as high and >25 mg P kg^{-1} is rated as very high. Thus, the available P of the soils of the study area, with the exception of the higher elevation of Tiro-Afeta and lower elevation Dedo sits of farm land, was between 5-9 mg P kg^{-1} qualifying for the low ranges and Dedo location 3 was qualifying for moderate level, were Tiro-Afeta location 1 qualify for the very low ranges (Table 3). Also results from the soil analysis for plant available P in Dedo and Tiro afeta upper and middle elevation are in the range of the values (5.0 to 10.1 mg P kg^{-1} soil) found for Nitisols in the Ethiopian highlands (Agegnehu and Fessehaie, 2006) but lower elevation were higher in the ranges of (10.0 to 17.0 mg p kg^{-1}) under Dedo sites.

In general, soils with a pH less than 5.5 (as is the case for both Dedo location 1 and Tiro-Afeta location 1) in the higher elevation, are deficient in available P content because of complexation and fixation of cations by adsorbing surfaces in the soil. Due to P complexation and slow release of P fertilizers, the proportion of the P available for plants becomes inadequate (Leon and Le Mare, 1990; Marschner, 1995; Agegnehu and Sommer, 2000).

4.2. Effects of faba bean and soybean on chemical characteristics of soil

Grain legumes such as *Vicia faba L.* and *Glycine max L.* were grown on soils of Ferralic Nitisol properties at Dedo and Tiro-Afeta, as characterization made by (Alemayehu, 2009) at Southwestern Ethiopia. A pot experiment was designed based on the physico-chemical characteristics under different location of the soil from Dedo and Tiro-Afeta. Design of the experiment and statistical methods for data analysis were explained in the section ‘Materials and Methods’.

Physico-chemical soil data for Dedo and Tiro-Afeta are given first before planting. Pot experiments were conducted on greenhouse soil from three farmer’s fields for each district and selected chemical properties were analyzed after plant harvested. Then the results from plants such as, *Vicia faba L.* and *Glycine max L.* analysis were discussed for both Dedo and Tiro-Afeta soil separately, followed by a comparison between the two soils. Sub pots, Wheat and Teff were included as a reference crop for estimation of biological nitrogen fixation. Pearson correlation coefficients (r) were calculated for the parameters at each locations pot experiment. For Dedo and Tiro-Afeta soil, data for the measured parameters (Pht, NN, RDW, SDW, ANF, %P and %N) are given first. Then, for every measured parameter, the effects of the location factors, as assessed by ANOVA hierarchical model selection, were discussed.

The pH_{H2O} of Dedo and Tiro-Afeta soil after plant growth in the pot experiment showed significant ($p<0.01$) differences. There way a decline in pH for all treatments relative to the initial soil pH (Table 4 and Appendix table 9) under faba bean grown. The highest value of pH was recorded under Dedo lower elevation (6.18±0.14) and the lowest value of pH was under Dedo location 1 (5.4±0.05) pH value for faba bean grown. The faba bean grown under Tiro-Afeta soils at each treatments were significantly affected ($P<0.01$). The highest value of pH was recorded under location 3 (5.8±0.06), while the lowest value (5.4±0.12) was recorded under location 1 Tiro-Afeta as shown (Table 4).

Generally, as shown *Vicia faba L.* (Table 4) grown soil pH were decreased under all locations, perhaps, legumes remove more calcium and magnesium (replaced with hydrogen) than some cereal crops. Removing the basic cations decreases OH^- ions and increases H^+ thus lowering the pH. Thus net efflux of H^+ into the rhizosphere occurs, resulting in decreases in rhizosphere pH and eventually in bulk soil pH. This has been demonstrated in a number of studies (e.g. red clover, Mengel and Steffens 1982; white clover, lucerne, faba bean and soybean, in Haynes, 1983; pasture legumes, Tang *et al*., 1997). Legume species differ greatly in their ability to acidify the rhizosphere and external media. A net excretion of protons from roots per unit biomass has been reported to range up to an order of magnitude across different species (Jarvis and Hatch, 1985; Liu *et al*., 1989; McLay *et al.*, 1997; Tang *et al*., 1997a; 1997b). As reported (Raven, 1993), the acid generated by N_2-fixing legumes varies from 0.2 to 1 mol H^+ per mol N fixed.

But in this investigation all legume crop residues were removed from the soil and transported to analysis of N and P in the laboratory, these might be another reason for the decrease of pH value in the soil after harvested *Vicia faba L.* crops. The magnitude of the pH changes varied with type and rate of plant materials added and was positively correlated with the amount of excess cations added via plant materials to the soils. This is supported by other studies in which the degree of pH increase of an acidic soil with organic matter addition was well correlated with the amount of basic cations (Pocknee and Sumner, 1997). In contrast the application of legume shoots, roots and leaves in to soils significantly increased soil pH (Tang *et al*., 1997c).

The form and amount of nitrogen in soil have prominent influence on acid production by the plants. The uptake and assimilation of one mole of $NH4^{+}$ are associated with the excretion of 1.1-1.2 moles of H^{+} (Raven, 1993). However, if all the legume residues were returned *in situ* to the soil and no N losses occurred, net acidification of the soil would be zero (Helyar, 1976) because of the de-acidifying process in the decomposition of plant materials (Mengel, 1994). It can be concluded that the application of legume residues, which usually have high ash alkalinity, is not in itself likely to cause soil acidification. By contrast, the return of legume residues to the soil may increase soil pH. The decarboxylation of organic anions appears to be a major cause of soil pH increases.

The concentration of N in the soils was significantly ($P<0.05$) different and increased after faba bean grew under Dedo soil, as compared to soils nutrient conditions before faba bean planting (Table 5 and Appendix table 1). The highest value of N after harvest of faba bean was (0.23±0.01) recorded Dedo location 3 at lower elevation level increased by 4.5% as compared to initial soil N before planting (Table 4). The lowest value of N was recorded under Dedo location 1 (0.17±0.01) which increased by 13.3% as compared before planting N availability (Table 4). Similar results have been reported that legume crops have positive effects on nutrient status, especially on N and P status (Wang Z *et al*., 2008). For example, it have been reported that legume crops with the ability of symbiotic N_2 fixation in nodules could lead to significantly increase in the available soil N, and thus increased N availability for the cereal crops in the legume/cereal rotation system (Jeffries *et al*., 2003).

The concentration of N in the soil after faba bean grew under Tiro-Afeta was significantly different ($P<0.05$) among locations. The highest value N in the soil of Tiro-Afeta was recorded under location 3 (0.14±0.01) increased by 7.6% as compared to soil N before planting and the lowest value of N recorded under location 1 was (0.07±0.02) increased by 40% as compared to soil N before planting (Table 4). Thus, in these faba bean plants play an important role in increasing the N status in soils, which may be further increased the fertility of soils.

Generally, under both locations the amount of N added in to soil after plant harvested were different. High value of N was added at low N concentration in the soil before planting faba bean. This might be related to the amount of N existed before planting in the soil, as soil relatively high amount of initial N affect N-fixation in the soil (high amount of mineral nitrogen in soil has slows of the effect on nodulation) (Dogan *et al*., 2010; Keerio *et al*., 2001) which used sufficient amount of N for their growth.

The concentration of P in the soils was significantly ($P<0.05$) different after faba bean growth under both Dedo and Tiro-Afeta locations (Table 4 and Appendix table 1). The highest value of available P was recorded under Dedo location 3 (12.6±0.4 mg p kg^{-1}), which resulted in increased of N by 9.01% after faba bean growth, while the lowest value of available P concentration was recorded under Dedo location 1 (6.9±0.8 mg p kg^{-1}) increased by 2.9% (Table 4). The highest value under Tiro-Afeta location 3 was recorded (9.28±0.3 mg p kg^{-1}) increased by 4.2%, similar effects have been reported as, (Kamh *et al*., 1999, Nuruzzaman *et al*., 2005) legumes can mobilize more P from poorly soluble P compared to non-legumes. The lowest value under location 1 recorded (4.3±0.3 mg p kg^{-1}) not increased compared to before planting were affected by low pH value soil was recorded at initial pH value. The main limiting factors for crop growth, such as low pH, low cation exchange capacity (CEC) and organic matter, which easily lead to nutrient deficiency and element toxicity, such as phosphorus (P) deficiency and aluminum (Al) toxicity, results in decreases the amount P around root area by P complexation (Zhang *et al*., 2009).

After faba bean grew under both transects at different location OC, where decreased as compared to its results before planting. This was might be due to crop residue removal (leaf and litter from the plant) and limited mineralization by microorganisms within a short period of time, therefore crops can only uptake existed carbon for their growth were decreased initial nutrient availability.

Table 4: Effects of faba bean in selected chemical characteristics of soils after harvest

Location	Parameters			
	pH_{H2O}	% N	Av. P	%OC
DL1	5.4±0.05[c]	0.17±0.01[c]	6.9±0.8[b]	1.6±0.01[c]
DL2	5.6±0.13[b]	0.19±0.01[b]	9.26±0.52[b]	1.8±0.06[b]
DL3	6.18±0.14[a]	0.23±0.01[a]	13.3±0.2[a]	2.2±0.01[a]
P value	**	**	**	**
LSD (0.05)	0.151	0.022	1.61	0.09
CV (%)	1.15	4.83	7.22	2.08
TaL1	5.4±0.12[c]	0.07±0.02[b]	4.3±0.36[c]	0.6±0.28[b]
TaL2	5.6±0.04[b]	0.12±0.01[a]	5.9±0.8[b]	1.09±0.02[a]
TaL3	5.8±0.06[a]	0.14±0.01[a]	9.28±0.3[a]	1.36±0.04[a]
P value	**	*	**	*
LSD (0.05)	0.16	0.03	1.49	0.37
CV (%)	1.32	13.58	10.11	16.25

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Mean ± standard deviation of fababean grown soil chemical characteristics after pot experiments in Dedo and Tiro afeta where %N= percentage of Nitrogen, Av. P= available Phosphorus ($mgkg^{-1}$) and OC= organic matter.

The pH_{H2O} of Dedo and Tiro afeta soil after soybean growth in the pot experiment showed a significant ($p<0.05$) difference and there way decrease of pH for all locations relative to the initial soil pH (Table 5 and Appendix table 1), for Dedo district the highest value of soybean grown of pH was recorded under lower elevation (6.18±0.14) at location 3, while the lowest value of pH was under location 1 (5.44±0.04). The highest and lowest value of pH (5.86±0.05 and 5.44±0.11) of soybean grown soil under Tiro-Afeta location three and one respectively (Table 5).

Table 5: Effects of soybean in selected chemical characteristics of soils after harvest

Location	Parameters			
	pH $_{H2O}$	% N	Av. P	OC
DL1	5.44±0.04^{c}	0.16±0.01^{c}	6.84±0.8^{b}	1.6±0.02^{c}
DL2	5.64±0.12^{b}	0.19±0.00^{b}	8.89±0.8^{b}	1.8±0.06^{b}
DL3	6.18±0.14^{a}	0.23±0.01^{a}	12.66±0.4^{a}	2.2±0.01^{a}
P value	**	**	**	**
LSD (0.05)	0.13	0.013	2.2	0.09
CV (%)	1.02	2.9	9.3	2.2
TaL1	5.44±0.11^{c}	0.07±0.02^{b}	4.7±0.9^{b}	0.5±0.3^{b}
TaL2	5.63±0.03^{b}	0.12±0.01^{a}	6.01±0.9^{b}	1.09±0.01^{a}
TaL3	5.86±0.05^{a}	0.14±0.01^{a}	10.06±0.3^{a}	1.3±0.05^{a}
P value	**	**	**	*
LSD (0.05)	0.163	0.03	2.05	0.35
CV (%)	1.27	11.31	13.06	16.06

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Mean ± standard deviation of soybean grown soil chemical characteristics after pot experiments in Dedo and Tiro afeta where %N= percentage of Nitrogen, Av. P= available Phosphorus (mgkg^{-1}) and OC= organic matter.

The concentration of N in the soils soybean grown pots was significantly ($P<0.05$) different and increased after harvested under both Dedo and Tiro-Afeta soil (Table 5 and Appendix table 2). The highest value of the N after soybean harvested of was (0.23±0.01) under Dedo location 3. It was increased by 4.5% as compared to initial soil N before planting (Table 5). The lowest value of N was recorded under Dedo location 1 (0.16±0.01), which increased by 6.6% as compared before planting N availability as shown (Table 5). The highest value N in the soil was recorded under Tiro-Afeta location three (0.14±0.01) increased by 7.6% as compared to soil N before planting and the lowest value of N recorded under location one was (0.07±0.02) increased by 40% as compared to soil N before planting (Table 5). As reported (Wang *et al*., 2008) soybean crops have positive effects on soil nitrogen. It has higher nodulation and symbiotic N_2 fixation potential, and in turn could significantly increase in the available soil N, and thus increased N availability for the cereal crops in the legume/cereal rotation system (Jeffries *et al*., 2003).

The concentration of P in the soils was significantly ($P<0.05$) different under both Dedo and Tiro-Afeta locations, P increased after soybean growth, however Dedo location 1 and 2 were not significantly different as Tiro-Afeta location 1 and 2 (Table 5 and Appendix table 2). The highest value of available P under Dedo location 3 (12.25±0.8 mg p kg^{-1}) increased by 3.77% after soybean growth and the lowest value of available P concentration under Dedo location 1 (6.84±0.8 mg p kg^{-1}) increased by 2.1% (Table 5). The highest value under Tiro-Afeta location 3 was recorded (9.66±0.29 mg p kg^{-1}) increased by 13.03%, similar effects have been reported as, (Kamh *et al.* 1999; Nuruzzaman *et al.*, 2005; Hassan *et al*., 2012) legumes can mobilize more P from poorly soluble P compared to non-legumes and the lowest value under Tiro-Afeta location 1 recorded (4.7±0.9 mg p kg^{-1}) increased by 9.3% compared to before planting as shown (Table 5). Generally soybean grown under Tiro-Afeta soil were better to increases P from 9.3% to 13.03% than Dedo soil were 2.1% to 3.77% added during pot experiment under greenhouse condition.

After soya bean growth under both Dedo and Tiro afeta sites at different location OC where decreased as compare to its results before planting. As reported (Tarwali *et al.*, 1987; Abayomi *et al.*, 2001) and weed suppression (Versteeg *et al.*, 1998). Organic inputs from legumes could improve nutrient supply/availability and/or improved soil-water holding capacity. Moreover, legumes offer other benefits such as providing cover to reduce soil erosion, maintenance & improvement of soil physical properties, increasing soil organic matter, cation exchange capacity and microbial activity unlikely, these pot experiments was might have no added organic matter and limitation of mineralization by microorganisms within a short period of time and crops can only uptake existed carbon for their growth were decreased initial nutrient availability.

4.3. Contribution of N and P by faba bean and soybean biomass

The biological nitrogen fixation of the faba bean and soybean grown in Dedo and Tiro afeta was calculated with the nitrogen difference method. For nitrogen difference, the percentage of the total N in the above ground biomass that was derived from atmospheric N fixation and the amount of N_2 fixed (kg N ha^{-1}) was calculated (Table 6).

Table 6: SD± and Mean comparison of TP, TN and ANF of *Vicia faba L.* and *Glycine max L.* plant for Dedo and Tiro afeta soil after pot experiment.

Location	Faba bean			soybean		
	TNP	ANF	P	TNP	ANF	P
DL1	127.4±7.12^{b}	129.6±7.3^{b}	19.2±2.1^{b}	75.6±7.1^{b}	77.3±7.6^{b}	17.6±2.6^{b}
DL2	141.4±7.12^{b}	142.6±8.3^{b}	22.03±1.1^{b}	91.3±12.5^{b}	92.6±12.6^{b}	20.5±1.5^{b}
DL3	174.1±7.12^{a}	175.3±7.1^{a}	28.7±1.6^{a}	148.8±7.1^{a}	150.3±7.7^{a}	28±1.8^{a}
P Value	**	**	**	**	**	*
LSD (0.05)	19.29	20.85	3.39	23.03	23.98	5.112
CV (%)	5.76	6.16	6.404	9.65	9.91	10.22
TaL1	71.4±2.7^{c}	73.3±0.5^{c}	12.3±0.8^{c}	97.5±7.3^{c}	99.6±5^{c}	12.5±0.8^{c}
TaL2	96.3±7.1^{b}	96.6±6.8^{b}	15.2±2.4^{b}	127±7.1^{b}	128.3±7.3^{b}	15.4±2.3^{b}
TaL3	113.4±5.4^{a}	114±5.1^{a}	22.3±0.7^{a}	139.4±7.1^{a}	140.6±6^{a}	22.5±0.9^{a}
P Value	**	**	**	**	**	**
LSD (0.05)	14.154	13.08	2.64	3.64	4.41	2.712
CV (%)	6.65	6.1	6.97	1.32	1.58	7.101

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Given above table as mean ± standard deviation, where, ANF= Amount of N fixed (kg N ha^{-1}), TNP= Total N in plant (kg N ha^{-1}) and P= Phosphorus in plant biomass (kg ha^{-1}) determined by the nitrogen difference method.

Total Nitrogen concentration in the above ground biomass of faba bean for both Dedo and Tiro-Afeta locations were given in (Table 6). Total Nitrogen were significantly affected (P≤ 0.05) by elevation under Dedo and highly significantly (P≤ 0.01) different under Tiro-Afeta locations (Table 6 and Appendix table 9). The highest value obtained (174.1±7.12 kg N ha^{-1}) from Dedo location 3 and the lowest value under Dedo recorded from location 1 (127.4±7.12 kg N ha^{-1}). An average of faba bean concentration under Tiro-Afeta (113.4±5.4 kg N ha^{-1}) at location 3 was highest value and (71.4±2.7 kg N ha^{-1}) was the lowest value at location one (Table 6).

When thus, entire (total) above ground biomass of faba bean is incorporated in to the soil, an extra (127.4 to 174.1 kg N ha^{-1}) for Dedo and (71.4 to 113.4 kg N ha^{-1}) for Tiro-Afeta will be added to the soil and contribute to the building up of soil fertility in the districts. With the usual practice, only nodules and roots remain in the soil after harvest. When farmer's practice would be changed and above ground biomass are incorporated, the total N available for mineralization is then the sum of the N that was present in the nodules, roots and shoots. The results for N return to the soil (kg N ha^{-1}) are similar to values found by (Nemecek, 2010) (125 to 168 kg N ha^{-1}), except for Tiro-Afeta.

The highest plant N was when soybean was supplied with Dedo location 3 (12.2 mg P kg^{-1}) as shown (Table 6). This increase may be due to supply of phosphorus that seems important for Rhizobium to fix relatively more nitrogen from soil, which resulted in increased plant growth and N uptake by root and then to shoots. Phosphorus plays a vital role in physiological and developmental process in plant life and favorable effect of this important nutrient might have accelerated the growth process that increases N uptake in plants (Fatima *et al*., 2007).

Total Nitrogen concentration in the above ground biomass of *Glycine max L.* for both Dedo and Tiro-Afeta locations were given in (Table 6). Total nitrogen were significantly affected ($P \leq 0.05$) by elevation under both Dedo and Tiro-Afeta locations (Table 6 and Appendix table 10). The highest value was obtained (148.8±7.1 kg N ha^{-1}) from Dedo location 3 and the lowest value under Dedo recorded from location 1 (75.6±7.1 kg N ha^{-1}) at Dedo district. An average of soybean concentration under Tiro-Afeta (139.4±7.1 kg N ha^{-1}) at location three was highest value and (97.5±7.3 kg N ha^{-1}) was the lowest value at location one (Table 6).

When entire (total) above ground biomass of soybean is incorporated into the soil, an extra (75.6 to 148.8 kg N ha^{-1}) for Dedo and (97.5 to 139.4 kg N ha^{-1}) for Tiro-Afeta will be added to the soil and contribute to the building up of soil fertility in the region. Similarily, the highest N concentration was recorded location 3 (139.4±7.1), while the lowest was at location 1 at Tiro-Afeta district (Table 6). When farmer's practice would be changed and above ground biomass are incorporated, the total N available for mineralization is then the sum of the N that was present in the nodules, roots and shoots.

Values for amounts of N_2 fixed (kg N ha^{-1}) of faba bean were significantly different ($P \leq 0.05$) under both Dedo and Tiro-Afeta locations (Table 6 and Appendix table 10). The highest value of N_2 fixed in the faba bean under Dedo location 3 (175.3±7.1 kg N ha^{-1}), while the lowest value obtained from location 1 (129.6±7.3) kg N ha^{-1}. The highest value of N_2 fixed in the faba bean (114±5.1) kg N ha^{-1} under Tiro-Afeta recorded location three and the lowest value obtained from location 1 (73.3±0.5) kg N ha^{-1} (Table 6). Correlation matrix (Table 12) also indicated, there was a positive and significantly relationship between ANF and SDM content (r=0.908*).

Values for amounts of N_2 fixed at Dedo location 3 are generally comparable to the values found by (Amanuel *et al.*, 2000) for faba beans in Ethiopian Nitisols (169 to 210 kg N ha^{-1}) and similar found by (Amsalu *et al*., 2014) for fababean SW Nitisols (137.1 to 177.7 kg N ha^{-1}).

Values for amounts of N_2 fixed of soybean were significantly different ($P \leq 0.05$) under Dedo Tiro-Afeta locations (Table 6 and Appendix table 10). The highest value of N_2 was fixed at Dedo location 3 (150.3±7.7 kg N ha^{-1}), while the lowest value was obtained from location 1 (77.3±7.6 kg N ha^{-1}). The highest value of N_2 fixed in the soybean (140.6±6 kg N ha^{-1}) under Tiro afeta recorded location three and the lowest value obtained from location one (99.6±5) kg N ha^{-1} (Table 6).

An estimate of 26-188 kg N / ha in the tropics have been made while soybean could fix 15-162 kg N / ha (Giller and Wilson, 1991; Larue *et al*., 1981). Based on the experimental site used, amount of N_2 fixed was in the range of 77.3 to 150.3 kg N / ha under Dedo and 99.6 to 140.6 kg N / ha under Tiro-Afeta in the soybean studied. This is higher than the 41-50 kg N / ha reported by (Yusuf *et al*., 2006).

Phosphorus concentrations for faba bean grown in Dedo and Tiro-Afeta were significantly ($P \leq 0.05$) different (Table 6 and Appendix table 10). The highest value of phosphorous in fababean above ground biomass under Dedo location three recorded (28.7±1.6) kg ha^{-1} and the lowest value recorded under location one (19.2±2.1) kg ha^{-1} in (Table 6). The average P content in the above ground biomass of fababean grown in Dedo soil was similar to the values reported by (Jensen *et al.*, 2009). Phosphorus concentration for fababean biomass under Tiro-

Afeta location three were recorded (22.3±0.7) kg ha^{-1} and the lowest value recorded under location one (12.3±0.8) kg ha^{-1}. When compare concentration of phosphorous in fababean biomass were recorded under Dedo was higher than Tiro afeta biomass phosphorous concentration. These might be related the availability of phosphorous exists at Dedo soil results increases the biomass of fababean which increases phosphorous content. Correlation matrix (Table 12) also indicated, there was a positive relationship and significance difference between number of total P in plant and above ground dry weight (r=0.985**) *Vicia faba L.* grown soil. Recent as reported that the highest p concentration recorded from higher biomass production of the fababean. from Dedo soil (Amsalu *et al*., 2014).

Phosphorus concentrations for soybean grown in Dedo and Tiro-Afeta were significantly ($P\leq 0.05$) different (Table 6 and Appendix table 10). The highest value of P in soybean biomass under Dedo location 3 (28±1.8 kg ha^{-1}), while the lowest value was recorded at location 1 (17.6±2.6 kg ha^{-1}) as shown (Table 6). soybean grown under Tiro-Afeta location 3 recorded the highest value (22.5±0.9) kg ha^{-1}, while the lowest value was recorded location 1 (12.5±0.8) at kg ha^{-1}. A P efficient legume in cropping systems is emerging as an alternative and/or complementary strategy to the mineral fertilizers for sustainable agricultural intensification of low input cropping systems. A complementary strategy to increase soil fertility is the inclusion of P efficient (efficient at producing biomass yield under limited available P conditions, (Wanga *et al*., 2010) grain legumes as bio-fertilizers in traditional cropping systems (Belane and Dakora, 2010), e.g. by growing them in rotation with cereals.

The highest P (28 kg ha^{-1}) was accumulated when soybean was supplied with (12.2 mg P kg^{-1}) in the soil while the minimum of (12.5 kg ha^{-1}) was accumulated in the soil (4.2 mg P kg^{-1}). Supplying soybean with 12.2 mg P kg^{-1} resulted in an increased in P concentration due to supply of nutrients and well developed root system resulting in better absorption of water and nutrient. Increase P concentration in the plant is favorable to nodulation and biological nitrogen fixation in legumes.

4.4. Biomass production by faba bean and soybean

Table 7: SD± and Mean comparison of biomass by faba bean and soybean under Dedo and Tiro afeta.

Location	faba bean		soybean	
	RDW (t ha^{-1})	SDW (t ha^{-1})	RDW (t ha^{-1})	SDW (t ha^{-1})
DL1	1.2±0.1^{b}	14.0±0.6^{b}	1.25±0.12^{c}	11.74±0.65^{c}
DL2	1.5±0.1^{b}	17.4±0.6^{a}	1.62±0.06^{b}	14.47±0.72^{b}
DL3	2.3±0.39^{a}	20.1±1.7^{a}	2.28±0.21^{a}	18.56±0.79^{a}
P Value	*	**	** **	
LSD (0.05)	0.6	2.7	0.2877	1.8462
CV (%)	15.5	6.9	7.38	5.45
TaL1	0.5±0.04^{c}	10.2±0.1^{b}	0.54±0.04^{c}	7.34±0.56^{c}
TaL2	0.8±0.1^{b}	11.3±1.1^{b}	1.04±0.22^{b}	10.83±0.56^{b}
TaL3	1.6±0.1^{a}	17.0±1.1^{a}	1.706±1.73^{a}	13.9±1.7^{a}
P Value	**	**	**	**
LSD (0.05)	0.27	1.48	0.4231	2.9016
CV (%)	12.1	5.1	16.99	11.38

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Given above table as mean ± standard deviation, where, RDW= Root dry weight (t ha^{-1}) and SDW, Shoot dry weight (t ha^{-1}) for different crops (*Vicia faba L.* and *Glycine max L.* for different elevation level soil from the Dedo and Tiro afeta pot experiment.

Root dry weight of the faba bean was significant different for the Dedo at different location and highly significantly (P≤ 0.01) different for the Tiro-Afeta location (Table 7 and Appendix table 9). The highest average for RDW recorded (2.3±0.39 t ha^{-1}) under Dedo location 3 and the lowest value of RDW for faba bean (1.2±0.1 t ha^{-1}) was recorded at location 1 of Dedo district. The highest value under Tiro-Afeta recorded (1.6±0.1 t ha^{-1}), while the lowest value was location one (0.5±0.04) t ha^{-1} (Table 7).

Root dry weight (RDW, t ha^{-1}) and shoot dry weight (SDW, ton ha^{-1}) data are shown in (Table 9). Root dry weight of the soybean was significantly different (P≤ 0.05) for the Dedo and Tiro-Afeta at different location (Table 7 and Appendix table 11). The highest average for RDW recorded (2.28±0.21 t ha^{-1}) under Dedo location 3, where the lowest value of RDW for soybean (1.25±0.12 t ha^{-1}). The highest value under Tiro-Afeta recorded (1.706±1.73 t ha^{-1}) and the lowest value was location 1 (0.54±0.04) t ha^{-1} (Table 7).

Shoot dry weight was significantly affected (P≤ 0.05) by elevation under both Dedo and Tiro-Afeta (Table 7 and Appendix table 9). Shoot dry weights from Tiro-Afeta field were very low compared to Dedo. The highest value of Dedo recorded (20.1±1.7 t ha^{-1}) at location 3 and the lowest value of Dedo obtained (14.0±0.6 t ha^{-1}) at location 1 (Table 7). The highest value of SDW of faba bean recorded from Tiro afeta (17.0±1.1 t ha^{-1}), while the lowest value (10.2±0.1 t ha^{-1}). Both RDW and SDW under both Dedo and Tiro-Afeta at different location varies because the dry weight of faba bean depends on amount of the P in the soil, as (Toomsan *et al.*, 1995; Amsalu *et al.*, 2014) found at different P level dry weights increases with increasing P. Correlation matrix (Table 12) also indicated, there was a positive and significantly relationship between RDW and SDW with Av. P content (r= 0.980**) for root dry weight and (r=0.983**) for shoot dry weight.

Shoot dry weight of the soybean was significantly different (P≤ 0.05) for the Dedo and Tiro-Afeta at locations (Table 7 and Appendix table 11).The highest value SDW of Dedo recorded (18.56±0.79 t ha^{-1}) at location three and the lowest value of obtained (11.74±0.65 t ha^{-1}) at location one (Table 7). The highest value of SDW of *Glycine max L.* recorded from Tiro afeta (13.9±1.7 t ha^{-1}) and the lowest value (7.34±0.56 t ha^{-1}). Shoot dry weight increased significantly with increasing level phosphorus in the soil. Correlation matrix (Table 13) also indicated, there was a positive relationship between (r=0.979**) available P of initial existed in the soil with shoot dry matter contents. These results agreed with the recent reports of other workers (Bekere *et al.*, 2012; Bekere and Hailemariam, 2012). Also as reports by (Tejera *et al.*, 2005) working with bean showed a positive significant correlation between nodule number and shoot dry weight and nodule number and N % confirming the importance of symbiosis in N accumulation in legumes.

4.5. Plant height, Number of nodule and Nitrogen derived from atmosphere

Table 8: Mean comparison of plant height, number of nodule and nitrogen derived from atmosphere for Dedo and Tiro-Afeta under pot experiment.

Location	Faba bean			Soybean		
	P.ht	NN	Ndfa	P.ht	NN	Ndfa
DL1	66.1± 4.6[b]	64.5±1.3[b]	92.9±0.3[a]	33.8±2.5[b]	9±1.32[b]	88±1.2[a]
DL2	69.8±6.3[b]	67.1±2.0[b]	91.03±0.4[ab]	36.3±2.6[b]	10.3±0.57[b]	86.6±1.7[a]
DL3	77.3±2.4[a]	87.0±5.6[a]	89.2±1.8[b]	40.5±0.8[a]	26.6± 6.04[a]	88.5±0.5[a]
P Value	**	**	ns	*	**	ns
LSD (0.05)	4.84	5.45	2.85	3.49	7.921	3.303
CV (%)	3.004	3.29	1.37	4.174	22.78	1.66
TaL1	60.6±4.4[c]	13.8±3.4[c]	96.4±1.1[a]	30.7±2.1[b]	8±2.17[b]	98.2±1.3[a]
TaL2	63.6±3.5[b]	19.6±2.1[b]	92.3±1.4[b]	33.6±1.8[b]	11.2±0.7[ab]	93.9±1.1[b]
TaL3	66.7±2.1[a]	35.1±5.0[a]	90.3±0.5[b]	38.6± 0.7[a]	14.5± 1.3[a]	91.1±0.4[c]
P Value	**	**	**	*	*	**
LSD (0.05)	2.91	4.88	2.77	3.83	3.54	2.64
CV (%)	2.01	9.42	1.31	4.913	13.93	1.23

**=highly significant (0.01); *= significant (0.05), ns =non-significant. Plant height= P.ht (cm), number of nodules= NN and %Ndfa= %N derived from atmosphere (mean ± standard deviation) per plant for two crops (*Vicia faba L.* and *Glycine max L.*).

ANOVA indicated significant difference ($P<0.05$), of plant height due to effects of faba bean and soybean under both Dedo and Tiro-Afeta sites at different locations of plant height at 75 % flowering stages (Table 8 and Appendix table 11). The increase in plant height was only because of location differences was supported by the fact that crops differ with respect to absorption of available nutrients, nitrogen fixation and accumulation of other relevant nutrients (Chabot *et al.*, 1996). The highest height of faba bean was recorded under Dedo location 3 (77.3±2.4), while the lowest height under Dedo was recorded location 3 (66.1± 4.6) (Table 8). The highest height of faba bean was recorded under Tiro-Afeta location 3 (66.7±2.1) and the lowest height under Tiro afeta location 1 (60.6±4.4) as shown above (Table 8). When compared the height of faba bean under Dedo sites were higher than to Tiro-

Afeta sites at all location because of their general symbiotic competence, greater available phosphorus in the soil which resulted in a reasonable plant height growth. Correlation matrix (Table 12) also indicated, there was a positive and significant relationship between plant height with available P in the soil content(r=0.945**) and Total N (r=0 .945**) under faba bean grown soil.

Though not significant ($P \leq 0.05$) difference in plant height at some location especially at Dedo location 1 and 2 also, at Tiro-Afeta location 1 and 2 (Table 8 and Appendix table 10). Due to availability of nitrogen and other nutrients (Hulugelle *et al*., 1986; Crasky *et al*., 1998; Sanginga *et al*., 1996) and absorption of nutrients. The highest height of soybean was recorded under Dedo location 3 (40.5±0.8), while the lowest height under Dedo was recorded location 1 (33.8±2.5) as shown above (Table 8). The highest height of soybean was recorded under Tiro-Afeta location 3 (38.6± 0.7) and the lowest height under Tiro-Afeta location 1 (30.7±2.1).

The highest number of nodules faba bean plant (87.0±5.6) was obtained from Dedo location 3. Whereas the lowest number of nodules per plant (64.5±1.3) were obtained from Dedo location 1 (Table 8). Nodules of Dedo mostly situated near the top (crown) of their roots, with a dominating deep dark red color inside. This confirms beneficial characteristics for nodulation initiation in Dedo soil and a high potential N_2 fixation efficiency of the nodules (Amanuel *et al.*, 2000; Habtemichial *et al.*, 2007; Lindstrom and Mousavi, 2010).

The results obtained at Tiro-Afeta showed that, there is highly significant difference ($P \leq 0.05$) in number of nodules for faba bean (Table 8 and Appendix table 9). The highest number of faba bean nodules obtained from location 3 (35.1±5.0), while the lowest number of nodules obtained from location 1 (13.8±3.4). Higher number nodules per plant was observed on faba bean grown in Dedo than were soybean grown Tiro afeta soil.

Results from nodule assessment soybean showed significances ($P \leq 0.05$) difference (Table 8). The highest number of soybean nodules per plant (26.6±6.04) under Dedo location 3, where lowest number of nodules recorded at Dedo location 1 (9±1.32). Soybean under Tiro-Afeta highest number of nodules were recorded location three (14.5± 1.3), while the lowest number of nodules recorded location 1 (8±2.17). (Singleton *et al*., 1984) reported that, in addition to the nodule formation, deficiency of phosphorus in legume also markedly affects the development of effective nodules and the nodule leghaemoglobin content. Correlation matrix (Table 13) also indicated, there was a positive and significance relationship between number of nodule with available P in the soil content(r=0.833*) soybean grown soil. It therefore suggests that the presence of sufficient phosphorus in soils as in the soils of experimental field may be beneficial to nodule formation and nitrogen fixation through the prevention of the phosphorus concentration in the plants at the later growth stage. The highest nodule number was obtained from higher phosphorus existed soil as compared to the lower phosphorus existed soil. Nodule number increases with increasing phosphorus in the soil.

The nitrogen derived from the atmosphere of faba bean statistically no significant ($P \leq 0.05$) different under all Dedo locations, but was significantly different under Tiro-Afeta locations (Table 8 and Appendix table 11). The highest value of nitrogen derived from the atmosphere of faba bean under Dedo location 1 (92.9±0.3), while the lowest value was recorded Dedo location 3 (89.2±1.8) as shown (Table 8).

The highest value of nitrogen derived from the atmosphere of faba bean under Tiro-Afeta location 1 (96.4±1.1), while the lowest value was recorded at Tiro-Afeta location 3 (90.3±0.5) as shown (Table 8). Correlation matrix (Table 12) indicated, there was a negative and significance relationship between Ndfa and TN in the soil content(r=-0.821*) under faba bean grown soil. These under both Dedo and Tiro-Afeta result shows highest recorded nitrogen derived from the atmosphere under lower initial nitrogen existed in the soil because Soils with a higher N content generally result in less N_2 fixation by the legume (Jensen *et al.*, 2009).

Among the family of the Leguminosae (Fabaceae), faba bean is one of the best N_2 fixers (Amanuel *et al.*, 2000; Jensen *et al.*, 2009). Similarly, another report indicated that up to 96% of the N taken up by the faba bean was derived from the atmosphere (Lopez-Bellido *et al.*, 2006).

The nitrogen derived from the atmosphere by soybean was no significant ($P \leq 0.05$) different under three Dedo locations, but was highly significantly ($P \leq 0.01$) differences noted at Tiro-Afeta locations (Table 8 and Appendix table 10). The highest value of nitrogen was derived from the atmosphere by soybean under Dedo location 1 (88±1.2), while the lowest value recorded Dedo location 2 (86.6±1.7). The highest value of nitrogen was derived from the atmosphere of soybean under Tiro afeta location 1 (98.2±1.3), while the lowest value recorded Tiro-Afeta location 3 (91.1±0.4). These under Dedo (86.6% to 88%) and Tiro-Afeta (91.1% to 98.2%) result shows highest recorded nitrogen derived from the atmosphere under lower initial nitrogen existed in the soil. Correlation matrix (Table 13) also indicated, there was a negative and no significantly relationship between (r=-0.343) initial TN and Ndfa, because soils with a higher N content generally result in less N_2 fixation by the legume (Jensen *et al.*, 2009). Also as reported by (Solomon *et al.*, 2012) most grain legumes including soybean can obtain between 50 and 80 % of their nitrogen requirements through biological fixation, but some, like fababean will fix up to 90 %.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

Before planting soil analysis showed that pH, total N, OC and plant available P contents in Dedo soil was more optimal for *Rhizobium*-legume symbiosis than in Tiro-Afeta soil. In Tiro afeta soil, especially the pH, plant available P and N content were limiting for a good *Rhizobium*-legume symbiosis. The results of the current study revealed a significant effect of variation in Dedo and Tiro-Afeta location on establishment of grain legumes such as faba bean and soybean for soil fertility improvement. The suitability of Dedo soil for faba bean growth, as expected from its physicochemical characteristics, was confirmed by the performance fababean under Dedo locations soils in a greenhouse experiment.

The value of pH after fababean and soya bean were grown at both Dedo and Tiro-Afeta locations decreased when compared against the from initial pH value. This has mainly been attributed to the large uptake of cations over anions by legume roots during N_2 fixation. The return of legume residues to the soil is unlikely to cause soil acidification.

The concentration of N and P value after fababean grown at Dedo and Tiro-Afeta location soil increased as compared against initial value except Tiro-Afeta location 1. Also the concentration of N and P value after soya bean grown at Dedo and Tiro-Afeta location soil increased as compared to from initial value.

The value of P in fababean biomass under Dedo (28.7 kg ha^{-1}) and (19.2 kg ha^{-1}) the highest and lowest respectively. When compared, the concentration of P in fababean biomass were recorded under Dedo was higher than Tiro-Afeta fababean biomass P concentration. The highest P (28 kg ha^{-1}) value under Dedo was accumulated when soybean was supplied with (12.2 mg P kg^{-1}) in the soil of Dedo location 3 while the minimum of (17.6 kg ha^{-1}) was accumulated in the soil (4.3 mg P kg^{-1}) at location 1 of Tiro-Afeta. Supplying soybean with 12.2 mg P kg^{-1} resulted in an increased in P concentration due to supply of nutrients and well developed root system resulting in better absorption of water and nutrient. The highest value of P concentration in the fababean grown under Tiro-Afeta (22.3 kg ha^{-1}) and the lowest value (12.3 kg ha^{-1}) recorded under Tiro afeta. The highest P (22.5 kg ha^{-1}) and lowest value was (12.5 kg ha^{-1}) value soya bean grown under Tiro-Afeta. When compared, the concentration of P in soya bean biomass was recorded under Tiro afeta was higher than that was recorded under fababean biomass.

The average value of fababean for RDW recorded (1.2 to 2.3 t ha^{-1}) under Dedo location and the value under Tiro-Afeta recorded (0.5 to 1.6 t ha^{-1}). The value of soya bean for RDW recorded (1.25 to 2.28 t ha^{-1}) at Dedo location and the value under Tiro afeta recorded for soya bean RDW (0.54 to 1.7 t ha^{-1}). The value of SDW Dedo fababean recorded (14 to 20.1 t ha^{-1}) and the value of SDW of fababean recorded from Tiro afeta (10.2 to 17.0 t ha^{-1}) and for soya bean SDW under Dedo (11.74 to 18.56 t ha^{-1}) and under Tiro afeta (7.34 to 15.53 t ha^{-1}) recorded. It can be concluded that the application of legume residues, which usually have high ash alkalinity and increases the pH value in the soil.

The biological nitrogen fixation of the fababean and soya bean grown in Dedo and Tiro-Afeta was calculated with the nitrogen difference method. Result shows highest recorded nitrogen derived from the atmosphere under lower initial nitrogen existed in the soil because Soils with a higher N content generally result in less Ndfa by the legume.

Finally, when farmer's incorporating above ground biomass in the soil, an extra from fababean (127.4 to 174.1 kg N ha^{-1}) for Dedo and (71.4 to 113.4 kg N ha^{-1}) for Tiro-Afeta while for soya bean (75.6 to 148.8 kg N ha^{-1}) for Dedo and (97.5 to 139.4 kg N ha^{-1}) for Tiro afeta will be added to the soil and contribute to the building up of fertile soils in the region.

5.2. Recommendations

However, the present study should be further evaluated under various agro- ecological/elevation conditions in order to come up with conclusive recommendations to be used by smallholder farmers. The results revealed that Dedo soil were more suitable for faba bean production than Tiro-Afeta soils, while Tiro-Afeta soils were found to be more suitable for soybean production. Therefore, we suggest the production of these crops based on the suitability of soils and climates. In this study focused selected grain legumes only for soil fertility potential were evaluated therefore, further study should consider the effect grain legume on yield potential under different elevation levels.

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6. APPENDIXES

Table 9: Appendix 1 Relative change and statistic test (LSD) for selected soil properties on effects of fababean

parameters	Relative changes (%)												
	DL1	DL2	DL3	R^2	P Value	LSD	CV%	TaL1	TaL2	TaL3	R^2	P value	LSD	CV%
pH	-1.09	-1.58	-0.64	0.986	0.0004	0.1504	1.151	-11.09	-1.23	-1.86	0.935	0.0046	0.169	1.32
TN	13.3	5.5	4.5	0.94	0.0028	0.02	4.8	40	9.1	7.6	0.89	0.0132	0.034	13.5
Av.P	2.9	5.2	9.01	0.96	0.0028	1.61	7.22	0	0	4.2	0.95	0.0022	1.43	0.0022
OC	-11.6	-13	-15.7	0.99	<.0001	0.09	2.08	-7.6	-10.6	-9.9	0.89	0.0117	0.37	16.25
CEC	-58	-1.1	-1.2	0.94	0.0026	6.13	10.8	-1.8	-1.9	-3.2	0.98	0.0004	1.95	4.5
Ca	0	-0.1	-0.5	0.95	0.0023	2.99	9.55	-2.1	-1.1	-3.2	0.96	0.0013	2.73	12.5
Mg	-5.5	0	-2.7	0.95	0.0025	0.61	10.8	-6.6	-10	-4	0.97	0.0006	0.224	5.12
K	-6.6	0	-3.5	0.94	0.0028	0.27	18.5	-25	0	0	0.92	0.0053	0.289	22.2
Na	-40	-56.2	-49.4	0.75	0.0625	0.016	9.2	-37.5	-51.5	-63.9	0.82	0.0325	0.023	15.3

Table 10: Appendix 1 Relative change and statistic test (LSD) for selected soil properties on effects of soya bean

parameters	Relative changes (%)												
	DL1	DL2	DL3	R^2	P Value	LSD	CV%	TaL1	TaL2	TaL3	R^2	P value	LSD	CV%
pH	-0.36	-0.87	-0.64	0.98	0.0002	0.1325	1.015	-0.36	-0.7	-0.84	0.93	0.0051	0.1629	1.27
TN	6.6	5.5	4.5	0.98	0.0004	0.013	2.93	40	9.1	7.6	0.94	0.0048	0.0288	11.31
Av.P	2.1	1.02	3.77	0.92	0.0032	2.2002	9.33	9.3	1.8	13.03	0.93	0.0043	2.05	13.06
OC	-11.6	-13	-15.7	0.98	0.0001	0.094	2.16	-23.1	-10.6	-13.9	0.902	0.0109	0.3685	16.06
CEC	-2.01	-1.18	-1.2	0.94	0.0026	6.136	10.82	-1.8	-2.4	-3.9	0.98	0.0004	1.9305	4.46
Ca	-1.12	0	-0.5	0.95	0.0022	2.962	9.47	-4.3	-1.1	-3.9	0.96	0.0012	2.707	12.52
Mg	-5.5	-4.5	-5.4	0.94	0.0029	0.636	11.18	-6.6	-10	-8	0.98	0.0003	0.173	4.05
K	-10	-1.7	-4.4	0.94	0.0025	0.2629	18.31	-45	-5.4	-3.2	0.96	0.0011	0.2137	16.93
Na	-45.4	-43.7	-29.4	0.78	0.0803	0.058	28.9	-25	-38.4	-34.7	0.87	0.0197	0.056	24.44

Table 11: Appendix 1 Statistic test (LSD) for selected plant parameters on effects of fababean and soya bean

parameters	Dedo								Tiro afeta							
	Fababean				Soybean				Fababean				Soybean			
	R^2	P Value	LSD	CV%	R^2	P Value	LSD	CV%	R^2	P Value	LSD	CV%	R^2	P Value	LSD	CV%
TNP	0.92	0.006	19.2	5.76	0.95	0.002	23.03	9.6	0.94	0.003	14.15	6.65	0.99	<.0001	3.63	1.32
TPP	0.94	0.003	3.38	6.4	0.89	0.011	5.11	10.22	0.96	0.001	2.63	6.97	0.96	0.001	2.71	7.1
RDW	0.59	0.247	1.12	30.5	0.96	0.001	0.28	7.38	0.97	0.001	0.27	12.05	0.93	0.004	0.42	16.9
SDW	0.91	0.008	2.71	6.96	0.96	0.001	1.84	5.45	0.97	0.0004	1.48	5.08	0.93	0.003	2.9	11.38
Ht	0.94	0.007	4.84	3.0	0.9	0.015	3.49	4.17	0.94	0.011	2.91	2.01	0.89	0.011	3.82	4.91
NN	0.97	0.001	5.44	3.29	0.92	0.006	7.92	22.7	0.97	0.001	4.88	9.42	0.87	0.017	3.54	13.9
ANF	0.91	0.008	20.8	6.16	0.95	0.002	23.9	9.91	0.94	0.002	13.1	6.09	0.99	<.0001	4.41	1.58
Ndfa	0.77	0.055	2.84	1.37	0.43	0.357	3.3	1.66	0.91	0.008	2.77	1.31	0.93	0.004	2.64	1.23

Table 12: Pearson's correlation matrix for various plant parameters and soil physicochemical parameters after fababean grown.

	pH	TN	Av. P	TNP	TPP	Ht	NN	RDW	SDW	Ndfa	ANF	OC	CEC	Ca	Mg	K	Na	Clay	Silt	Sand
pH	1																			
TN	0.668	1																		
Av P	.890*	.895*	1																	
TNP	.723	.994**	.924**	1																
TPP	.848*	.926**	.991**	.951**	1															
Ht	.857*	.945**	.964**	.971**	.966**	1														
NN	0.552	.966**	.821*	.966**	.875*	.894*	1													
RDW	.842*	.902*	.980**	.914*	.978**	.927**	0.805	1												
SDW	.806	.889*	.983**	.913*	.985**	.925**	.840*	.972**	1											
Ndfa	-.830*	-.821*	-.908*	-.819*	-.883*	-.846*	-0.658	-.956**	-.871*	1										
ANF	.711	.995**	.917**	1.000**	.947**	.966**	.971**	.909*	.908*	-0.81	1									
OC	0.681	.999**	.908*	.994**	.938**	.946**	.961**	.919**	.906*	-.836*	.995**	1								
CEC	.957**	0.565	.826*	0.625	0.753	0.789	0.441	0.75	0.737	-0.758	0.609	0.575	1							
Ca	.885*	.849*	.980**	.868*	.954**	.915*	0.73	.984**	.958**	-.963**	.859*	.865*	.838*	1						
Mg	.974**	0.805	.958**	.853*	.936**	.947**	0.724	.909*	.896*	-.852*	.844*	.814*	.914*	.926**	1					
K	.962**	0.647	.891*	0.687	.848*	0.798	0.5	.888*	.832*	-.903*	0.675	0.668	.901*	.924**	.926**	1				
Na	-0.443	-0.158	-0.138	-0.181	-0.102	-0.303	-0.065	-0.081	0.043	0.191	-0.174	-0.131	-0.436	-0.122	-0.366	-0.27	1			
Clay	.936**	.828*	.990**	.866*	.968**	.937**	0.739	.964**	.961**	-.906*	.857*	.844*	.884*	.980**	.974**	.939**	-0.174	1		
Silt	-0.51	0.221	-0.071	0.145	-0.007	-0.073	0.297	0.017	0.071	0.045	0.157	0.219	-0.524	-0.066	-0.342	-0.404	0.676	-0.187	1	
Sand	-0.573	-.886*	-.873*	-.873*	-.885*	-0.811	-.830*	-.912*	-.926**	.843*	-.871*	-.902*	-0.512	-.881*	-0.696	-0.655	-0.234	-.817*	-0.408	1

**=highly significant (0.01) ;*= significant (0.05), ns =non-significant; pH=Potential for Hydrogen ; OC=Organic Carbon ; TN=Total Nitrogen; Av.P=Available Phosphorous ; TNP=Total N in Plant; TPP=Total P in plant; Ht=Height of plant; NN=Number of Nodules; RDW= Root dry weight; SDW=Shoot dry weight; Ndfa=N derived from atmosphere; ANF=Amount of N fixed; CEC=Cation Exchange Capacity; Ca^{2+}= Calcium; Mg^{2+}=Magnesium, k^{+}=Potassium; Na^{+}=Sodium.

Table 13: Pearson's correlation matrix for various plant parameters and soil physicochemical parameters after soya bean grown.

	pH	TN	Av.P	TNP	TPP	Ht	NN	RDW	SDW	Ndfa	ANF	OC	CEC	Ca	Mg	K	Na	Clay	Silt	Sand
pH	1																			
TN	0.51	1																		
Av.P	0.636	0.711	1																	
TNP	0.7	0.6	0.592	1																
TPP	0.576	0.773	.985**	0.571	1															
Ht	0.724	0.627	.970**	0.697	.953**	1														
NN	0.51	.957**	.833*	0.766	.871*	0.803	1													
RDW	0.707	0.447	.899*	0.489	.815*	.863*	0.593	1												
SDW	0.682	0.686	.979**	0.61	.984**	.983**	.826*	.832*	1											
Ndfa	-0.361	-0.343	-0.707	0.045	-0.741	-0.647	-0.388	-0.596	-0.75	1										
ANF	0.702	0.593	0.592	1.000**	0.568	0.696	0.761	0.496	0.608	0.05	1									
OC	0.316	0.4	0.619	-0.073	0.685	0.555	0.403	0.447	0.686	-.971**	-0.081	1								
CEC	0.628	.892*	.935**	0.706	.958**	.904*	.965**	0.745	.933**	-0.583	0.702	0.569	1							
Ca	0.761	0.626	.975**	0.593	.958**	.975**	0.774	.897*	.985**	-0.751	0.593	0.674	.907*	1						
Mg	0.525	.914*	.835*	0.605	.902*	0.801	.943**	0.557	.870*	-0.616	0.596	0.664	.959**	.819*	1					
K	1.0**	0.316	0.636	0.7	0.576	0.724	0.51	0.707	0.682	-0.361	0.702	0.316	0.628	0.761	0.525	1				
Na	0.2	-0.2	0.34	0.432	0.248	0.482	0.058	0.447	0.333	0	0.441	-0.2	0.118	0.337	-0.083	0.316	1			
Clay	0.731	0.746	.984**	0.704	.972**	.977**	.879*	.874*	.978**	-0.636	0.703	0.569	.964**	.978**	.871*	0.731	0.32	1		
Silt	-0.197	-0.517	-0.097	-0.779	-0.108	-0.159	-0.542	0.04	-0.082	-0.55	-0.777	0.499	-0.338	-0.03	-0.304	-0.197	-0.089	-0.219	1	
Sand	-0.559	-0.375	-.857*	-0.174	-.839*	-.812*	-0.484	-.840*	-.861*	.933**	-0.174	-.839*	-0.689	-.893*	-0.624	-0.559	-0.243	-0.797	-0.415	1

**=highly significant (0.01) ;*= significant (0.05), ns =non-significant; pH=Potential for Hydrogen ; OC=Organic Carbon ; TN=Total Nitrogen; Av.P=Available Phosphorous ; TNP=Total N in Plant; TPP=Total P in plant; Ht=Height of plant; NN=Number of Nodules; RDW= Root dry weight; SDW=Shoot dry weight; Ndfa=N derived from atmosphere; ANF=Amount of N fixed; CEC=Cation Exchange Capacity; Ca^{2+}= Calcium; Mg^{2+}=Magnesium, k^{+}=Potassium; Na^{+}=Sodium.

Table 14: Total nitrogen in reference crops

Reference (control) crop for Dedo soil		Total nitrogen (%)
Wheat	DL1	0.09±0.02
	DL2	0.76±0.56
	DL3	0.17±0.04
Reference (control) crop for Tiro afeta soil		
Teff	TaL1	0.02±0.01
	TaL2	0.03±0.02
	TaL3	0.02±0.01