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Research article

Effects of Interseeded Green Manure Legume Species and Termination Time on the Performance of Maize (*Zea Mays L*) Crop and Soil Characteristics

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This research experiment was conducted to examine the effects of intercropped legume species and their termination time (incorporation dates) on the performance of maize (Zea mays L) crop and soil characteristics. The experiment was laid out in randomized complete block design (RCBD) in a factorial combination of three termination times and the three maize-legume combinations along with sole maize as a control treatment. Maize variety, BH-540 was planted and then three legume species Lablab (Lablab purpureus), Cowpea (Vigna unguiculata) and Vetch (Vicia villosa) were simultaneously intercropped and incorporated into the soil at 30, 45 and 60 days after planting between the maize rows. Most of the growth (days to silking, plant height, leaf area) and yield parameters (maize kernel rows, kernels, maize stover, grain yield) of maize crop were significantly (P<0.05) influenced by the treatments involved. Significantly highest maize grain yield (7.78 t ha^{-1}) was obtained when cowpea biomass incorporated. Similarly, the highest maize grain yield was obtained when green manures were terminated at 30 days after planting. The results indicated the highest N recovery in maize stover and grain was obtained due to cowpea incorporation. However, the total N recovery (stover and grain) was very low (-45.62 to 17.47 kg ha^{-1}). This suggests the release of N from green legumes and its synchronization was not sufficient to satisfy the demand of maize plant needs for growth, stover and maize grain yield production and to improve soil characteristic. The highest biomass and N yield were applied to soil in the order of lablab > cowpea > vetch within the range of 0.39 t ha^{-1} to 2.11 t ha^{-1} and 8.37 kg ha^{-1} to 76.03 kg ha^{-1} respectively. The economic analyses revealed that green legume cowpea and incorporation at 30 days after planting generated an income of 87 %and 34 % per Birr invested respectively.

Key words: Green-manure, legumes, termination-time, N recovery, economic advantage, residue.

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INTRODUCTION

Background and Justification

In Ethiopia, as in most developing countries, the economy is primarily based on agricultural production. Agriculture accounts for 42.7% of the gross domestic product (GDP) and 70% of the total export revenue (IMF, 2012/13), and employs about 80% of the labour force in the country (CSA, 2012/13). However, the agriculture is predominantly subsistence in nature. Smallholder farmers with an average holding of less than one hectare (ha) account for over 90% of the agricultural area under crop production, and 95% of the agricultural outputs (Legesse and belayneh, 2003). The agricultural production system is mainly rain fed and traditional, which is characterized by low input of improved seeds, fertilizer, pesticides and other technologies (Legesse and belayneh, 2003).

The flow of nutrients in and out of agricultural systems is generally characterized by lower storage capacity, less cycling efficiency, continual loss and net removal of nutrients, unlike natural systems where biomass production is in equilibrium with nutrient reserves (Bohlool *et al*., 2004). The prevailing farming systems of Hawassa Zuria, located in Southern Nations and Nationalities Peoples of Regional State (SNNPRS), are predominantly rainfed maize, haricot bean, enset, coffee and some tuber and root crops in conjunction with rearing of livestock. The soils of the areas are low in fertility, especially in nitrogen (N), organic matter (OM). The trend of continuous growing cereals on arable lands in the areas is undoubtedly further depleting the nutrients in the soil which are already low. The sustainability of such agricultural systems is, therefore, greatly dependent on optimizing the balance between inputs and outputs of nutrients. The use of inorganic fertilizers, to alleviate the problem of low soil fertility for successful crop production in these areas, however, is limited by high costs and unreliable availability of inorganic fertilizers; even the few farmers who use fertilizers cannot afford recommended rates.

Thus, it is important to promote economically viable and environment-friendly interventions for sustainable agriculture in the rain fed farming systems of Hawassa Zuria area. Legume N fixation, a microbiological process which converts atmospheric N_2 into a plant-usable form, offers an economically attractive and ecologically sound alternative means of reducing external inputs and improving internal resources (Bohlool *et al.,* 2004). Legume green manures are beneficial for soil conservation and may provide a positive agronomic and economic alternative to fallow (Zentner *et al*., 2004).

Intercropping of soil-improving legume green manures with cereal crops is a promising, low-cost, ecological means of improving soil fertility (Giller *et al*., 1997). Symbiotic nitrogen fixation has been estimated to contribute approximately half of the amount of nitrogen (N) applied in inorganic N fertilizers (Smil, 2005). Incorporating leguminous green manure crop provides a large amount of nitrogen and carbon source to the soils for subsequent as well as intercropped crops. There are many leguminous green manure crops and that have been utilized all over the world (Mappaona *et al*., 1994; Badaruddin and Meyer, 1990). Nevertheless, the contribution of legumes as cover crops may be limited in tropics, where there is short rainy season. Therefore, interseeding and incorporation of legume crops is another way of enhancing their contribution as fertilizer source.

Several studies have examined the use of green manuring in succession or rotation (Nosse *et al*., 2008; Morgor and Camara, 2009). However, these techniques imply the cultivation of a non-cash crop probably without immediate economic revenue, constitutes a problem for small holder farmers who need to cultivate their land intensively. Intercropping legumes between main crops and green manuring could be an alternative to succeeding or rotation cropping, although intercropping green manures between two or more main crops is still under investigation. The practice of legume and cereal intercropping is common among smallholder farmers as food source for humans. But scientific studies are rare despite potential advantages for soil fertility restoration and increased options for plant protein sources for poor households. The study reported here sought to bridge this knowledge gap with a view to increase the productivity of legumes/maize intercropping systems.

Besides offsetting the feed shortage of smallholder agriculture forage crops like cowpea (*Vigna unguiculata*), lablab (*Lablab purpureus*), and vetch (*Vicia villosa*) grown as intercrop with maize and terminated at different times could have the potential in improving soil fertility. Hence, there is a need to evaluate the effects of these crops as intercrop on the productivity of maize and subsequent soil fertility status at Hawassa Zuria area of SNNPRS, Ethiopia.

OBJECTIVE

This research was conducted with the general objective to determine the influences of intercropping and termination timing of three forage legume crops on maize yield and soil properties of Hawassa Zuria area; with the specific objectives:

- ❖ To evaluate the performance of forage legumes as green manure crop intercropped with maize,
- ❖ To determine the response of the maize crop to intercropping of green manure crops and
- ❖ To assess the effect of termination time of green manure crops on the performance of maize and the soil properties.

LITERATURE REVIEW

Strategies of integrating nitrogen fixing legumes in to cropping systems

Different strategies can be used in intercropping of legumes with cereals crops depending on time of intercropping, termination and the rainfall pattern. For instance, according to Tanimu *et al*., (2007) incorporating some legume species such as *Centrosema pascuorum* and *Centrosema brasilianum* after two years of growth more beneficial, while other legume species can be incorporated after one year of growth, such as *Chamaecrista rotundifolia*. Upendra, (2001) also indicated that the delayed termination of a hairy vetch cover crop by 2 weeks significantly increased N accumulation. Incorporation of such residue into the soil in chisel plows or moldboard plowing increased soil inorganic N compared with no till by increasing N mineralization from the residue, but did not increase silage corn yield. Delayed corn planting following late termination, however, increased soil mineral N and maize N concentration and uptake, regardless of tillage, probably due to better synchrony of cover crop N release with maize N demand. On the other hand the legume biomass was harvested and applied in maize plots in difference system, according to Nyambati *et al*., (2003) indicated that maize grain yield was highest where the residue was incorporated and lowest where it was removed.

The cropping system should be adjusted according to the growing rate of the legume species in intercropping. Such adoption of the technology might be hindered by the fact that, some legumes do not have immediate food grain benefit like the grain legumes (i.e. cowpea and lablab). The fallow legumes and food crops have to be intercropped either simultaneously or in a relay pattern to improve the yield of the crop without losing a season for food crop cultivation (Tanimu *et al*., 2007).

The rainfall patterns affect the planting time of the legume, which is intercropping with the food crops. Intercropping of green manure legumes with maize is feasible for the regions receiving bimodal rainfall where farmers produce two times in a year (Eyhorn *et al*., 2002). In this system green manure legumes were either planted at the same time with maize or planting was delayed by one to two weeks to reduce competition. The legume was planted in between maize rows. After the maize was harvested, the legume was left to continue growing during the short fallow period preceding land preparation for the following crop. As the land was prepared, the legume biomass was incorporated into the soil. In the regions receiving unimodal rainfall, usually there was one maize crop of the year. The legume green manure system for such a region requires that legumes were planted between maize rows and that lower maize leaves were pruned to reduce competition for light. The maize were harvested and the legume was left growing in the field as short term fallow until land preparation for the long rainy season maize crop (Eyhorn *et al*., 2002).

In addition to intercropping time, residue decomposition and nutrient release patterns were more affected by legume cutting strategies than by cropping systems. Nutrient pools from the shorter cutting strategies were potentially available within relatively short periods (2 to 4 weeks). A longer cutting interval for Dolichos provided relatively larger nutrient pools that were potentially available over a longer period (8 to 16 week). These larger nutrient pools would likely be beneficial to a long duration crop like cassava or to a strategically planted maize crop (Njunie *et al*., 2004).

For some green manure species, herbicide application may be a viable alternative than tillage for the termination of established stands. Herbicide application allows sufficient mineralization to meet the N needs of main crop, but reduced the potential for N losses by reducing the size of the soil inorganic N pool. The suitability of this practice may depend on soil and environmental conditions. Herbicide application may improve synchrony between N release from residues and N need of main crop, thereby improving N use efficiency and reducing N losses (Ramona *et al*., 1999).

Potential benefits of green manure in soil improvement

In crop production, a basic constraint is soil nutrition problem which restrict on farm crop yields. This can be happen because of continuous cropping system without fertilizer application on the same farm land leads to soil depletion. Such problem can be resolved by the application of synthetic or organic fertilizer. Green manuring is one of the practices to enhance the soil fertility and uptake of nutrients. Vaiyapuri *et al*., (2007) suggested that the intercropping the legume marigold in two rows in between cotton rows had contributed ultimately more nutrient uptake of cotton through improving soil characteristics status. It can be balanced by the planting legumes which improve the capture, productive use and recycling of water and nutrients, such as end of season residual and fallow moisture.

The levels of organic carbon, total nitrogen (N), phosphorus (P) and the exchangeable bases also increased with the addition of both the food legume and the natural fallow materials. The levels of N and P were particularly increased with the addition of pigeon pea plant stover into the soil. Exchangeable Ca dominated the exchange complex in most of the soils where food legume had been incorporated. Acidity decreased with the incorporation of the various food legumes and the natural fallow materials (Egbe and Ali, 2010). Leguminous herbaceous cover crops grown in situ play a major role in N capture and internal cycling in ways compatible with farmer constraints. Green manures from the legume family have the ability to take up nitrogen from the air, tapping a free source of soil fertility (High and Chorlton, 2005).

Legumes reduce fertilizer costs for cash limited smallholders farmers. About 90 % of farmers preferred incorporating the legume biomass into the soil. They explained that maize grown where the legume is incorporated always looks healthier and in case of water stress the maize takes longer to wilt. They also said that legume incorporated soil is light compared to others and it is easier to till (Mureithi *et al*., 2000).

The synergistic complement to chemical nitrogen fertilizer, grain legumes reduce fossil fuel use and associated emissions of greenhouse gases that contribute to climate change. Wind and water erosion may be prevented by using green manures, as 'cover crops'. When adverse weather conditions tend to be occurs, bare soil at this time is bad practice. The green manure roots hold the soil and the top growth prevents splashing and surface runoff (High and Chorlton, 2005).

Effects of intercropping green manure on the soil properties

The improvement of the selected soil chemical properties under improved fallow related to mucuna above and below ground biomass incorporation and decomposition. The use of mucuna as a green manure increased the soil pH (H_2O), exchangeable bases (Ca^{++}, Mg^{++}, and K^+), organic matter (OM), and the available P. The results showed that mucuna could be one of the alternative legume cover crops to be used as green manure to improve the important soil chemical properties. Moreover, the residual effects of improved fallow after maize crop harvesting showed improving trends of the selected soil chemical properties (Wakene *et al*., 2007). Similarly the work done in different parts of tropics by Pypers *et al*., (2005) and Lee *et al*., (2006) where the application of green manure increased available nutrients, organic matter content, and reduced exchangeable acidity. Green manure has also been found to enhance the availability of native phosphorous and other micronutrients to crops as well as improving soil aeration and organic matter (Maobe *et al*., 2011).

Tamiru Hirpa, (2013) reported that delaying incorporation attributable to improvement of soil conditions and prolonged nutrient supply by the late incorporation. It could, therefore, be suggested that any N containing material must be able to produce a large pool of mineral N before the period of rapid N uptake by main crop. Generally the higher N and P uptake by maize crop in excess of actual green manure accumulation implies that cropping systems including legumes as green manure could probably be the most efficient ones due to the direct N input, mobilization of soil nutrients, and modification of soil environment for crop growth.

Biomass production of forage legumes

Leguminous plants with high biomass production can improve the productivity and sustainability of smallholder farming. Hairy vetch is a temperate legume often suggested as a preferred legume cover crop to supply nitrogen in a maize production system (Czapar, 2002). It is described as one of the best legumes in its ability to be productive in low soil fertility or acid soils (Dastikaite *et al*., 2009). Lanyasunya *et al*., (2007) demonstrated that in a tropical climate in Kenya hairy vetch can yield dry matter of up to 9.5 t ha^{-1} and in Iran and Japan, sole hairy vetch can produce dry matter yields of up to 6.14 t ha^{-1} (Shobeiri *et al*., 2010) and 4.47 t ha^{-1}(Anugroho and Kitou, 2011) respectively. The results of (Cherr *et al*., 2006) showed that hairy vetch (*Vicia villosa*) has dry weight ranges from 1.5-10.0 t ha^{-1} and according to (Muluneh and Angaw, 2014) the dry biomass was 3.5 t ha^{-1}. The Average dry matter production when it was mono-cropped in north Ethiopia was 629.55 kg ha^{-1} (Fassil Kebede, 2010). Hairy vetch biomass in monoculture ranged from 4.98 to 7.08 Mg ha^{-1} and averaged 5.94 Mg ha^{-1}, hairy vetch biomass increased as the seeding rate of hairy vetch increased (Poffenbarger, 2014).

The dry matter yields of lablab when in-row intercropped with maize was lower (1.7 t ha^{-1}) than when grown as sole crops (9 t ha^{-1}), however the proportion of leaf and pod under the shaded conditions of the intercrops was shown to be higher (33.6%) than in sole crops (23.7%) for lablab (Maasdorp and Titterton, 1997). When lablab grown as monocropped and planted at the beginning of the growing season at northwestern Kenya, it produced greater than 5 t ha^{-1} dry matters compared to about 2 t ha^{-1} when relay cropped in maize (Nyambati *et al*., 2003). It grown as rotations with maize-bean intercrop for two seasons in sub-humid highlands of East Africa indicated that the produced legume biomass yield was 4.67 Mg ha^{-1} (Wortmann *et al*., 2000). Lablab yielded 0.13 t ha^{-1} and 0.86 t ha^{-1}leaf biomass from defoliated and undefoliated treatments respectively. Lablab accumulated more biomass in the stem than mucuna (1.8 vs. 1.3 t ha^{-1}). Leaf N accumulation for the defoliated lablab treatment averaged 4% that of undefoliated lablab (Nyambati *et al*., 2009).

The studies previously reported on the dry matter yield of cowpea but, in Ghana 3.4 t ha^{-1} was recorded (Aikins and Afuakwa, 2008) and dry matter production variation has been observed across experimental sites and soil characteristics like plant nutrient availability. The study in North West lowlands of Ethiopia shown that the average dry matter yield for the cowpea was 4.28 t ha^{-1} and ranged from 3.72 to 4.73 t ha^{-1} (Bilatu *et al*., 2012; Afuakwa, 2008). On the other hand the results of (Cherr *et al*., 2006) indicated that Cowpea (*Vigna unguiculata*) has dry weight ranges from 0.6-8.5 t $ha^{-1}$and.

The legume biomass production (3.0 to 14.8 t ha^{-1}) was highest under medium rainfall compared to high rainfall (2.5 to 8.4 t ha^{-1}) or low rainfall (2.5 to 4.9 t ha^{-1}) (Lupwayi *et al*., 2011). Biomass production by cowpea increases with time for instant the work in western Ethiopia shows that the biomass production at mid vegetative stage was 1.6 t ha^{-1} and 2.1 t ha^{-1} at mid flowering stage (Tamiru Hirpa, 2013).

Nitrogen fixing capacity of forage legumes

The ability of legumes to fix N allows farmers to grow them with minimal inputs of N fertilizer. Non-legume crops grown in intercropping or in rotation with them usually have reduced fertilizer N requirement, which had both economic and environmental benefits. Grain legumes contribute less N than herbaceous legumes to intercropped crops, because most of the N fixed biologically by grain legumes was translocated to grain. Both the grain and the residues were invariably removed from field for human and livestock use (Giller *et al*., 1997).

Tanimu *et al*., 2007 the adoption of the technology might be hindered by the fact that, the legumes do not have immediate food grain benefit like the grain legumes (i.e. cowpea, soybean and Lablab). For such cases the fallow legumes and food crops have to be intercropped either simultaneously or in a relay pattern to improve the yield of the crop without loosing a season for food crop cultivation. Amount of N fixed varies widely within and between different legume cover crops, depending on species and environment like soil pH and management (inoculation). Although the accumulation of N in leguminous crops can exceed 500 kg N ha^{-1}under tropical conditions, the actual contribution of N to main crops was more modest, 20-100 kg N ha^{-1} (Peoples and Craswell, 1992). Legume cover crops have been reported to fix up to 450 kg ha^{-1} (Unkovich and Pate, 2000).

Most of the N in grain legumes was contained in the high protein grain and removed from the farm at harvest. Even in bushy, creeping legumes like cowpea, which have more residues than less bushy legumes, at least 50% of their N was contained in the grain (Lupwayi *et al*., 2011). The limited N contained in these residues was released slowly or even immobilized by the decomposing microflora. Giller *et al*., (1997) reported that only 12 to 24% of cowpea shoot residue N was recovered in the main crop. Adjei-Nsiah *et al*., (2008) observed a net N contribution of 8 to 11 kg N ha^{-1} from the 23 to 26 kg N ha^{-1} added through cowpea residues. The amount of N_2 fixed by a legume crop varies widely because it depends on the soil environment. The amounts of N_2 fixed by grain legumes in sub Sahara Africa as ranging from 11 to 201 kg N_2 ha^{-1} for sole cropped cowpea, 9 to 125 kg N_2 ha^{-1} for intercropped cowpea (Mwanarusi *et al*., 2010). Averagely the N content of cowpea ranges from 15-154 kg ha^{-1} (Cherr *et al*., 2006) and 30 kg N_2 ha^{-1} was produced through cowpea fixation. Cowpea tissue nitrogen content increased with increase in time from crop emergence to first leaf harvest from 2 weeks after emergency to 4 weeks after emergency (Mwanarusi *et al*., 2010).

The work in Southern Guinea Savanna of Nigeria indicated that Sole cowpea fixed the highest amount of N (63.00 kg ha^{-1}) while bambara groundnut which fixes atmospheric nitrogen through symbiosis with Rhizobium bacteria. Therefore they were beneficial in rotation and intercropping and it intercropped with maize fixed the lowest N (10.16 kg ha^{-1}) (Moses *et al*., 2013). The N-value of growing cowpea monocropped prior to sol maize was equivalent to the application of 50 kg N ha^{-1} as mineral fertilizer. When maize followed a maize-cowpea intercrop, grain yield was increased by 67%. Around 34% of the N contained in cowpea residues was recovered in the following maize as estimated by N (Vesterager *et al*., 2007).

The concentration of nitrogen varies in legumes plant part for instance according to the study in northwestern Kenya the nitrogen contribution from undefoliated lablab treatments was 47 kg N ha^{-1}, out of this, the leaf fraction contributed the greatest amount of N 54% of the total and root contributed the least 5% (Nyambati *et al*., 2003). Ibewiro *et al*., (1998) studied the N contribution of the legume mucuna, lablab showed that their roots was only 3 and 4% of the total N, their incorporation resulted in maize grain yield that was 38 and 89%, respectively, of the yield obtained when whole residue was incorporated. This was attributed to the low quality of roots that may have improved the synchronization of N release with N uptake of the maize crop.

The soil N content was improved 6.6 times more than the original soil N content (0.014%) from the plots where vetch, was grown. This legume produces 3.99% N in its leaves and 0.093 % N in the soil where it was incorporated (Fassil Kebede, 2010). On the other hand the N content ranges from 58-257 kg ha^{-1} as suggested by (Cherr *et al*., 2006). The research conducted at the central highlands of Ethiopia indicated that the nitrogen fixation potential of hairy vetch was 127.64 kg N ha^{-1}. Hairy vetch N content increased significantly with increasing proportion of hairy vetch biomass, reaching a maximum with the greatest hairy vetch biomass proportion. Nitrogen contents of monoculture hairy vetch ranged from 145 to 222 kg ha^{-1} averaged 180 kg ha^{-1} (Poffenbarger, 2014).

The time of flowering of the legumes affect the N fixation, the two years work on morphological and phenological variations in Lablab accessions were indicated that the flowering time in 140 days, nitrogen production increased from 15 kg ha^{-1} for the very early-flowering accessions to 159 kg ha^{-1} for the late flowering accessions and then decreased to 135 kg ha^{-1} for the extremely late-flowering accession with a mean nitrogen yield of 64.1 kg ha^{-1}. Higher dry matter yields were associated with late to extremely late-flowering groups and lower dry matter yields with very early to intermediate flowering groups. Accessions belonging to the very late-flowering group had the highest N and root dry matter yields, while the very early flowering group produced the lowest N and root dry matter yields (Ewansiha *et a*l., 2007).

Effects of green manure on maize yield

In smallholder agriculture, green manure legumes can play a major role in improving farm productivity in different cropping system. For instance when legume residue was applied, for undefoliated lablab yielded higher maize grain than undefoliated mucuna (6.72 vs. 4.46 t ha^{-1}), and defoliated mucuna resulted in higher maize grain yield than defoliated lablab (6.08 vs. 3.98 t ha^{-1}). The undefoliated lablab (6.72 t ha^{-1}) residue application yielded higher maize grain yield than the natural fallow control (4.11 t ha^{-1}). Therefore single-year or alternate-year intercropping of mucuna and lablab can increase maize grain yield (Nyambati *et al*., 2009).

The legume lablab has been shown to increase grain yields of maize crop compared to continuously grown maize. Even incorporation of only the roots of lablab had a positive effect on maize as compared to a control where no residue was applied (Ibewiro *et al*., 1998). The results obtained by Odhiambo *et al*., (2010) from a two year study on green manure-maize rotation system showed that cowpea, lablab gave yield increases of 77 and 134 %, respectively, above the control treatment. Lablab grown as rotations with maize-bean intercrop for two seasons in sub-humid highlands of East Africa resulted in two year averages for maize biomass yield of 9.78 Mg ha^{-1} and maize grain yield of 3.22 Mg ha^{-1} (Wortmann *et al*., 2000). The lablab biomass has been produced 5.7 t ha^{-1} in the short rainy season of Kenya and maize grain yield planted as main crops two weeks after incorporation was 3.78 t ha^{-1} (Birech *et al*., 2008).

The grain yield of maize grown after cowpea monocrop was doubled and the N uptake increased by 60% compared to maize following maize (Vesterager *et al*., 2.007). In Kenya, averaged over two years, *C.ochroleuca* and *Mucuna pruriens* green manure improved maize grain yield by 1.5 t ha^{-1} compared to no incorporation (Ojiem *et al*., 2000), while in southern Cameroon, Hauser and Nolte, (2002) obtained maize yields greater than 4 t ha^{-1} after a short-term fallow with mucuna.

A significant difference in maize grain yield was observed between sol maize and maize after monocropped Lablab. Average grain yield ranged between sol maize (4.52 Mg ha^{-1}) to lablab (10.59 Mg ha^{-1}). Addition of 100 kg N ha^{-1} gave an increase in yield of 74% (3.33 Mg ha^{-1}) above the sol maize. Lablab treatment produced a significantly higher grain yield than sol maize but was not different from the other green manure legumes (Odhiambo *et al*., 2010). The kernels per row of maize crop shows an increment at the plot of mid vegetative, mid flowering and pod setting stage of cowpea plant which was 29, 32.3 and 40 kernels respectively. Similarly the 1000 seed weight was 294.9, 307.3 and 315.3 g and the total dry matter was 6.56, 8.36 and 10.59 t ha^{-1}. The total grain yield was 3.37, 4.59 and 5.1 t ha^{-1} at mid vegetative, mid flowering and pod setting stage of cowpea plant (Tamiru Hirpa, 2013). The screening trials on mucuna (*Mucuna pruriens*); sunhemp (*Crotalaria juncea*), lablab(*Lablab purpureus*); cowpea (*Vigna unguiculata*) and butterfly pea (*Clitoria ternatea*) at different season indicated that, Maize yield ranged between 4.0 to 6.4 t ha^{-1} in the first seasons and between 5.8 to 8.4 t ha^{-1} in the second season (Cedric, 2014).

A supplement dose of 40 kg N ha^{-1} applied at 45-50 days was effective to support plant growth when organic manure N had been exhausted. The organic manure N with an effect similar to basal nitrogen application, increased plant growth in cereals while the supplemental nitrogen application at this stage lead to increase size and weight (Ehsan *et al*., 2014).

Impacts of incorporation time on legumes biomass

The amount of biomass and N provided by the green manure crops depend on growth stage at the time of incorporation. Selection of suitable legume species and age at termination determines the amount of biomass and nutrient concentration. Nitrogen supply to crops by means of N mineralization on green manure residue must be synchronized with crop N demand (Cobo *et al*., 2002), and it is necessary that biomass addition time and crop growth rate match (Lahti & Kuikman, 2003).The effects of incorporation time on green manure N and P inputs were sustained more by the uptake of maize crop than species contribution.

Time of incorporation of green manure crops was influenced several variables. According to Birgitta, (2000) the chemical composition and amounts of incorporated plant material was changed with time, when the climatic conditions for decomposition and losses of N. Time of incorporation of green manures was more effective way to control the temporal pattern of N mineralization than choice of species; however, intercropping during part of the cropping period did not result in higher N uptake by the vegetable crop throughout. On the contrary, with the latest time of incorporation the N yield was lower than with earlier incorporation, due to competition between the vegetable and the green manure crop.

Green manure species needs different duration to produce valuable biomass For instance one year growth before incorporation, *Chamaecrista rotundifolia* gave higher grain yield than *Centrosema pascuorum* and *Centrosema brasilianum*; while at two years growth before incorporation *Centrosema pascuorum* and

Centrosema brasilianum gave higher mean grain yields (Tanimu *et al*., 2007).

Biomass from late incorporated legumes stover was lower than from early incorporated legumes stover, due to the loss of leaves by harvest time. Application of organic and inorganic fertilizers separately or in combination, increased maize yields at all sites, but higher fertilizer use efficiency was obtained when the green manures were combined with 35 kg N ha^{-1} (Sakala, 1999).

Economic benefits of forage legumes intercropping with maize.

Systematic soil incorporation of N-fixing legume crops as a green manure could be an important agronomic approach in order to reduce the need for costly external inputs and improve internal resources for sustainable production. SegunOlasanmi and Bamire, (2010) reported that maize-cowpea intercropping was found to be profitable than their sole crops. On the other hand, Osman *at al*., (2011) reported that intercropping with two rows of cowpea and one row of millet gave significantly higher economic benefit than mixture with one row of each of the crops. Oseni, (2010) found that intercropping with two rows of sorghum and one row of cowpea gave higher economic return compared to the other planting arrangements and the sole crops. These results suggest that intercropping could improve the system's productivity, increase the income for smallholder farmers, and compensate losses (Osman *et al*., 2011). Other advantages of intercropping include potential for increased profitability and low fixed costs for land as a result of a second crop in the same field (Thobatsi, 2009). According to Seran and Brintha, (2010) the intercropping system provides higher cash return to smallholder farmers than growing the monocrop.

Mucheru-Muna *et al*., (2010), using benefit cost ratio, found that maize with beans as the intercrop resulted in 40 percent higher net benefits relative to the conventional system with beans, and 50–70 percent higher benefits, relative to maize with cowpea or groundnut. The report on adoptable maize/legume systems for improved maize production in northern Tanzania showed that the economic analysis indicated better returns in maize with lablab than for maize monocrop. The enhanced returns included cash and labour saving (Mmbaga & Friesen, 2003).

The use of cowpea as green manure raises the economic profits from maize production. The net profit realized was found to be significantly greater than the reported mean profit from the use of chemical fertilizer. The study recommends that manuring maize plots is the most economically profitable in maize production system that can be used by small farmers to sustainably raise income and promote soil health as an alternative to chemical fertilizers (Fabunmi and Agbonlahor, 2012).

MATERIALS AND METHODS

Description of the study areas

This experiment was conducted at Hawassa Zuria area, southern Ethiopia, at Hawassa University's Research and Farm Center (RFC). Hawassa Zuria is located between latitude at 07° 03'N and longitude 38° 3' E and found in Sidama Zone of Southern Nations, Nationalities and Peoples Regional State (SNNPR). The rainy season of the study area extends from March through September. Based on the time of crop harvest the main season locally called mehere, extends from June to September. Mean annual minimum to maximum temperature ranges from 12-27^{0}C, respectively (Figure 1). The average annual rainfall ranges between 674-1365 mm and the mean altitude of the area is 1,670 meters above sea level (Figure 2). The soil type within the area is generally categorized as Andosol (Girma Abera *et al*., 2013). Consequently, the soils are loose and prone to water erosion during the heavy rains and also to wind erosion during the dry season when crops are harvested (Ethio-organic seed action, 2007).

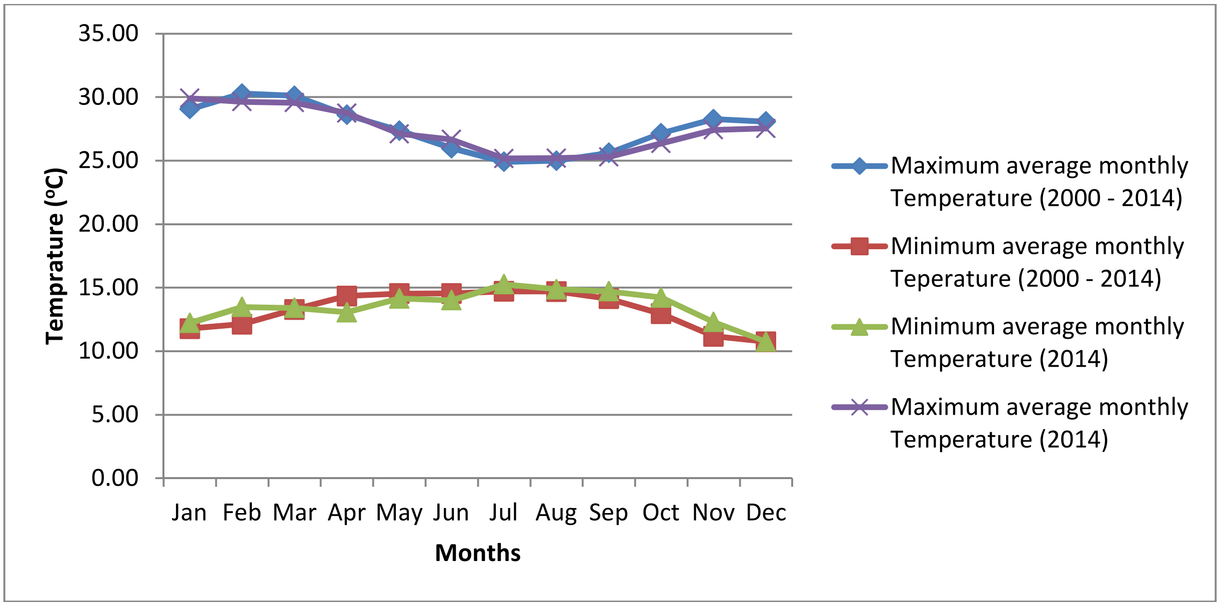

Figure 1 Average minimum and maximum temperature during the experimental year 2014 and average of 15 years from 2000 - 2014.

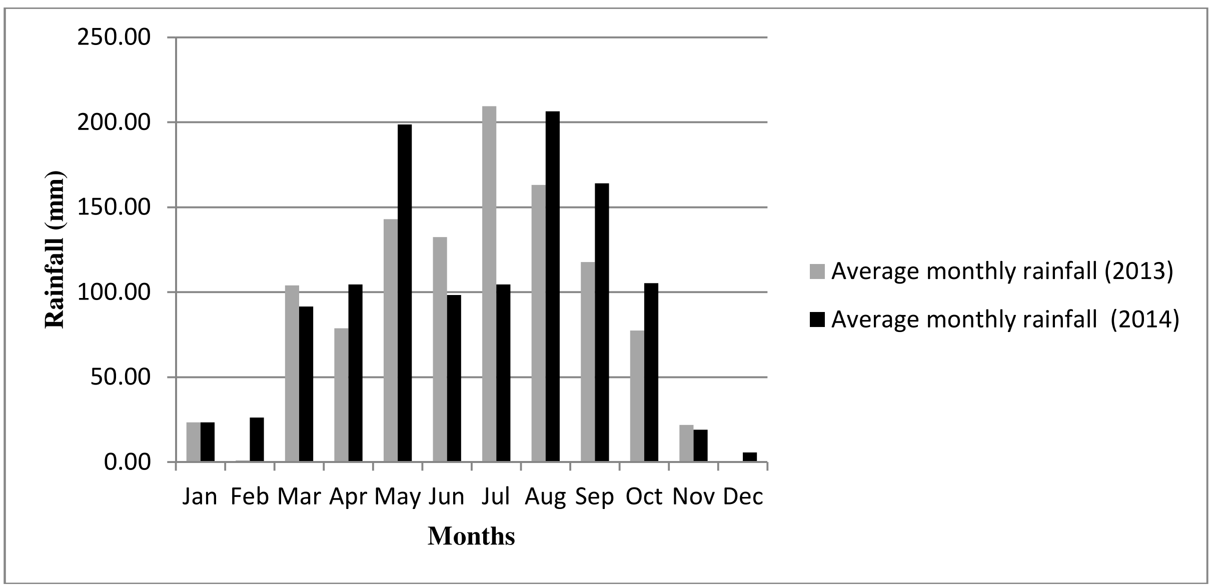

Figure 2 Total rainfall during 2013 and 2014 experimental year at Hawassa.

Sources of planting material and cultural practices

Seed of maize variety BH-540 was obtained from Southern Nations, Nationalities and Peoples Regional State Seed Enterprise, while the forage legumes namely lablab (*Lablab purpureus*), cowpea (*Vigna unguiculata*) and vetch (*Vicia villosa*) seeds that were used for the experiment obtained from Southern Nations, Nationalities and Peoples Regional State of Agricultural Research Institute. The maize variety is commonly cultivated in the region with an average yield of 48-60 Q ha^{-1} as stated by Southern Nations, Nationalities and Peoples Regional State's Agriculture Bureau.

Land was prepared in accordance with a standard practice and the crop was grown as rain-fed. Before sowing the component, the land was plowed to prepare a suitable seed bed and seeds of the legumes as well as maize were sown by hand with their own spacing. For maize the inter- and intra-row spacing of 75 × 30 cm was used in which two rows of the green manure legume crops were introduced and simultaneously planted at 25 cm apart from each other and from the maize row and at 10cm spacing between plants. At the time of planting, all plots were received a basal application of 100 and 50 kg ha^{-1}of Diamonium Phosphate (DAP) for maize and legumes, respectively. Generally, crops in these studies were raised according to the standard cultural practices applicable to the areas. Each experimental plot size was 3.75 m length and 4.5 m width respectively.

Soil sampling

Soil sampling were done twice, before planting and at post-harvest by weighing 300 g collected up to rooting depth of 20 cm for analysis of selected chemical and physical properties, as pre-planting soil sampling was important for identifying initial soil conditions in the fields, and latter sampling was considered to see the experimental and residual effects.

Soil samples were randomly taken from a depth of 0-20 cm from 12 places (spots) to represent the entire experimental field before planting and composited to one sample. The post-harvest soil samples were randomly collected from 6 places per plot used to see the experimental and residual effects. The collected soil samples were air-dried and ground to pass through a 2 mm sieve to determine soil physical and chemical properties.

Soil analysis

Soil and plant tissue analyses for certain parameters relevant to the study were carried out at Assosa Agricultural Research Center soil laboratory. Soil pH was determined at 1:2.5 soils: water ratio using a glass electrode attached to a digital pH meter (Page, 1982). Organic matter was determined based on the oxidation of organic carbon with acid dichromate (Cr_2O) medium following the Walkey and Black method as described by (Dewis and Freitas, 1970). Total N in soil was determined by the Kjeldahl method (AOAC, 1994). Available soil P was determined according to the methods of Olsen and Dean (1965), soil texture was determined as per the hydrometer methods, Cation exchange capacity (CEC) of the soil was determined from ammonium acetate saturated samples that were subsequently replaced by Na from a percolated sodium chloride solution and exchangeable K was determined from the extract with flame photometry.

Treatments and Experimental procedure

A factorial experiment consisting three legume crops, lablab (*Lablab purpureus*), cowpea (*Vigna unguiculata*) and vetch (*Vicia villosa*) were sown in intercropping with maize (*Zea mays* L.) as green manure and terminated at different termination dates. The treatments of this experiment included: maize intercropped with lablab (*Dolichose lablab*) (ML), maize intercropped with vetch (*Vicia villosa*) (MV), maize intercropped with cowpea (*Vigna unguiculata*) (MC) and sole maize (SM); while dates of green manure termination times were 30, 45 and 60 days after planting (DAP) (Table 1). Hence, the experiment was laid out in randomized complete block design (RCBD) with factorial combination, where the three termination times and the three maize-legume combinations plus sole maize as a control were arranged as treatments, resulting into a total of 10 treatments replicated three times.

Table 1. Treatment combinations of green manure legume species intercropped with maize and the three incorporation time.

Factor A	Factor B	Treatment code
Termination time	Sole maize	T1
30	Maize + Lablab	T2
	Maize + Vetch	T3
	Maize + Cowpea	T4
45	Maize + Lablab	T5
	Maize + Vetch	T6
	Maize + Cowpea	T7
60	Maize + Lablab	T8
	Maize + Vetch	T9
	Maize + Cowpea	T10

Maize growth and yield related parameter

Leaf area (cm): Leaf area was measured by taking five leafs present on five randomly sampled plants. The maximum leaf width and height from the tip to leaf sheath were measured and, so the leaf area of each plot were calculated by multiplying the leaf width, leaf height and correction factor which is 0.75 as described by(Lazarov, 1965).

Leaf area index (%): Leaf area index was calculated by the ratio of leaf area to the area of ground cover as described by (Watson, 1947; Watson, 1952) using the following formula,

$$\mathrm{LAI} = \frac{\text{Total leaf area per plant}}{\text{Area of ground covered per plant(cm)}} \qquad \text{(Eq. 1)}$$

Days to maturity: Days to maturity was recorded when all plants formed black layer at the base of the seed.

Days to 50% tasseling: Days to 50% tasseling was recorded when 50% or more plants in a plot start produce tassel.

Days to silking: Days to silking also recorded when the silks are visible outside the husk.

Plant height (cm): Plant height was also measured (cm) from ground level to terminal stem using measuring stick at maturity for five randomly taken plants per plot and the average was taken for estimation.

Cob length: The average cob length was measured by taking five cobs randomly from each plot by using ruler and the number of cob/m^2 was recorded by counting the cob found in 1m^2 of the plot.

Number of kernel rows: The number of kernel rows per cob was recorded from five randomly taken cobs from each plot then count the rows per cop and take the average of the five cobs of the row.

Number of kernels: The number of kernels per row was recorded from the five random sample cob then count the kernels per row of the cob finally take the average number of kernels per row.

Thousand kernel weight (gm): Thousand kernel weight was counted using electronic seed counter from a bulk of thresh seed and weighed using sensitive balance from a plot at harvest by adjusting at 12.5 % moisture using moisture tester and total grain yield from each plots was also taken from the central three rows.

Legumes biomass (ton): To estimate the biomass yield, herbage sampling ware done from 1 m x 1 m quadrate of each plot on the dates of the respective incorporation and oven-dried until a consistent weight is achieved.

Harvest index (%): Harvest index was calculated as the ratio of grain yield to above ground biomass per plant multiplied by 100 at harvest from the respective treatments.

Plant tissue analysis

Legumes biomass N concentration (%): Plant materials of green manure legumes crops were milled and sieved with 0.5 mm to prepare for the analysis of N concentrations using Micro-Kjeldahl method (AOAC, 1994).

Maize stover and grain nitrogen concentrations (%): Maize stover is the above-ground, non-grain plant material that remains following grain harvest. Maize stover nitrogen concentrations were determine from components sampled material including the ear shank upward, vegetative material from approximately four inches above the soil surface to just below the ear and cobs. Grain also sampled from the bottom, the middle and at the tip of the cob and tested for nitrogen concentration from the sample oven dried using Micro-kjeldahl method (AOAC, 1994).

Apparent N recovery

The amount of N recovered from green manure residue, apparent N recovery (ANR), were computed from N uptake of the maize crop and N produced from each green manure which were incorporated into the soil using the following formula:

$$\text{ANR} (\% = 100 \text{ x} \frac{\text{N uptake from GM treatment (kg/ha)} - \text{N uptake from control treatment (kg/ha)}}{\text{Applied N from GM (kg/ha)}} \quad \text{(Eq. 2)}$$

Economic analysis

The economic performance of intercropping green manure with maize evaluated to decide which forage legumes and termination date were produce better yield and economic benefit to justify the adoption of this system by farmers. The variable costs to be considered in the analysis were costs of forage legumes seed and costs of labour to apply agronomic practices. Therefore, Marginal rate of return (MRR) was computed as MRR = marginal net benefit/marginal cost, expressed as a percentage. The higher the value of MR the more profitable is the cropping system. Furthermore, the economic analysis was carried out as described by (CIMMYT, 1998) to estimate the benefit-cost ratio. A dominance analysis was done and the un-dominated treatment was further had been subjected to marginal rate analysis.

Data analysis

Analysis of variance (ANOVA) of soil and crop data was undertaken using a linear model by SAS Statistical computer software. Treatment means were separated using least significant difference (LSD) test at 5% probability levels.

RESULTS AND DISCUSSION

Physico-chemical properties of soil of the experimental site before sowing

Surface soil samples collected from the experimental field before planting was analyzed for some selected soil properties (pH, OC, TN, P, K). The soil sample before sowing has optimum soil reaction with a pH value of 7.02 for the surface of 0-20 cm depth. The soil texture of the study site was found to be loam, i.e. good in soil water holding capacity and fertility. Its potassium (0.70 m.e $100g^{-1}$) and cation exchange capacity (14.20 m.e $100g^{-1}$) were appeared to be low. The results revealed that total nitrogen and organic carbon content of the soil, before planting were found to be 0.07% and 1.4%, respectively. These values are found to be low, perhaps attributed to continuous crop production with little organic residues retention. According to ILACO, (1981), soil having 0.05 - 0.125 % N are grouped as low in nitrogen and this holds true for the soil of the present experimental site. The soils containing less than 10 ppm P are considered as low in available P, those in the range of 10 - 20 ppm as medium and the rest containing greater than 20 ppm are classified as high in available P (Max, 1998). Thus, the available P (18.96 ppm) of the experimental site was found at a range of medium.

Legume tissue nutrient concentration, biomass yield and nitrogen yield

The green manure biomass N concentrations were non-significantly varied among the legume species. But the highest N content of legume recorded with lablab. Nevertheless, as expected the green manure legumes termination time had significantly ($p<0.05$) influenced legume nitrogen concentration, higher N content being registered during 30 days of termination as compared to 45 and 60 days termination time after planting (Table 2).

Biomass yield of the legume species at three difference termination time (30, 45 and 60 days after planting) are presented in table 2. Significant variation was observed among the mean of the legume species biomass production ($P < 0.05$). The result indicated lablab produced significantly the highest biomass than all the other green manure legumes. The result of this research showed that the legume biomass yield ranges from 0.39 t ha^{-1} to 2.11 t ha^{-1} with vetch and lablab respectively. No interaction effect was observed on legume biomass production (Table 2). The same conclusion was reached by Parr, *et al*., (2011) who found no interaction between termination date and total biomass.

Table 2 Main effects of green manure legumes and termination time of legumes on legume tissue nutrient concentration, biomass yield and nitrogen yield.

Legumes	Legume biomass NC (%)	Legume biomass (t ha^{-1})	Legume N yield (kg ha^{-1})
Lablab	3.11	2.11^{a}	65.52^{a}
Vetch	2.70	0.39^{c}	10.19^{c}
Cowpea	2.70	1.53^{b}	39.27^{b}
Mean	2.84	1.34	38.33
LSD	NS	0.19	9.19
CV%	18.10	13.77	23.99
Termination time			
30	3.47a	1.19^{b}	41.73
45	2.60b	1.29^{b}	34.64
60	2.44b	1.56^{a}	38.62
Mean	2.89	1.34	38.33
LSD	0.51	0.19	NS
CV%	18.10	13.77	23.99
LS*IT	*	NS	*

Means across the column and the row with the same letter are not significantly different at 5% probability level. NC=Nitrogen concentration.

The results indicated that lablab produced 441% higher biomass yield than vetch, and also it produced 37.9% higher biomass than cowpea. As it is evident from table 2 the result of the legumes biomass across the termination time of the legume showed increasing trend with increasing growing time. The effect of termination time did not significantly affect the legumes biomass between 30 and 45 days after planting. Similarly the result made by Mulgeta Habte, (2014); Schomberg *et al*., (2007) found that when compared across age, dry matter yield of all the green manures was directly influenced by age. Accordingly, dry matter yield was higher as time of growth extended. In the contrary late incorporation tended to have lower legume biomass as compared to early incorporation (Sakala *et al*., 2000). On the other hand, biomass production of legumes were significantly higher when terminated at 60 days after planting than that of 30 and 45 days growing period (Table 2). Therefore the mean results revealed that there was more biomass differences observed among the legume species than among the termination times.

Effects of green manure legumes and termination time on nitrogen yield

Nitrogen yield of green manure legume species varied from species to species as well as among legume growing stages. The interaction effect of legume species and termination time of legumes was significant ($P > 0.05$) on above ground biomass N yield. The termination time had showed a clear trend of increase with vetch and decrease with cowpea, while clear trend was not observed with lablab (Table 3). Similar findings reported that N yield of cowpea, showed the highest at mid-flowering stage followed by a decrease trend (Tamiru Hirpa, 2013; Franchini *et al*., 2003). The legume specie vetch and lablab recorded the highest N yield at the termination time of 60 days after planting (Table 3). Similar to the present findings McCauley *et al*., (2012) reported higher N yield with pea and lentil termination at poding than at bloom. The legume vetch had no significant difference across termination time. In the same way Sainju and Singh, (2001) observed no significant effect on N yield of hairy vetch.

The legume lablab N yield resulted due to terminating at 60 days after planting had significantly higher N yield (76.03 kg ha^{-1}) as compared to the other treatments (Table 3). Cheruiyot *et al*., (2003) in a study on the effect of legume managed fallows (garden pea, common beans and lablab) on soil N found accordingly that among the legume species, lablab showed outstanding positive effect on maize yield. The lowest N yield recorded from vetch (8.37 kg ha^{-1}) at 30 days of termination after plating.

When the N yield averaged over green manure legume species, the highest N yield was recorded at the termination time of 30 days after planting, this result was in agreement with the report (Mulgeta Habte, 2014; Olujobi and Oyun, 2012) who stated that nitrogen yield measured from legume species was relatively high at early stage after planting compared to the later stages. The N yield of the legumes was varied across termination time and unexpectedly the lowest N yield was recorded at 45 days after planting. Similar finding was observed by Schomberg *et al*., (2007) who stated growing period had significantly influence the N yield of legume and having a predominantly nonlinear response across the planting dates. On the other hand the average of N yield of each legume showed that an increasing trend from the legume vetch (10.19N kg ha^{-1}), cowpea (39.27 N kg ha^{-1}) to lablab (65.52 N kg ha^{-1}). This result showed that a significant effect was observed on N yield due to the species difference and the N yield of the species lablab significantly higher by 17.2% and 36.25% from the legume species cowpea and vetch, respectively.

Table 3 Interaction effects of green manure legume species and termination time of legumes used as green manure on legumes nitrogen yield.

Legumes	Nitrogen yield (Kg ha^{-1})			
	Incorporation time in days			
	30	45	60	Mean
Lablab	65.99^{b}	54.54^{c}	76.03^{a}	65.52
Vetch	8.37^{f}	11.03^{f}	11.18^{f}	10.19
Cowpea	50.82^{c}	38.33^{d}	28.65^{e}	39.27
Mean	41.73	34.63	38.62	
LSD		9.267		
CV%		23.986		
LS*IT	*			

Means across the column and the row with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

Therefore the legume lablab had higher N yield but the released N had no contribution for maize in intercropping rather it may be immobilized or leached. Similarly, Tamiru Hirpa (2013) reported that the N from some legumes couldn't largely contribute to better growth and grain yield of the crop in the subsequent season, attributable to leaching loss and fixation of the released N, before being taken up by maize crop and/or lower reserve size in the soil.

Effects of green manure legumes and their termination time on maize growth parameters.

Days to tasseling and maturity

Even if the effects of legumes and termination time showed non-significant effect, the plots treated by lablab delayed tasseling period in comparison to the rest of the treatments (Table 4). These results agreed with Wogayehu Worku, (2004) who reported that days to 50% tasseling took longer period for intercropping maize with common bean than sol maize. The plots treated with the legume vetch showed the shortest period to tasseling, but it was statistically at par with the plots treated with lablab and cowpea.

The results of days to tasseling due to termination time found to be insignificant variable trends with increasing dates of termination. Days to tasseling showed some increment from 30 to 45 days after planting and unexpectedly decreased when the legume delayed up to 60 days after planting.

Even if the effects of legumes and termination time were found non- significant on days to maturity. The applications of the legume cowpea resulted in late maturing effect of maize relative to the other plots treated with the legume lablab and vetch (Table 4). The same days to maturity recorded due to the application of the legume lablab and vetch incorporated. Delaying of maturity time of maize plant consistently increased with increased termination time from 30 to 60 days after planting. The results of this finding agreed with Wogayehu Worku, (2004) who stated that days to maturity of maize were prolonged when it was associated with bean.

Termination of the legumes at 60 days after planting delayed the maturity days as compared to the two termination time (30 and 45 days). On the other hand the number of days taken for tasseling and maturing maize plant significantly affected due to legume intercropped up to 60 days old. The days to tasseling were longer in intercropped than sol maize cropping but after incorporated the legumes the days to maturity were short at the plot of legume incorporated plot than the sol maize.

Table 4 Main effects of green manure legumes and termination time of legumes on maize days to tasseling and maturity.

Legumes	Days to Tasseling	Days to maturity
Lablab	71.22	149.67
Vetch	70.33	149.67
Cowpea	71.33	149.89
Mean	70.96	149.74
LSD	NS	NS
CV%	1.42	1.01
Termination time		
30	70.78	149.11
45	71.11	149.33
60	71.00	150.78
Mean	70.96	149.74
LSD	NS	NS
CV%	1.42	1.01
LS*IT	NS	NS
Sol maize	68.667[b]	150.67[a]
Maize in intercropped	70.962[a]	149.74[b]
LSD	0.72	0.60

Means with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

Days to silking

The interaction effect of the legumes species and termination time had a significant ($P<0.05$) effect on days to silking (Table 5). The application of lablab which was incorporated at 60 days after planting had significantly delayed silking period as compared with the rest of the combination. The plots that received the legume vetch incorporated at 60 days after planting had an early silking period relative to the application of the rest of legumes and termination time combination while days to silking showed slightly delayed with increased levels of termination time with the application of lablab and cowpea.

Table 5. Interaction effects of green manure legumes and termination time of legumes used as green manure on maize days to silking.

Legumes	Days to silking			
	Incorporation time in days			
	30	45	60	Mean
Lablab	74.67[b]	74.67[b]	76.33[a]	75.22
Vetch	75.33[b]	75.00[b]	73.67[c]	74.67
Cowpea	74.00[bc]	75.00[b]	75.00[b]	74.85
Mean	74.67	74.89	75.00	
LSD		0.862		
CV%		1.14		
LS*IT		*		
Sol maize		73.333[b]		
Maize in intercropped		74.852[a]		
LSD		0.73		

Means with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

The average mean result of days to silking across each termination time had no remarkable effect however days to silking were delayed (74.67, 74.89 and 75.00 days) with increasing termination time (30, 45 and 60 days after planting), respectively. Similarly the average mean of days to silking across the legumes showed a delayed effect from the legume vetch, cowpea and lablab (74.67, 74.85 and 75.22), respectively. This result in contrast with Adesoji *et al*., (2013) incorporation of green manure significantly reduced the days to 50% silking as compared with sol maize. Generally when maize-legume simultaneously intercropped and terminated after 60 days silking of maize significantly delayed as compared to sol maize cropping.

Plant height, ear height and cob length

Maize grown intercropped with legumes which was cropped simultaneously showed a significant ($P<0.05$) effect on plant height due to planting the legume species between the maize rows, but the terminated time had no significant effect on plant height (Table 6). The results showed that taller maize plant height was recorded on lablab treated plots followed by vetch. This result agreed with Adesoji *et al*., (2013) who stated that incorporation of mucuna and lablab at 6, 9 and 12 weeks after sowing gave significantly taller plants than incorporation of soybean where there was no significant difference among green manure crops on plant height. In the present study, maize grown on cowpea incorporated plots recorded the least plant height. However the species vetch and lablab have more attributable to plant height than the species cowpea which had decreasing trend with increasing termination time.

Even if termination time had non-significant effects, plant height of maize over the increasing termination time of the three legumes (30, 45 and 60) showed that decreasing trend (197.78, 195.56 and 195.33 cm) respectively. This result is in agreement with Diniz *et al*., (2007) who reported that the later green manure incorporation results in reduced plant growth. On the other hand, legume incorporated plots had significantly higher effect on plant height. This study agreed with Adesoji *et al*. (2013) who stated that incorporation of legumes produced significantly taller plants than the control.

The effects of legumes incorporated had a significant ($P<0.05$) effect on ear height, similar to plant height. In contrast, termination time had no significant effect on ear height. The plots treated with vetch (97.11 cm) and cowpea (88.33 cm) produced the tallest and the shortest ear height as compare to the lablab incorporated plots, respectively (Table 6). Even if termination time had non-significant effects unexpectedly the plots that received green manure legumes incorporated at 45 days after planting showed greater effect on ear height relative to the other two termination time. This result in line with Arif *et al*., (2011) who reported that crop residues incorporation increased ear length of maize compared with the residues removed treatment. The legumes incorporation showed variable trends of ear height with the increasing of termination time.

Table 6. Main effect of green manure legumes and termination time of legumes used as green manure on maize Plant height, Ear height and cob length (cm).

Legumes	Plant height (cm)	Ear height (cm)	Cob length (cm)
Lablab	201^{a}	96.44^{a}	19.27
Vetch	197.33^{a}	97.11^{a}	20.44
Cowpea	190.33^{b}	88.33^{b}	20.18
Mean	196.22	93.96	19.96
LSD	5.73	4.53	NS
CV%	2.92	4.82	12.44
Termination time			
30	197.78	93.22	20.84
45	195.56	95.67	19.38
60	195.33	93.00	19.67
Mean	196.22	93.96	19.96
LSD	NS	NS	NS
CV%	2.92	4.82	12.44
LS*IT	NS	NS	NS
Sol maize	185.67^{b}	94.667	19.333
Maize in intercropped	196.22^{a}	93.962	19.964
LSD	2.97	NS	NS

Means across the column and the row with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

Soil incorporation of legume plants as green manure and termination time at 30, 45 and 60 days after planting had no significant effects on cob length of maize plant (Table 6). However the mean indicated that the application of vetch gave the highest cob length. The termination time showed the longest cob length was recorded from the plots where the legumes incorporated at 30 days after planting, while the shortest cob length was from 60 days after planting. Generally the plant height and cob length record higher result when the maize plant affected by the legumes but the unincorporated maize plot indicate the reverse at ear height. However out of the three parameter incorporated of legumes had significant effect on plant height of maize.

Leaf Area and Leaf Area Index

Plant leaf area is important parameter in physiological and agronomic research. It was measured at maturity of the maize plants when it reached for harvesting stage. The analysis of variance showed that leaf area was significantly (P<0.05) affected due to the interaction of legumes incorporated and its stage of growth (Table 7). Delaying termination time from 30 to 60 days after planting consistently decreased the leaf area due to the application of the legumes vetch and lablab. But in the case of cowpea the results showed that variable trend and the leaf area recorded at 60 days after planting greater than the two termination time (Table 7). The highest leaf area was obtained at the combination of cowpea with the termination time of 60 days after planting. The lowest leaf area obtained from the combination of vetch with the termination time of 60 days after planting.

The average maize leaf area for the various combinations of termination time and green manure legumes treatments ranged from 9098 to 10706 cm^2. The highest maize leaf area was recorded at 30 days of green manure legumes termination followed by 60 days after planting. On the other hand, lablab application resulted in the production of the highest average mean leaf area of maize.

Leaf area index was determined as the ratio of leaf area to sampled ground area. The interaction effect of legumes and termination time significantly (P<0.05) affected the leaf area index (Table 7). Delaying termination time of vetch and lablab from 30 to 60 days after planting had decreased leaf area index, while the results were not consistent in case of cowpea. This result is similar with Tamiru Hirpa, (2013) report who observed that an increasing trend of LAI of subsequent maize crop was observed with delayed incorporation of green manure crops. The highest leaf area index was obtained at the combination of cowpea with the termination time of 60 days after planting. The lowest leaf area index obtained from the combination of vetch with the termination time of 60 days after planting.

Table 7 Interaction effects of green manure legumes and its termination time on maize leaf area and leaf area index.

Legumes	Leaf area (cm^2)			
	Incorporation time in days			
	30	45	60	Mean
Lablab	10564.00^{a}	10348.00^{a}	9908.36^{ab}	10273.45
Vetch	10375.00^{a}	9404.66^{b}	9098.52^{bc}	9626.06
Cowpea	9619.21^{b}	9510.46^{b}	10706.00^{a}	9945.22
Mean	10186.07	9754.37	9904.29	
LSD		600.128		
CV%		5.99		
LS*IT		*		

Legumes	Leaf area index			
	Incorporation time in days			
	30	45	60	Mean
Lablab	3.52^{a}	3.45^{a}	3.30^{ab}	3.42
Vetch	3.46^{a}	3.14^{b}	3.03^{bc}	3.21
Cowpea	3.20^{b}	3.17^{b}	3.57^{a}	3.31
Mean	3.39	3.25	3.30	
LSD		0.200		
CV%		5.99		
LS*IT	*			

	Leaf area	Leaf area index
Sol maize	9857.40	3.29
Maize in intercropped	9948.30	3.32
LSD	NS	NS

Means across the column and the row with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

The average mean leaf area index of maize plots treated by the three legumes termination time showed that the highest maize leaf area index recorded by the legumes incorporated at 30 days followed by 60 days after planting. The lowest leaf area index recorded by the legumes incorporated at 45 days after planting which was lower by 0.14% from the legumes incorporated at 30 days after planting. On the other hand the average mean leaf area index of maize due to the application of each legume showed that the legume lablab ranked highest from the legumes vetch and cowpea. Generally both leaf area and leaf area index are not significantly affected by legumes incorporation as compared to sol maize plots, however the higher result recorded when maize plots incorporated with legumes.

Effects of green manure legumes and their termination time on maize yield components.

Number of kernel rows per cob

The results revealed that kernel rows per cob were significantly affected ($p < 0.05$) by green manure legumes and termination time interactions. Interestingly the plots that received lablab terminated at 30 days after planting showed higher kernel row as compared to the other two legume species (Table 8). The production of kernel rows with the incorporation of legumes had no liner relationship along their increasing termination time. In general there appeared to be no clear trends of green manure termination time on maize kernel rows per cob (Table 8).

The mean result of kernel rows per cob of the three termination time produced by the green manure species showed those variable trends. The study of this research indicated that the three legumes have a good effect on kernel rows per cob when they were terminated at 30 days after planting and the species cowpea had the highest kernel rows as compare to the lablab and vetch species. Higher maize kernel rows were recorded at incorporated plot however legumes incorporation plots had no significant number of kernel rows as compared to sol maize plot. The results obtained by Turgut *et al.*, (2005) rows per cob were non-significant between the plots receiving green manuring and without green manuring plots.

Table 8 Interaction effects of green manure legumes and termination time on maize kernel row per cob.

Legumes	Number of kernel row per cob			
	Incorporation time in days			
	30	45	60	Mean
Lablab	12.87[a]	12.07[b]	12.47[a]	12.47
Vetch	12.67[a]	12.73[a]	12.53[a]	12.64
Cowpea	12.80[a]	12.40[a]	12.80[a]	12.67
Mean	12.78	12.40	12.60	
LSD		0.473		
CV%		3.69		
LS*IT		*		
Sol maize		12.600		
Maize in intercropped		12.792		
LSD		NS		

Means with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

Maize stover

The analysis of variance indicated significant ($P<0.05$) interaction effects of green manure legume species and termination time on maize stover weight. The highest stover weight was recorded from the plots treated by lablab on 60 days after planting. According to Tamiru Hirpa, (2013) the biomass production of maize crop increased with delayed incorporation of legume crops at pod-setting stage of growth, as compared to mid-vegetative and mid-flowering stage in legume to maize rotation experiment whereas the lowest stover yield was recorded on the plot that received cowpea incorporated after 45 days planting (Table 9).

Termination time did not showed consistent trends in terms of affecting maize stover yield. However, significantly the highest stover yield was harvested when lablab was terminated at 60 days after planting, followed by cowpea termination at 30 days, while the list was registered when vetch was terminated at 45 days. The average maize stover yield for the combination of termination time and legumes treatments ranged from12.25 to16.96 t ha^{-1}.

Table 9 Interaction effects of green manure legumes and termination time on maize stover weight.

Legumes	Maize stover (t ha^{-1})			
	Incorporation time in days			
	30	45	60	Mean
Lablab	14.15^{b}	12.63^{c}	16.96^{a}	14.58
Vetch	12.81^{bc}	12.30^{c}	13.74^{b}	12.95
Cowpea	14.41^{b}	12.25^{c}	13.07^{bc}	13.24
Mean	13.79	12.39	14.59	
LSD		1.099		
CV%		8.03		
LS*IT		*		
Sol maize		15.41^{a}		
Maize in intercropped		13.59^{b}		
LSD		0.93		

Means with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

On the other hand the average mean stover yield of maize due to the application of each legume showed that the legume lablab ranked highest from the legumes vetch and cowpea and the unincorporated plots yielded significantly higher maize stover than the incorporated maize plots, this result in conformity with the report of Tanimu *et al*. (2007) Stover yield was not significantly affected by legume incorporation as compared to unincorporated maize treatment in the first season. In contrast with, Kouyate *et al*., (2000) reported an increase in cereal stover yields by 49%, when crop residues were incorporated as compared to no residues incorporation treatment. Therefore application of 60 days old legumes using as a green manure has no significant effect on maize stover production.

Maize grain yield, number of kernels per row and 1000 seed weight

Maize grain yield as influenced by legumes and termination time application presented in Table 10. The analysis of variance indicated that significant (P<0.05) grain yield differences due to the application of legumes incorporated at the base of maize plant. The highest maize grain yield was recorded with the application of the legume cowpea as compared to the legume vetch and lablab which were no significant difference on maize yield. Similarly in organic broccoli cultivation under tropical conditions, the incorporation of velvet bean biomass up to 15 days after transplanting reduces organic compost needs from 25 to 12 Mg ha^{-1} as compared to transplanting the legume after 30 and 45 days (Diniz *et al*., 2007). The lowest grain yield recorded by the legumes lablab (6.71 t ha^{-1}) incorporated plots which was lower by 0.083% from the legumes cowpea (7.78 t ha^{-1}) incorporated plots.

Increasing termination time from 30 to 60 days showed that there was no linear and consistent yield increment. This result in contrast with Tamiru Hirpa, (2013) delaying legume termination time to the pod-setting stage of growth, maize grain yield followed legume incorporation have higher yield compared to mid-vegetative stage of incorporation. Maize grain yield for termination time of legumes ranged from 6.57 to 7.61 t ha^{-1} which was found due to the termination time of 45 and 30 days after planting respectively. Similarly maize yields in early incorporated plots were higher than in late incorporated plots of legumes (Waddington, 2003).

In the present study, significant (P<0.05) effect of green manure crop species and termination time was observed in number of kernels per row of cob. The results obtained by Turgut *et al*., (2005) stated that seeds per row were significantly greater in plots that receiving green manuring than those without green manuring. The result of number of kernels as affected by green manures crops incorporated at 30, 45 and 60 days after planting showed those 41.89, 40.35 and 38.84 kernels per row respectively. This result in line with Tamiru Hirpa, (2014) increasing trends of kernels per row observed by decreasing time of the legumes incorporation. The species cowpea incorporated plots recorded the highest but this result was not significantly different from lablab incorporated plots. Significantly higher number of kernels per row of a cob was resulted at sol cropping of maize as compared to maize in intercropped. Generally the species cowpea had higher potential to produce more number of kernels when incorporated to the soil within 30 days after planting (Table 10).

Table 10 Main effects of green manure legumes and termination time on maize grain yield, number of kernels per cob and 1000 seed weight.

Legumes	Maize grain (t ha^{-1})	No of kernels per row	1000 seed weight (gm)
Lablab	6.71[b]	40.07[a]	54.11
Vetch	6.93[b]	38.69[b]	51.78
Cowpea	7.78[a]	41.89[a]	54.44
Mean	7.14	40.22	53.44
LSD	0.75	2.18	NS
CV%	10.47	5.42	7.18
Termination time			
30	7.61[a]	41.33[a]	52.11
45	6.67[b]	40.24[a]	53.44
60	7.13[a]	39.07[b]	54.78
Mean	7.14	40.22	53.44
LSD	0.75	2.18	NS
CV%	10.47	8.03	7.18
LS*IT	NS	NS	NS
Sol maize	7.12	42.60[a]	53.33
Maize in intercropped	7.13	39.79[b]	53.44
LSD	NS	2.25	NS

Means with the same letter are not significantly different at 5% probability level. LS=Legume species IT=incorporation time.

Effects of green manure legume species and termination time with respect to 1000 Seed weight of maize was found to be non-significant effect ($P > 0.05$). Similarly Amole *et al*., (2013) revealed that the weight of 1000 grains of maize in the first year of planting was not significantly influenced by the mixture of maize and lablab under sown after two weeks of planting maize. Even if no significant effects of termination time and the legumes the 1000 Seed weight due to cowpea incorporated recorded the highest weight followed by the legume lablab and vetch treated plots. The result of 1000 seed weight over the termination time indicated that an increasing trend due to the delayed termination time of the legumes. The results of maize grain yield and thousand seed weight showed that higher record when it was intercropped with legumes cowpea. The legumes incorporation had no significant effects on maize grain yield and thousand seed weight as compared to unincorporated plots of maize. The observation corroborates findings by Mureithi *et al*., (2003); Maobe *et al*., (2010) whereby application of 1.0 t dry matter ha^{-1} of mucuna green manure equivalent to 27 kg N ha^{-1} or 30 kg N ha^{-1} had failed to show significant increase in maize yield.

Harvest Index

Dividing grain yield to above-ground dry matter at 0% water content resulted in an average harvest index. The analysis of variance showed that incorporation the legumes but not termination time affected significantly harvest index of maize (Table 11). The highest harvest index was resulted due to the application of cowpea incorporated which showed a significant difference on harvest index as compared to the legume lablab incorporated plot. The plots treated by the legume cowpea incorporated plots recorded 12.66% and 4.69% increment over the legume lablab and vetch treated plots, respectively.

Even if the termination time had no significant effects the mean results of harvest index showed that a linear decreasing trend when the termination time delayed from 30 to 60 days after planting (Table 11). There was 5.59 % difference between the termination time of 30 and 60 days after planting. This result showed that the incorporation of legumes at 30 days after planting had better harvest index than the later termination time. Therefore harvest index of maize more affected by the legumes rather than the termination time of legumes within 60 days in simultaneous cropping system. Significantly higher result in harvest index with incorporated the legumes as compared to unincorporated maize plots. Similarly Karand., (2014) reported higher harvest index of corn with green manuring over without green manuring.

Table 11 Main effects of green manure legumes and termination time on maize harvest index.

Legumes	Harvest index (%)	Termination time	Harvest index (%)
Lablab	46.76[b]	30	55.53
Vetch	54.10[a]	45	54.17
Cowpea	58.79[a]	60	49.95
Mean	53.22	Mean	53.22
LSD	6.73	LSD	NS
CV%	12.66	CV%	12.66
LS*IT		NS	
Sol maize		46.27[b]	
Maize in intercropped		52.759[a]	
LSD		4.15	

Means across the column and the row with the same letter are not significantly different at 5% probability level. LS=Legume species, IT=incorporation time, HI= Harvest index.

Maize stover and grain nitrogen concentration and nitrogen yield affected by legumes and their termination time.

The effects of legume species on maize stover and maize grain nitrogen concentration were non-significant (P > 0.05). The results in agreement with Bith, (2000) who reported green-manure species and time of termination did not influence N-uptake of leek or lettuce. However the mean indicated that the highest N content of stover was recorded due to lablab incorporation whereas the highest grain nitrogen content was observed with cowpea incorporation. Similarly the termination time of the legumes also had no significant (P > 0.05) effect on nitrogen concentration of maize stover and grain (Table 12). To contribute adequate amounts of plant-available N to the main crop in intercropping systems, the incorporated green manures must decompose sufficiently and in synchrony with the N demand of maize. Stover and grain N yield of maize were non-significantly affected by legumes. Mean N yield of maize stover produced by green manure legumes and time of legume incorporation were ranged from 39.47 to 44.92 Kg ha^{-1} and 40.50 to 47.92 Kg ha^{-1} respectively (Table 12).

Table 12 Main effects of green manure legumes and termination time on maize stover and grain nitrogen concentration and nitrogen yield.

Legumes	Maize grain NC (%)	Grain N yield in kg ha^{-1}	Maize stover NC (%)	Stover N yield in kg ha^{-1}
Lablab	1.09	75.87	0.32	44.72
Vetch	1.11	80.60	0.28	39.47
Cowpea	1.14	86.67	0.30	44.92
Mean	1.11	81.05	0.30	43.04
LSD	NS	NS	NS	NS
CV%	28.73	15.57	7.56	32.73
Termination time				
30	1.12	85.55	0.29	40.50
45	1.10	77.19	0.28	40.69
60	1.12	80.40	0.32	47.92
Mean	1.11	81.05	0.30	43.04
LSD	NS	NS	NS	NS
CV%	28.73	15.57	7.56	32.73
LS*IT	NS	NS	NS	NS
Sol maize	1.147	79.193	0.327	45.533
Maize in intercropped	1.114	81.046	0.298	43.036
LSD	NS	NS	NS	NS

Means across the column and the row with the same letter are not significantly different at 5% probability level. LS=Legume species, IT=incorporation time, NC=nitrogen concentration.

Even if no significant effects of termination time the mean results of the legumes along their termination time showed variable trends, for instance the mean maize stover N yield showed an increasing trend with increasing termination time (from 30 to 60 days), but grain N yield showed a decreasing trend (Table 12). Similarly Mohr *et al*., (1999) stated that time of termination did not have a consistent effect on N uptake by the first wheat crop established after alfalfa. Albeit the order of N yields of the stover were **vetch < lablab< cow pea** (39.47, 44.72and 44.92 N Kg ha^{-1}), respectively. The termination time at 60 days after planting had higher N yield as compared to the termination time of 30 days after planting. Generally delaying the termination time of legumes up to 60 days after planting as a green manure had greater potential to improve the N yield of the stover.

There was no significant effect due to legumes and time of termination on nitrogen yields of maize grain (Table 12). Similar observation were made by Tamiru Hirpa, (2013); Bith, (2000) where the variations among green manure species and control treatments were found to be non-significant in total N yield of maize grain. However, N yield of maize grain varies due to intercropped legumes and their termination time effects. The highest maize grain N yield was observed at 30 and followed by 60 days after planting (Table 12). The results as suggested by Witt *et al*., (2000); Sangakkara and Nissanka, (2003) highlight the benefits of early application of legume stover in tropical farming system to obtain higher N yield of maize, since the maize plant would get longer periods for N assimilation for growth and development. In contrast observations were made by Clark *et al*., (2007) whereby increased N yield of maize crop was observed by delaying termination date of various legume and non-legume cover crops, which attributed to higher N supplied by the late termination.

Even if no significant effects of legumes incorporation on maize grain nitrogen yield the legumes incorporated plots had higher as compared to sol plots but the reverse is true in maize stover nitrogen concentration and yield. Generally growing of maize crop in intercropping with the legumes used as a green manure, produce more N in maize grain when the legumes incorporated at early stage than the later stage. The incorporation of 60 days old legumes with simultaneous cropping system is not sufficient to produce nitrogen in maize-legume cropping systems.

Effects of green manure legumes and termination time on soil properties

The use of legumes as green manure and their termination time had no significant effects between all legumes treated plots on soil chemical as well as physical properties (Table 13). This is because of the fact that the amount of biomass and nutrients applied via these legumes in one season would not be expected to substantially affect the soil properties; hence longer time might be required to observe meaningful changes in soil physical and chemical properties. Similar to the present findings, other reports indicated that legume incorporation with double row sowing and time of termination had no effect on soil available nutrient status (Vaiyapuri *et al*., 2007 and Ratilla and Escalada, 2006).

Table 13 Soil physical and chemical properties of the soil as affected by legumes species and termination time of legumes.

parameters	pH	OC (%)	CEC (m.e 100 g^{-1})	N (%)	P (ppm)	K (m.e 100 g^{-1})	Texture
BS	7.02	1.40	14.20	0.07	18.96	0.70	Loam
Effects of green manure legumes application							
Lablab	6.85	1.75	11.87	0.19	21.85	0.76	Loam
Vetch	6.85	1.80	12.51	0.15	20.90	0.76	Loam
Cowpea	6.85	1.79	13.29	0.18	20.37	0.73	Loam
Incorporation time							
30	6.86	1.79	12.64	0.18	21.47	0.77	Loam
45	6.86	1.75	11.58	0.15	21.13	0.75	Loam
60	6.83	1.80	13.44	0.19	20.52	0.72	Loam
CV%	0.91	3.90	30.41	25.11	30.41	7.19	
LSD	NS	NS	NS	NS	NS	NS	
BS	7.02	1.40	14.20	0.07	18.96	0.70	Loam
AH	6.85	1.78	12.56	0.17	21.04	0.75	Loam
LSD	0.019	0.020	NS	0.019	0.65	0.015	

Means across the column and the row with the same letter are not significantly different at 5% probability level. BS=before sowing, AH=after harvest.

The soil pH was relatively reduced as compared to before sowing perhaps the green manure legume may have produced more anions during decomposition. The soil pH reduction to the optimum for crop growth has significant impact on soil total N availability. Even if no significant effects of legumes the highest N content was recorded due to the legume Lablab and terminated at 60 days after planting (0.19%) followed by the legume cowpea and terminated at 30 days after planting (0.18%) respectively. According to Nyambati *et al*., (2009) and Mahala *et al*., (2012) lablab residues are rich in nitrogen, hence total soil N was increased after lablab incorporation.

The average effect of incorporation of green manure legumes at respective time as compared to soil before sowing had significant effect on soil chemical properties except cation exchange capacity (CEC) and soil texture. Accordingly significantly higher soil available phosphorus, potassium, organic carbon and nitrogen were produced due to in situ legume incorporation than soil before sowing (Table 13). This result in agreement with Ehsan *et al*., (2014) who stated that maximum organic matter contents, available phosphorus and potassium are found in green manured plots where sesbania is grown and rotavated in-situ. Furthermore, Vaiyapuri *et al*., (2007) reported early incorporation of marigold with double row intercropped with cotton maintained higher soil available N and P. However, the intercropping of legumes and in situ incorporation at different stage had no significant effect on the cation exchange.

The results showed that legumes could be one of the alternative crops to be used as green manure to improve the important soil chemical properties on long term basis. Moreover, the residual effects of green manure legumes after maize crop harvesting showed improving trends of the selected soil chemical properties. The improvement of the selected soil chemical properties could be due to legumes biomass decomposition and nutrient release to soils as green manure. Those results is in agreement with the work done in different parts of the tropics (Pypers *et al*., 2009; Lee *et al*., 2006) where the application of crop residues and green manure increased available nutrients, organic matter content, and reduced exchangeable acidity.

Apparent N recovery

Nitrogen recovery by maize stover at harvest ranged between -59.44% and -1.24% of the N applied in the legumes residues, while maize grain nitrogen recovery ranged between -5.07 to 19.03 (Table 14). In general, the stover N recovery was found to be negative indicating that there was immobilization of nitrogen from soils. Nevertheless, the degree of nitrogen immobilization by maize stover was varied among applied legume green manure types. Total N recovery of maize ranged from -45.62 with vetch to 17.47 with cowpea. The highest N immobilization occurred when vetch was applied as green manure, followed by lablab. Total (stover + grain) positive N recovery was recorded when cowpea was applied as green manure to maize plots (Tabale 14).

The delayed termination time from 30 to 60 days after planting had increased the effects on N recovery of maize stover. In general the supplemented N from green manure legumes was lower than the demand of the maize when the legume incorporated at all termination time except the legume terminated at 60 days after planting.

Table: 14 Effect of green manure legumes and termination time used as green manure on apparent nitrogen recovery (ANR %).

legumes	Stover (%)	Grain (%)	Total (%)	Soil N (%)
Lablab	-1.24	-5.07	-6.31	63.12
Vetch	-59.44	13.83	-45.62	52.13
Cowpea	-1.56	19.03	17.47	60.87
Incorporation time				
30	-12.05	15.23	3.18	61.21
45	-13.99	-5.78	-19.76	52.63
60	6.18	3.13	9.31	62.50

On the other hand the N recovered by maize grain due to the incorporation of cowpea recorded higher result followed by the legume vetch. The legume lablab incorporation contributed below the demand of maize grain. At 60 days legumes treated plots had positive impact on N recovery of maize grain but less recovery resulted as compared to early incorporated legumes (Table 14). Like N recovery of maize stover, the grain recovered due to the application of legumes showed variable trends with increasing termination time. The supplied N with the legumes terminated at 45 days old was resulted below the demand of the plant to set the seed.

Generally these results suggested that incorporation of green manure legumes alone irrespective species and termination time might not be sufficient to meet N requirements and to achieve the yield potential of maize crop in Hawassa soils unless supplemented with small doses of mineral fertilizers. According to N'Dayegamiye and Tran (2001) recovery rates for green manure derived N was varied from 19-36%, which was lower than many of the fertilizer N recovery rates (25-52%). Lower recovery rates for green manure derived N may have been due to stabilization of N in organic forms rather than loss through leaching, volatilization, and denitrification.

The results revealed that legumes incorporation and termination time effects on soil N recovery were varied from 52.13 to 63.12 % N and 52.63 to 62.50 % N, respectively. Large residual mineral N (100 - 200 kg N ha^{-1}) was reported to remain in soil profiles after harvest of the plant crop in the soybean fallow treatments (Bell, M.J., *et al*., 2006). In the present study the highest soil N was found when vetch was applied followed by cowpea and then lablab incorporation. As termination time of the legumes increases the soil N content showed a variable trend and the highest and the least soil N was recorded at the termination time of 60 and 45 days after planting respectively (Table 14).

Economic Analysis

The results of the partial budget analyses and the data used in the development of marginal rate of return are given in Table 15. The treatments ranked in order of increasing total variable cost (TVC) revealed that sol maize costs less than from other legume treated plots. It is clear that sole maize plot had considerably reduced costs of labor and legume seed compared to others. The highest gross field benefit (GFB) and net benefit (NB) were, however, obtained when the legume cowpea was incorporated (50591.45 and 39888.50 ETB ha^{-1}) respectively. Those results in agreement with the work of Egbe and Ali, (2010) legumes produced comparable net benefits and these were significantly higher than values from 15 kg NPK application and the fallow check. Similarly, the highest gross field benefit (GFB) and net benefit (NB) were obtained at the termination time of 30 days after planting (49457.85 and 38686.31 ETB ha^{-1}) respectively.

Table 15 Partial budgets with dominance and marginal analysis to establish the profitability of maize production as affected by green manure legumes and incorporation time.

Partial budget with dominance				
	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Dominance
		Legumes		
Sole maize	46260.50	8388.27	37872.23	-
Lablab	43521.40	10771.54	32749.86	dominated
Vetch	45016.40	10685.80	34330.60	dominated
Cowpea	50591.45	10702.95	39888.50	Un-dominated
		Incorporation time		
30	49457.85	10771.54	38686.31	Un-dominated
45	43326.40	10685.80	32640.60	dominated
60	46345.00	10702.95	35642.05	dominated

Marginal rate of return (MRR %)					
	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Incremental cost	Incremental benefit	MRR (%)
Sole maize	8388.27	37872.23	-	-	-
Cowpea	10702.95	39888.50	2314.68	2016.27	87
30	10771.54	38686.31	2383.26	814.09	34

ETB = Ethiopian Birr; GFB = Gross field benefit; MRR = Marginal rate of return; NB = Net benefit; TVC = Total variable cost.

The dominance analysis, in this experiment, showed that all legumes and termmination time of legumes except the legume cowpea and termination time of 30 days after planting were those which had more variable costs. But net benefit return was lower than the treatments costing lower than the listed treatments (dominated). The plots treated with the incorporated cowpea and 30 days after planting were the un-dominated treatments compared to other cropping system (Table 15).

The analysis of marginal rate of return (MRR), on the other hand showed the return per unit production cost was highest from cowpea terminated and at a time of 30 days after planting (MRR = 0.87 and 0.34%), respectively (Table 15). SegunOlasanmi and Bamire, (2010) reported that maize cowpea intercropping was found to be profitable than their sole crops. Incorporating the legume cowpea in intercropped maize production expect to recover 1 Birr and obtain an additional 0.87 Birr return for 1 invested Birr during the production time. Similarly the report of Ratilla and Escalada, (2006) reported that incorporating cowpea when intercropped with upland rice rather than mungbean and bushbean was the most suitable green manure crops for the highest net income return. This result showed the legume cowpea and the terminated time at 30 days after planting were the most successful legume stage to minimize production costs compared to the rest of the treatments. Even if the cropping system of growing maize crop following green manure legumes incorporation, the report of Tamiru Hirpa, (2013) showed the reverse result who stated that cowpea and legume termination time at pod-setting were the most efficient in reducing production costs compared to the respective treatments.

SUMMARY AND CONCLUSIONS

A field experiment involving green manuring of lablab, vetch and cowpea to maize was conducted during 2006 growing seasons at Hawassa University Research Station. The simultaneous cropping of maize with green manure legumes was made to evaluate the potential effects of legumes as a green manure to maize crop performance and to the soil characteristics. Treatments applied were a control plot (sol maize), three legume species (lablab, vetch and cowpea) with three time of incorporation (30, 45 and 60 days after planting) were planted in double cropping with maize in randomized complete block design with three replications. For the legumes component, at each incorporation time, legume biomass and nitrogen concentration were significantly affected by cropping system.

For the maize crop, most of the growth and yield parameters, plant height, ear height, grain and stover nitrogen, days to tasseling, days to maturity, 1000 seed weight were non-significantly affected due to both incorporation time and legume species. Across incorporation time no significant effects was observed on harvest index. Maize grain yield and number of kernels were significantly influence by time of legumes incorporation and legumes species. Whereas the interaction effects of legume species by time of their incorporation showed significant influence on number of kernel rows, days to silking, maize stover, leaf area and leaf area index. On the other hand the simultaneous cropping of legumes and incorporated when the legumes at a range of 30 to 60 days old had no significant effects on maize nitrogen concentration, grain yield and thousand seed weight and significantly affect maize stover, number of kernels per row and plant height. Even if non-significant result were observed on some of maize parameters incorporating legumes at 30 days after planting and cowpea incorporation contribute to the highest plant height, 1000 seed weight, number of kernel rows, kernels per cob, maize grain NC and yield this were contribute to the total maize grain yield.

The effects of intercropping and in situ incorporation of green manure had significant effects on all selected chemical properties except cation exchange capacity (CEC) and texture of soil as compared to soil before sowing (Table 13). Recovery of N by maize crop in simultaneous maize based cropping system in the ranges of 30 to 60 days old legumes were the highest recovery recorded due to cowpea incorporation (17.47%) as compared to the legume lablab (-6.31%) and vetch (-45.63%) (Table 14). The incorporation of vetch and lablab at specified time was below the demand of maize crop. With respect to time of incorporation, the highest effect on maize recovery was at 60 days after planting (9.31 %), followed by 30 days after planting (3.18 %).

The residual effects of the legume lablab on soil nitrogen content (63.12 %) was the highest relative to the legume cowpea (60.87 %) and vetch (52.13 %) (Table 14). This result showed that the incorporation of legumes within 60 days of growing period is not sufficient time for fast nutrient availability to transfer significant nitrogen to simultaneously cropped maize crop. It can be concluded that cowpea can attribute well when used as a green manure in cropping systems involving maize production. In the areas where the supply of N-fertilizers is limited (as in most developing countries), the use of cowpea as a green manure may provide an alternative source of N and thereby reduce the dependency on costly commercial N-fertilizers.

The partial budget and the data used in the development of marginal rate of return indicated that net benefit of maize produced ranged from 32749.86 Birr ha^{-1} with the legume lablab to 39888.50 Birr ha^{-1} with the legume cowpea incorporation (Table 15). Whereas the highest result recorded at the time of 30 days after planting and the lower result obtained due to the time of 45 days after planting. Based on the dominancy analysis the legume cowpea and 30 days after planting were included in marginal rate of analysis and those treatments had the potential to add 0.87 and 0.34 birr return per 1 birr invested respectively. This means the association of maize in intercropping with legume cowpea and incorporation time of 30 days after planting was better than planting maize with the combination of vetch and lablab with the three time of incorporation but it was no enough benefit.

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LIST OF TABLES IN APPENDIX

Appendix Table 1 Fifteen years (2000-2014) average and the year 2014 weather data at Hawassa.

	Fifteen year average			2014 data		
Month	Min.temp (^oc)	Max.temp (^oc)	Rain fall (mm)	Min.temp (^oc)	Max.temp (^oc)	Rain fall (mm)
Jan	11.8	29.1	25.0	12.2	29.9	23.4
Feb	12.1	30.3	21.5	13.5	29.6	26.3
Mar	13.3	30.1	78.1	13.4	29.6	91.5
Apr	14.4	28.6	110.8	13.1	28.7	104.5
May	14.5	27.4	133.0	14.1	27.1	198.7
Jun	14.5	26.0	97.9	14.0	26.7	98.4
Jul	14.7	24.9	123.2	15.3	25.2	104.6
Aug	14.7	25.0	134.1	14.9	25.2	206.4
Sep	14.1	25.6	122.6	14.7	25.3	164.0
Oct	12.9	27.2	54.7	14.2	26.3	105.3
Nov	11.2	28.3	36.4	12.3	27.4	19.1
Dec	10.7	28.1	24.0	10.7	27.5	5.8

Appendix Table 2 Mean square of maize legume nitrogen (LN), stover nitrogen (SN) and grain nitrogen (GN) yield.

Mean Square				
Source of Variance	DF	LN (%)	SN (%)	GN (%)
Replication	2	0.610ns	0.016ns	0.014ns
Incorporation time	2	2.766*	0.001ns	0.004ns
Legume Species	2	0.499ns	0.005ns	0.003ns
IT*LS	4	0.805*	0.015ns	0.008ns
Error	16	0.264	0.007	0.007

Incorporation time= IT, Legume species=LS, Legume nitrogen = LN, Stover nitrogen = SN and Grain nitrogen = GN * and NS significant and non significant at 5 % probability level, respectively.

Appendix Table 3 Mean square of maize grain weight (GW), harvest index (HI), legume biomass (LB) and stover weight (SW) of maize.

Mean Square					
Source of Variance	DF	GW (t ha^{-1})	HI (%)	LB (t ha^{-1})	SW (t ha^{-1})
Replication	2	0.11ns	81.90ns	0.08ns	3.08ns
Incorporation time	2	2.00*	76.14ns	0.33*	11.13*
Legume Species	2	2.96*	331.12*	6.95*	6.78*
LT*LS	4	0.30ns	52.36ns	0.06ns	4.25*
Error	16	8.92	45.38	0.03	1.19

Incorporation time= IT and Legume species=LS, * and ns significant and non significant at 5 % probability level, respectively.

Appendix Table 4 Mean square of number of kernel row per cob (NKRPC), number of kernels per row (NKPR), 1000 seed weight (SSW) and cob length (CL) of maize.

Mean Square					
Source of Variance	DF	NKRPC	NKPR	SSW (gm)	CL (cm)
Replication	2	0.0415ns	2.246ns	41.333ns	34.424*
Incorporation time	2	0.077ns	11.566ns	16.000ns	5.4326ns
Legume Species	2	0.597*	23.1882*	19.000ns	3.4326ns
LT*LS	4	0.9304*	9.535ns	5.167ns	8.28815ns
Error	16	0.2198	4.751	14.708	6.16704

Incorporation time= IT and Legume species=LS, * and ns significant and non significant at 5 % probability level, respectively.

Appendix Table 5 Mean square of leaf area (LA), leaf area index (LAI), plant height (PH) and ear height (EH) of maize.

Mean Square					
Source of Variance	DF	LA (cm^2)	LAI	PH (cm)	EH (cm)
Replication	2	1816629.18*	0.20*	70.11ns	88.93*
Incorporation time	2	432790.02ns	0.05ns	16.44ns	19.70ns
Legume Species	2	943060.99ns	0.11ns	264.33*	214.93*
LT*LS	4	1272791.16*	0.14*	14.61ns	34.93ns
Error	16	354476.46	0.04	32.90	20.51

Incorporation time= IT and Legume species=LS, * and ns significant and non significant at 5 % probability level, respectively.

Appendix Table 6 Mean square of number of days to tasseling (DYT), days to silking (DYS) and days to maturity (DYM) of maize plant.

Mean Square				
Source of Variance	DF	DYT	DYS	DYM
Replication	2	0.925926ns	1.814815ns	0.25926ns
Incorporation time	2	0.259259ns	0.259259ns	7.37037ns
Legume Species	2	2.703704ns	0.925926ns	0.14815ns
LT*LS	4	1.759259ns	2.925926*	1.20370ns
Error	16	1.009259	0.731482	2.30093

Incorporation time= IT and Legume species=LS, * and ns significant and non significant at 5 % probability level, respectively.

Appendix Table 7 Mean square of legume nitrogen (LN), stover nitrogen (SN), maize grain nitrogen (GN) and residual soil nitrogen yield (RSN).

Mean Square					
Source of Variance	DF	LN	SN	GN	RSN
Replication	2	32.81ns	225.05ns	130.59ns	55170.37ns
Incorporation time	2	113.72ns	160.92ns	159.80ns	1570903.70ns
Legume Species	2	6894.43*	85.78ns	263.56ns	1849659.26ns
LT*LS	4	305.68*	218.02ns	259.34ns	769481.48ns
Error	16	84.52	198.35	159.25	750970.37

Incorporation time= IT and Legume species=LS, * and ns significant and non significant at 5 % probability level, respectively.

Appendix Table 8 Mean square of pH, cation exchange capacity (CEC), organic carbon (OC), nitrogen (N) and potassium (K) of residual soil.

Mean Square							
Source of Variance	DF	pH	CEC	OC	N	P	K
Replication	2	0.0124ns	202.54*	0.035*	0.00014ns	36.003	0.01978*
Incorporation time	2	0.0025ns	7.89ns	0.006ns	0.00464ns	2.047	0.00618ns
Legume Species	2	0.0002ns	4.56ns	0.007ns	0.00438ns	5.116	0.00263ns
LT*LS	4	0.0053ns	21.28ns	0.002ns	0.00184ns	3.881	0.00003ns
Error	16	0.00388	14.58	0.005	0.00188	10.904	0.00289

Incorporation time=IT and Legume species=LS, * and ns significant and non significant at 5 % probability level, respectively.