EFFECT OF BLENDED NPS FERTILIZER AND COMPOST ON GROWTH AND YIELD OF QUALITY PROTEIN MAIZE (*Zea mays* L.) AT JIMMA, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

BY

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MSc THESIS APPROVAL SHEET

We, the undersigned, member of the Board of Examiners of the final open defense by **Sisay Gurmu Begna** have read and evaluated his/her thesis entitled **"Effect of Blended NPS Fertilizer and Compost on Growth and Yield of Quality Protein Maize (Zea mays L.) at Jimma, Southwestern Ethiopia"** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Agronomy.**

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DEDICATION

This Thesis is dedicated to my father Ato Gurmu Begna and my mother W/ro Aregash Shibiru for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First I declare that this thesis is my work and that all sources of the materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHOCAL SKITCH

The author, Sisay Gurmu was born on January 19, 1990 at the vicinity of Adaba town, West Arsi zone, Oromia regional state. He attended his education at Uruba Wal-qixe from 1996-1998 and Cofira Shashe Primary school from 1999-2003 and Asassa Secondary and Preparatory School from 2004 to 2007. After successfully passing the Ethiopian School Leaving Certificate Examination, he joined Haramaya University in 2008 academic year and graduated with B.Sc. degree in Agriculture (Plant science) in July 2010.Then, after his graduation the author was employed by Becho woreda Agriculture and Rural development Bureau, Illu Aba Bor zone, Oromia regional state, and worked being agronomist between September 2010 and March 2013. Then he joined Ethiopian Institute of Agricultural Research in Jimma Agricultural Research Center since April 2013 in which he joined Jimma University College of Agriculture and Veterinary Medicine, School of Graduate Studies on October 2016 to pursue his M.Sc. Degree in Agronomy.

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ACRONYMS AND ABBREVATIONS

ADD	Agricultural Development Department
BHQPY	Bako Hybrid Quality Protein Yellow
CSA	Central Statistical Agency
EthioSIS	Ethiopian Soil Information System
FYM	Farm Yard Manure
IITA	International Institute of Tropical Agriculture
INM	Integrated Nutrient Management
JARC	Jimma Agricultural Research Center
LAI	Leaf Area Index
NFIU	National Fertilizer Input Unit
OC	Organic Carbon
OM	Organic matter
QPM	Quality Protein Maize
RDF	Recommended Dose of Fertilizer
RFR	Recommended Fertilizer rate
SNNP	Southern Nation Nationalities and Peoples
SSA	Sub Saharan Africa

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EFFECT OF BLENDED NPS FERTILIZER AND COMPOST ON GROWTH AND YIELD OF QUALITY PROTEIN MAIZE (*Zea mays* L.) AT JIMMA, SOUTHWESTERN ETHIOPIA

ABSTRACT

Maize (Zea maize L.) is among the leading cereals in production globally and an important potential food security crop in Ethiopia. However, its productivity is very low mainly due to low soil fertility. Studies on the combined use of organic and inorganic fertilizers for maize are lacking at Jimma conditions. Therefore, a field experiment was conducted to determine the effect of combined application of NPS fertilizer and compost on yield and yield components of maize on Nitisols of Jimma Zone, Southwestern Ethiopia during 2017 main cropping season. The experiment involved factorial combinations of five rates of NPS fertilizer (0, 45.5 kg ha^{-1} blended NPS+31.2 kg ha^{-1} urea, 91 kg ha^{-1} blended NPS+62.4 kg ha^{-1} urea, 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea, 182 kg ha^{-1} blended NPS+124.8 kg ha^{-1} urea) and five rates of compost based on N-equivalence of recommended fertilizer rate (0, 2.3, 4.6, 6.9 and 9.2 ton ha^{-1}) laid out in 5x5 factorial arrangements in RCB design with three replications. The N fertilizer equivalence value of applied compost at the rates of 2.3, 4.6, 6.9 and 9.2 ton ha^{-1} were 23, 46, 69 and 92 kg N ha^{-1} on dry weight basis, respectively. Data on the growth, yield and yield components of maize and some selected soil physico-chemical properties and nutrient uptake of crop were subjected to ANOVA using SAS version 9.3software. The results revealed that combined application of NPS fertilizer and compost significantly ($P<0.05$) affected days to 50% tasseling, 50% silking, days to 90% maturity, leaf area index, number of leaves per plant, stem girth, plant height, number of grains per row, grain yield and above ground biomass. However, number of ears per plant, ear length, number of grains per ear, ear diameter, thousand grain weight and harvest index were not affected by combined application of NPS fertilizer and compost. The highest grain yield (8453.2 kg ha^{-1}) and above ground biomass (15387.2 kg ha^{-1}) was obtained from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea and 9.2 ton ha^{-1} compost. Whereas, the lowest grain yield (2612.7 kg ha^{-1}) and above ground biomass (5139.9 kg ha^{-1}) was obtained from the control .Grain yield was increased by 223.54% over control and 24.1% over recommended NPS fertilizer. Partial budget analysis revealed combined application of 136.5 kg ha^{-1} blended NPS fertilizer +93.6 kg ha^{-1} urea with 6.9 ton ha^{-1} realized the maximum net return (40,925.46 birr ha^{-1}) with marginal rate of return (1228.6%). The NPS fertilizer and compost rates affected nutrient uptake and most of the soil properties evaluated and there were changes in total N, available P and soil bulk density (compost rates only) after harvest. Nonetheless, this one season and location study has to be reconfirmed in different seasons and over locations in order to make sound recommendation.

Keywords: Grain yield, inorganic fertilizer, organic fertilizer, recommended fertilizer rate, soil health.

1. INTRODUCTION

Globally, maize (*Zea mays* L.) is among the leading cereals in production along with rice and wheat. In Africa, Ethiopia is the third largest maize producer next to Nigeria and Egypt (FAOSTAT, 2016). Maize ranks second after teff in area coverage and first in total production in Ethiopia (CSA, 2017). In 2016/17 the maize crop area and grain production in Ethiopia was 2,135,572 ha and 7, 8471,175 ton, respectively with productivity of 3675 kg ha^{-1} (CSA, 2017). Normal maize grain has greater nutritional value as it contains 72% carbohydrate, 8.8% protein, 2.15% fiber and 2.33% ash (Shah *et al*., 2015). It is a good source of carbohydrates, fat, protein and some important vitamins (B6, A and E) and minerals (magnesium, potassium and phosphorus), but deficient in essential amino acids viz., lysine and tryptophan that reduces its biological value (Mbuya *et al*., 2011). The amount of these deficient amino acids has been increased by incorporating *opaque*-2 gene in quality protein maize (QPM) (Bisht *et al*., 2012). It produces 70-100% more of lysine and tryptophan than the most modern varieties of tropical maize (Vivek *et al*., 2008).

The dissemination and adoption of QPM is lagging behind normal maize in Sub-Saharan Africa where it is needed (Aman *et al*., 2016). Twumasi-Afriyie *et al*. (2016) reported that an estimated area of one million ha of land in Sub Saharan Africa (SSA) was under QPM production in 2015. Research on QPM is of recent history in Ethiopia. The work was started by testing introduced CIMMYT (International Maize and Wheat Improvement Center) QPM pools and populations in 1980 (Leta *et al*., 2001**)**. In Ethiopia BHQPY545 variety productivity was 8.0-9.5 ton ha^{-1} on research center and 5.5-6.5 ton ha^{-1} on the farmers field (Adefris *et al*., 2015). From experimental variety trials conducted at some locations in Ethiopia, for instance, some QPM entries yielded 9.5 ton ha^{-1}, which is an advantage of 20% over the best local check (Gemechu *et al*., 2016).

Declining soil fertility and management of plant nutrients aggravate the challenge of agriculture to meet the world increasing demand for food in a sustainable way. Insufficient application of nutrients and poor soil management, along with harsh climatic conditions and other factors, have contributed to the degradation of soils including soil fertility depletion in developing countries, especially in SSA (Goulding *et al*., 2008). Poor soil fertility is one of the principal factors that limit maize productivity in maize growing areas of Ethiopia (Abebayehu *et al*., 2011). Degradation of soil physico-chemical properties, soil acidity with high P sorption and soil nutrient depletion due to low chemical fertilizer use by most small-holder farmers who cannot afford the expensive fertilizers leads to declining in maize production in SSA (Vanlauwe *et al*., 2010).

Among plant nutrients nitrogen is a vitally important, a major yield determining nutrient and its availability in sufficient quantity throughout the growing season is essential for optimum maize growth (Kogbe and Adediran, 2003). It is a component of protein, nucleic acids and other compounds essential for plant growth process (Onasanya *et al.*, 2009). Whereas phosphorus is the second most important nutrient element (after nitrogen) limiting agricultural production (Kogbe and Adediran, 2003). It is used for growth, utilization of sugar and starch, photosynthesis, metabolic process which leads to higher yield of the crop (Ayub *et al*., 2002).

In Ethiopia, initial results of demonstration of blended fertilizers that include N, P, K, S, Zn, B conducted across 25,000 smallholder farms indicate that yield increases between 15-85% can be achieved and DAP is being gradually substituted by NPS starting from 2013/14 to meet the sulfur demand of most Ethiopian soils (EthioSIS, 2013). Sulfur deficiencies are occurring with greater frequency in more locations throughout Ethiopia. It is used in plants for the synthesis of the amino acids, cysteine and methionnine, various enzymes and coenzymes, and it is an integral component of membranes, lipids and chlorophyll proteins (Scherer, 2001).

Compost is one of the organic fertilizers and it is an alternative source of plant nutrients (Vanlauwe *et al.*, 2012; Ngwira *et al.*, 2013). Application of compost improves soil fertility parameters, such as alleviates acidification, benefits better microbial activity, soil aeration, increase soil organic matter, increases CEC, P availability and sustainable increase in crop yields (Diacono and Montemurro, 2010). Use of compost and sometimes in combination with inorganic fertilizers gave maximum grain yields of QPM (Balai *et al.* 2011). The highest grain yield (7179 kg ha^{-1}) of QPM hybrid was obtained from application of 10 ton ha^{-1} FYM + 100% RDF (150:75:37.5 kg ha^{-1} $N:P_2O_5:K$) (Ravi *et al.*, 2012).

The use of chemical fertilizer is essential for obtaining high yields in the weathered soils and can overcome the shortcomings of organic fertilizers. However, many small holders and resource-poor farmers cannot afford costly fertilizers to apply the recommended amount (Kotschi, 2013). Organic fertilizers have long lasting effect for soil health and farmers can prepare from the available materials though it is pertinent to study the effects of integrated use of inorganic and organic fertilizers for maize production. The inorganic fertilizers do not replace trace mineral elements in the soil, which become gradually depleted by crops removal and cannot maintain desirable soil physical properties such as water holding capacity and conducive conditions for microbial activity (Kumar and Sreenivasulu, 2004).

To ensure soil productivity, plants must have an adequate and balanced supply of nutrients that can be realized through integrated nutrient management where both natural and man-made sources of plant nutrients are used (Gruhn *et al.*, 2000). Various long-term research results have shown that neither organic nor mineral fertilizers alone can achieve sustainability in crop production (Tadesse *et al*., 2013). Rather, integrated use of organic and mineral fertilizers has become more effect in maintaining higher productivity and stability through correction of deficiencies of primary and secondary macronutrients and micronutrients (Aulakh *et al*., 2010). Therefore, judicious use of integrated nutrient management is an alternative to supply nutrient to crop needs and improve soil conditions (Naresh *et al*., 2013) thereby increasing crop productivity in an efficient and environmentally save without sacrificing soil productivity of future generations.

Currently, the lack of balanced and integrated application of nutrients reduced the yield potential of QPM and other maize varieties in most maize producing areas of Ethiopia. The productivity of maize is low as a result of continuous cropping, inadequate use of fertilizer inputs, very low or lack of the use of organic manure neither alone nor in combinations with mineral fertilizers. Since, the use of inorganic fertilizer in maize production is costly and its effect is short term, there is another option to use organic fertilizer in integrated form. For this, site specific testing of integrated nutrient management (INM) is becoming critical and sorting out of optimum nutrients for maize production that benefit farmers to get better nutrition and economic advantage, and sustain soil health. Therefore, site specific NPS fertilizer and compost investigation based on growth, yield and yield related parameters of QPM variety under agro-climatic conditions of Jimma, Southwestern Ethiopia is needed. Even though the cultivar was under production, the cultivar performance under the use of NPS fertilizer and compost has not been tested.

Hence, for better dissemination and adoption of QPM hybrid there is a need to understand its performance with various agronomic management practices, of which nutrient management is vital in influencing the growth and yield of the crop. Therefore, this study was initiated with the following objectives.

- To determine the optimum rate of NPS fertilizer and compost on growth and yield of QPM variety at Jimma area.

- To determine optimum and most economical combination of NPS fertilizer and compost for QPM production at Jimma area.

2. LITERATURE REVIEW

2.1 Constraints to Maize Production in Sub Saharan Africa

Low soil fertility is the primary constraint to maize productivity in Sub-Saharan Africa, accounting for an estimated 122 kilograms per hectare loss or 7% of the total smallholder yield gap (Gibbon *et al*., 2007). Inherently infertile soils, lack of agricultural inputs and over-exploitation of soils through mono-cropping with little nutrient inputs are the major factors to the decline in agricultural productivity (Kanonge *et al.,* 2009). The most limiting nutrients in such soils are phosphorus and nitrogen (Nhamo *et al*., 2003).

An array of diseases plagues in maize growing areas in Sub-Saharan Africa includes downy mildew, rust, leaf blight, stalk and ear rots, leaf spot, and maize streak virus. Insect pests, including stem and ear borers, fall army worms, cutworms, grain moths, beetles, weevils, grain borers, rootworms, and white grubs are also a great threat to the survival of maize in Africa. This adversely affects the lives of about 300 million people (IITA, 2009). The parasitic weed, known as witch-weed (*Striga*), is a major pest in sub-Saharan Africa and causes an estimated cereal grain loss of up to US$7 billion. In the Nigerian savanna, for example, weed-related yield losses ranges from 65 to 92% have been recorded (IITA, 2009). Management constraints, including late planting and row spacing also accounts for an additional yield loss.

Others factors which are often sporadic and localized in their occurrence are shade, ultra-violent exposure, photo-inhibition, air pollution, wind, hail, and gaseous deficiency (Shafiq-ur-Rehman *et al*., 2005). Generally, crops attain only about 25% of their potential yield, and most crop plants suffer a yield loss of up to 50% as a result of the limiting effects of these stress factors (Bray *et al*., 2000) which are location-specific, exhibiting variation in frequency, intensity, and duration. Drought and salinity are common in a few regions, posing a major catastrophe of salinization of over 50% of agricultural lands by 2050 (Wang *et al*., 2003).

2.2 Rationale of Fertilizer Use and Recommendations in Ethiopia

In Ethiopia commercial fertilizer mainly in the form of urea and DAP was introduced in the 1960s by higher learning institutions through limited laboratory and research activities (Murphy, 1968). This was followed in the early 1970s by nationwide on-farm demonstrations trials and as a result of these works a blanket rate of 100 kg ha^{-1} (18-46 kg ha^{-1} N- P_2O_5) or 50 kg ha^{-1} Urea + 100 kg ha^{-1} DAP (41-46 N-P_2O_5) were recommended irrespective of crop and soil types (NFIU,1992).

Research continued from mid 1970s onwards and recommendations specific to some soil types and crops were made. However, fertilizer trials carried out between 1975 and 1990 were conducted on few research stations, and little effort was made to extrapolate the results to wider range of environments. The only exception was NFIU/ADD (National Fertilizer Input Unit and Agricultural Development Department of the Ministry of Agriculture) fertilizer trials which were conducted over wider geographical areas with presumption that N and P in that order are the only plant nutrients that limit crop growth (ADD/NFIU, 1992).

Recommendation by NFIU were made for different crops based on soil colors, soil types by region and showed profitability of fertilizer use in different crop and soil situation. It also suggested application of more N than P, *i.e.* 1:1 Urea and DAP application. Nevertheless, the NFIU trials were agronomic in nature and the soil test data gathered were of very limited value with regard to the development of soil test-crop yield response curves. As a result, translation of the yield data from multi location field trials into site specific rate of fertilizer recommendations was a problem. Since 1995, blanket fertilizer recommendation, 100 kg urea ha^{-1}(46-0-0) and 100 kg DAP ha^{-1} (18-46-0) was reinstated as sole fertilizer recommendation in the country despite criticisms.

The mean fertilizer consumption in Ethiopia has risen from 132,522 metric ton (1995/96) to 858,825 metric ton (2014/15) period (CSA, 2015). Even though the amount of fertilizer imported increases every year, Ethiopian farmers still lag far behind other developing countries in fertilizer use. The average intensity of fertilizer use in the country (which is roughly less than 40 kg ha^{-1}) remains much lower than elsewhere (e.g., 54 kg ha^{-1} in Latin America, 80 kg ha^{-1} in South Asia, and 87 kg ha^{-1} in Southeast Asia). Subsequently, growth in fertilizer investment has not resulted in commensurate increases in yield and profitability as both are much lower than what is required to achieve food security and increased incomes.

Nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on the other hand have favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie *et al*., 2011). The national soil inventory data also revealed that in addition to nitrogen and phosphorus, sulfur, boron and zinc deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium, copper, manganese and iron (EthioSIS, 2013), which all potentially hold back crop productivity despite continued use of N and P fertilizer as per the blanket recommendation. Such deficient nutrients can often be included relatively cheaply in new fertilizer formula; when targeted to deficient soils, these nutrients can dramatically improve fertilizer-use efficiency and crop profitability. In Ethiopia DAP is being gradually substituted by NPS starting from 2013/14 to meet the sulfur demand of most of Ethiopian soils (EthioSIS, 2013).

The use of mineral fertilizers without recycling of organic materials resulted in higher yields, but this increase was not sustainable without the inclusion of organic soil amendments (Bationo *et al*., 1993). This indicates that the use of organic soil inputs in any form (FYM, conventional compost and vermin-compost) is very important. However, our small-scale farmers lack the information on the rate, quality, and of course alternate sources of these fertilizers.

To replenish the soil nutrient depletion, application of chemical fertilizers is essential. However, high cost of chemical fertilizers coupled with the low affordability of small holder farmers is the biggest obstacle for chemical fertilizer use. On the other hand, sole application of organic matter is constrained by access to sufficient organic inputs, low nutrient content, high labor demand for preparation and transporting. In this regard, integrated uses of inorganic and organic inputs are better than application of either inorganic or organic input alone for maize production (Wakene *et al*., 2001). Tolessa (1999a) indicated that application of FYM every three years at the rate of 16 ton ha^{-1} supplemented by N and P fertilizer annually at the rate of 20-46 kg N-P_2O_5 ha^{-1} was recommended for sustainable maize production around Bako area. The integrated use of 5 ton ha^{-1} of compost either with 55/10 or 25/11 kg of N/P ha^{-1} is economical for maize production in BakoTibe district. In another study conducted at Hawassa, Southern Ethiopia, the integrated use of coffee residue along with N fertilizer positively influenced soil moisture, soil nitrogen and organic matter, grain and water use efficiency of maize (Tenaw, 2006).

2.3 Major Nutrients Affecting Growth and Yield in Crop Production

2.3.1 Nitrogen

Nitrogen is a vitally important plant nutrient, the supply of which can be controlled by man (Adediran and Banjoko, 1995; Shanti *et al*., 1997). In maize production, it is a major yield-determining factor and its availability in sufficient quantity throughout the growing season is essential for optimum maize growth (Kogbe and Adediran, 2003).

In the soil, N found in decomposing organic matter may be converted into ammonium N ($NH4^+$) by soil microorganisms (bacteria and fungi) through mineralization (Pidwirny, 2002). Nitrogen in the form of NH_4^+ can then be adsorbed onto the surfaces of clay particles in the soil. The NH_4^+ ion that has a positive charge may be held by soil colloids because they have a negative charge. This process is called micelle fixation (Pidwirny, 2002). As this fixation is reversible, NH_4^+ may be released from the colloids by way of cation exchange.

In plant nutrition, nitrogen is involved in the composition of all amino acids, proteins and many enzymes. Nitrogen is also part of the puric and pyrimidic bases, and therefore is a constituent of nucleic acids (Mills and Jones, 1996). In addition to its role in the formation of proteins, nitrogen is an integral part of chlorophyll, which is the primary absorber of light energy needed for photosynthesis. An adequate supply of N is associated with vigorous vegetative growth and a dark green colour and an imbalance of N or an excess of this nutrient in relation to other nutrients, such as P, K, and S can prolong the growing period and delay crop maturity (Marti and Mills, 1991).

The supply of N is related to carbohydrate utilization. When N supply is insufficient, carbohydrates will be deposited in vegetative cells, which will cause them to thicken (Marti and Mills, 1991; Mills and Jones, 1996). When N supplies are adequate, and conditions are favorable for growth, proteins are formed from the manufactured carbohydrates, less carbohydrate is thus deposited in the vegetative cells and more protein is formed, and because protoplasm is highly hydrated, a more succulent plant results.

When plants are deficient in N, they become stunted and yellow in appearance. This yellowing, or chlorosis, usually appears first on the lower leaves; the upper leaves remaining green. In cases of severe N shortage, the leaves will turn brown and die (Mills and Jones, 1996).

2.3.2 Phosphorous

Phosphorus (P) is the most important nutrient element (after nitrogen) limiting agricultural production in most regions of the world (Holford, 1997; Kogbe and Adediran, 2003). It is a structural component of DNA and RNA, the two genetic entities that are essential for the growth and reproduction of living organisms. It also helps in assimilation of photosynthates into other metabolites and hence acts as an activity zone for CO2 assimilation. It is important for seed and fruit formation and crop maturation. Phosphorus helps in rapid growth of plant thus counteracting the effect of excess nitrogen application to the soil. Moreover, as an integral part of chromosomes, it stimulates cell division and is necessary for meristematic growth. Thus, adequate supply of phosphorus helps in rapid growth of plant. Living organisms whether plants or humans, also derive their internal energy from P-containing compounds, mainly adenosine diphosphate (ADP) and adenosine triphosphate (ATP). This means that inadequate P supply will result in a decreased synthesis of RNA, the protein maker, leading to depressed growth (Hue, 1995). It is known to be involved in several physiological and biochemical processes of plants being components of membranes, chloroplasts and mitochondria (Sanchez, 2007).

Plants extract P exclusively from the soil solution in either $H_2PO_4^{-1}$ or HPO_4^{-2} forms. It is estimated that as much as 90 % of added fertilizer phosphorus is fixed in these soils (Potash and Phosphate Institute, 2003). Generally, phosphorus in all its natural forms, including organic forms is very stable or insoluble and only a small proportion exists in the soil solution at any one time (Holford, 1997).

Phosphorus-deficient plants, therefore, are stunted with a limited root system and thin stems. In many plants, seedlings look stunted and older leaves may turn purple because of the accumulation of anthocyanins or purple pigments. The plants may produce only one small ear containing fewer, smaller kernels than usual. Grain yield is often severely reduced (Jones *et al*., 2003).

2.3.3 Sulfur

Sulfur is an essential element classified as a major element which is a component of some proteins and is a component of glucosides that are the source for the characteristic odors of some plants. Sulfur exists in the plant and soil solution as the sulfate anion (SO_4^{2-}). Sulfur is one of the essential nutrients for plant growth and an indispensable element for crop production and it is an integral part of proteins, sulpholipids, and enzymes (Das and Misra, 1991). Besides, it is involved in various metabolic and enzymatic processes including photosynthesis and respiration (Rao *et al*., 2001)

Sulfur is involved in the conformations and activities of many enzymes and stimulates seed production. It used in plants for the synthesis of the amino acids, cysteine and methionnine, various enzymes and coenzymes, and it is an integral component of membranes, lipids and chlorophyll proteins (Scherer, 2001). One of the most important S-containing proteins is ferredoxin, which is involved in CO_2 assimilation, glucose synthesis, glutamate synthesis, N_2 fixation, and NO_3 reduction.

2.4 Role of Organic Manures on Growth and Yield of Crop

Organic fertilizers increase the quality and yield of agricultural crops in ways similar to inorganic fertilizers (Bulluck *et al*., 2002); however, it does not cause high environmental pollution. Some of the important advantages of organic fertilizers include improved soil texture, water retention and resistance to erosion. Organic fertilizers provide nitrogen in a usable form, which will help plant to improve plant growth while at the same time neither cause burning of roots nor destroying beneficial micro-organisms in the soil. Organic fertilizers help to prevent diseases by meeting the plants 'nutritional needs and enhancing plant tolerance. Plant wastes such as wood ash, spent grain, rice bran, and sawdust were effective as fertilizers (Ogbalu, 1999). Plants can only use nutrients that are in an inorganic form. Manure N and P are present in organic and inorganic forms, and are not totally available to plants. The organic forms must be mineralized or converted into inorganic forms over time before they can be used by plants. Many studies have demonstrated that application of manure will produce crop yields equivalent or superior to those obtained with chemical fertilizers (Xie and MacKenzie, 1986). Crop quality has also been improved by manure application (Pimpini *et al*., 1992).

Manure improves the physical condition of the soil and increases P and biological activity (Chang *et al*., 1990). The organic matter, total N and micronutrient content of the surface soil are increased as a result of manure application. Manure, when applied, will be mineralized gradually and nutrients become available. However, the nutrient content of manure varies, and the reason is that the fertilizer value of manure is greatly affected by diet, amount of bedding, storage and application method (Harris *et al*., 2001). Cross and Strauss (1985) quoted for municipal wastes, 0.4-3.6 % N, 0.3- 3.5 % P_2O_5, and 0.5-1.8 % K_2O. Leonard (1986) quoted 1.1 % N, 1.1 % P_2O_5 and 0.5 % K_2O for poultry manure at 70 % moisture content.

Compost is also a slow-release fertilizer. Compared with fresh manure, its N is in a more stable form and not susceptible to loss as NH_3 gas (Leonard, 1986). The nutrient value of compost varies a lot and depends on what it is made from. Aside from N, P and K, it supplies varying amounts of secondary nutrients and micronutrients. In the preparation of compost it is desirable to mix materials for composting in the proportions that give rapid, effective and complete decomposition to a stable product (Harris *et al*., 2001). Compost that has been made from a variety of materials is likely to provide the best spectrum of nutrients.

2.5 Effect of Inorganic and Organic Fertilizers on Growth and Yield of Maize

2.5.1 Grain yield

Maize grain yield can be described as a function of the rate and duration of dry matter accumulation by the individual kernels multiplied by the number of kernels per plant (Westgate *et al*., 1997). In simple terms, maize grain yield is a product of the number of ears produced and the average weight of the grain on the ears. Thus anything that affects one or both of these factors will significantly affect the final yield. According to Hashemi *et al*. (2005), grain yield per unit area is the product of grain yield per plant and number of plants per unit area.

Use of organic manures alongside inorganic fertilizers often lead to increased SOM, soil structure, water holding capacity and improved nutrient cycling and helps to maintain soil nutrient status, CEC and soil biological activity (Saha *et al.,* 2008) which leads to increase the crop yield. Although chemical fertilizers are important input to get higher crop productivity, but over reliance on chemical fertilizers is associated with declines in some soil properties and crop yields over time and causes serious land problems, such as soil degradation (Hepperly *et al.,* 2009). Therefore, an integrated use of inorganic fertilizers with organic manures is a sustainable approach for efficient nutrient usage which enhances efficiency of the chemical fertilizers while reducing nutrient losses (Schoebitz and Vidal, 2016).

Synergistic effects of organic manures with inorganic fertilizers accumulate more total N in soil (Huang *et al.,* 2007), but sole application of FYM increased yield of maize (Anatoliy and Thelen, 2007), higher SOM content (44%), improved soil porosity (25%) and 16 times more water holding capacity (Gangwar *et al.,* 2006). The use of both organic and inorganic fertilizer has been reported to increase yield and sustain soil productivity (Chukwu *et al*, 2012).

Combined application of organic and inorganic fertilizers is considered a good option to enhance nutrient recovery, plant growth and ultimate yield otherwise higher N and P application rates are required to attain better yield in maize (Mubeen *et al*., 2013). Integrated use of chemical fertilizer with poultry manure (NPK150-85-50 + 7.0 ton ha^{-1}) resulted in maximum grain yield and biological yield (Mahmood *et al*., 2017). Further, these results are also in concurrence with Negassa *et al.* (2001) who found that corn yield was increased by 35% when combined (inorganic and organic) nutrients were applied. The highest grain yield and biological yield of maize were found in integrated fertilizers management treatments (50% urea and 50% vermin-compost) (Baharvand *et al*., 2014).Maize crop yield and quality obtained when adequate rates of organic soil amendment are incorporated into the soil (Motavalli *et al*, 1994).

The tendency to supply all nutrients through chemical fertilizers has to be avoided as this has deleterious effect on soil productivity. Studies carried out in southwest Nigeria (Ojeniyi and Adeniyan, 1999) have recommended combinations of farmyard manure and NPK fertilizer for sole and inter cropped maize. Verma (1991) on a clay soil found that increasing the rate of farmyard manure from 5.0 to 10.0 ton ha^{-1} and fertilizer application from 50 to 100% recommended dose of N, P and K increased the grain yield of maize. Nanjappa *et al*. (2001) reported that combined application of 50 or 75% recommended dose of fertilizer with 12 ton FYM ha^{-1} or 2.7 ton vermicompost ha^{-1} caused higher productivity of maize compared with the application of either only inorganic fertilizer or organic sources. The application of sulfur had positive effect on maize yield attributes and these are mainly responsible for higher yield (Kumar *et al*., 2017).

2.5.2 Number of cobs per plant

Number of cobs per plant is determined by prolific ability of the maize variety (Adefris *et al*., 2015) and the growth behavior of the crop which is dependent upon management practices, edaphic and climatic factors. In a study by Verma *et al.* (2003) reported that 1.63 cobs $plant^{-1}$ was produced with fertilizer dose of N120 P60 K40 which is significantly more, compared to N90 P45 K30 and N60 P30 K20 (1.25). Mehta *et al.* (2005) concluded that 60 kg P_2O_5 ha^{-1}

when applied to maize crop resulted more number of cobs plant^{-1} compared to 40 kg P_2O_5 ha^{-1} and control. Singh and Nepalia (2009) also observed that application of 125% recommended dose of fertilizer (RDF) in QPM hybrid significantly improved the number of cobs plant^{-1} (1.17) over 100% RDF and 75% RDF respectively. Significantly higher number of cobs ha^{-1} (68,900) resulted with 120 kg N ha^{-1} followed by 60 kg N ha^{-1} (67,100) and control (64,900) in maize trial by Jat *et al*. (2010).

Malaiya *et al*. (2004) reported N fertilizer treatments with FYM produced higher cobs per plant and the minimum number of cobs per plant was observed with sole FYM application. In normal maize, significantly more number of cobs plant^{-1} resulted with 150% RDF which is at par with number of cobs plant^{-1} with RDF + 10 ton FYM, followed by other treatments as reported by Tetarwal *et al*. (2011). Phosphorus 40 kg ha^{-1} produced higher number of cobs plant^{-1} followed by number of cobs plant^{-1} fertilized with 30 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1} as observed by Choudhary *et al*. (2012).

2.5.3 Leaf area index and crop growth

Leaf area index of a crop is the one-sided area of green leaf tissue per unit area of land occupied by that crop (Watson, 1997). That is the area of leaf per area of land. It is a key plant growth parameter that is frequently measured and estimated from leaf shape characteristics (Stewart & Dwyer, 1999). Leaf area index and distribution of leaf area within a maize canopy are major factors determining total light interception, which affects photosynthesis, transpiration, and dry matter accumulation. It can be estimated and used in crop growth models to calculate photosynthesis, assimilate partitioning, gas and energy exchange (Fortin *et al*., 1994). During the early vegetative stage of growth, leaf area determines total light interception. Thus, conditions favoring maximum area per leaf should optimize Co_2 fixation during that period (Morrison *et al*., 1992). It is important to note that only 50% of incident solar radiation can be used as photo synthetically active radiation (PAR). The remaining energy is of no value in photosynthesis and if absorbed, serves only to increase the temperature of the leaf (Monteith, 1981).

Integrated use of chemical fertilizer with poultry manure (NPK150-85-50 + 7.0 ton ha-1) resulted in maximum LAI (Mahmood *et al*., 2017). The highest leaf area index of maize was found in integrated fertilizers management treatments (50% urea and 50% vermicompost) (Baharvand *et al*., 2014). Kumar *et al*. (2005) reported that growth and yield of maize plants in terms of leaf area index varied significantly due to various fertility levels. Having maximum leaf area index, application of 100% NPK with 10 ton FYM ha^{-1} was superior over remaining fertility levels.

2.5.4 Days to tasseling and silking

In maize (*Zea mays L*.) tassel initiation is the first visible sign that a plant has shifted from the vegetative to the reproductive stage of development (Russell and Stuber, 1984). Contrarily, some authors reported that, it is incorrect to say that reproductive development begins with the initiation of the tassel because the early initials of ears are visible as buds at the axils of the lower leaves before the tassel is differentiated. Approximately 30 days after planting, when the stem is only 2 cm long and the plant just knee-height, the tassel is initiated. At this stage, the growing point is switched only partly from producing leaves to producing the terminal reproductive structure, the tassel.

Maize crop accumulates more heat units (thermal time) to tasseling, silking and physiological maturity with increasing the rate of N and vice versa (Amanullah *et al.,* 2009). Increase in N rate might have increased the rate of photosynthesis in the plant (Oikeh *et al.*, 1997) that resulted in the leaf durability and delayed some phenological characteristics in the crop (Gungula *et al*., 2003). Sufficient nitrogen results in rapid growth and hastened tasseling, while too little or no N, resulted in slow growth and delayed tasseling (Cock and Ellis, 1992). Application of blended fertilizer significantly decreased days to silking as compared to control and similarly, recommended NP fertilizers also significantly decreased days to silking as compared to control (Dagne, 2016).

2.5.5 Plant height

Plant height is a genetic trait. Thus, the number and length of the internodes determine the height of the stalk. In this way, plant height can vary from 0.3 m to 7.0 m, depending on the variety and growing conditions (Gyenes-Hegyi *et al*., 2002). Usually, early maturing varieties are shorter and late maturing ones are taller. In a tropical climate where the growing season may be as long as 11 months, some late maturing varieties can reach a height of 7 m (Koester *et al*., 1993). Yokozawa and Hara (1995) cited that the height of the final plant and the diameter of its stalk are strongly influenced by environmental conditions during stem elongation.

Kumar *et al*. (2005) reported that growth and yield of maize plants in terms of plant height varied significantly due to various fertility levels. Having tallest plants application of 100% NPK with 10 t FYM ha^{-1} was superior over remaining fertility levels. The plant height was found to be highest under combined application of poultry manure, FYM and RDF which are statistically on par but comparatively higher than 100% RDF (Wailare and Kesarwani, 2017).

2.5.6 Harvest index

Harvest index is the physiological efficiency and ability of a crop for converting the total dry matter into economic yield. It is the ratio of economic yield to biological yield and is a character of the movement of dry matter to economic part of the plant. It determines how many photosynthesizes are transformed into economic yield (Shah *et al*., 2009) which mostly depends on genetic traits of the cultivar and environmental conditions, such as photoperiod, air temperature, solar radiation, water supply and mineral nutrients (Belanger *et al*., 2001).

In an experiment by Kumar and Puri (2001) the maximum harvest index of 37.11% and 37.54% was recorded with 90 kg N ha^{-1} in 1996 and 1997 compared to 45 kg N ha^{-1} (35.82% and 35.81%) and control (33.33% and 34.63%). Also Kumar and Thakur (2004) showed that the highest harvest index of 47.9% was obtained with combined application of 50% RF + 10 t FYM. In other study the maximum HI of 42.4% and 42.6% resulted with the application of 120 kg ha^{-1} compared to 60 kg N (41.8% and 41.9%) and control (40.6% and 40.6%) in 2006 and 2007 respectively (Jat *et al.,* 2010). Application of enriched FYM + 150% RDF resulted in significantly the highest harvest index of 35.64% compared to the other treatments in HQPM-1 hybrid as noticed by Singh *et al.* (2011).

2.6 Effect of Inorganic and Organic Fertilizers on Soil Nutrient Status

Different results reported that integrated use of inorganic and organic practices significantly improved macro and micronutrient status of soils in maize production. Balanced application of NPK fertilizers with FYM or agricultural wastes improved the soil fertility status in addition to increase in maize yield (Ogundare *et al*., 2012). Using cattle manure as the only means to maintain soil fertility is possible, but in that case very large quantity of manure is needed. Moreover, the use efficiency of chemical fertilizer applied alone is low in physically and chemically degraded soils (Bationo *et al*., 2007).Organic resources have been found to enhance the soil organic matter status and the functions it supports while mineral resources are targeted for supplying key limiting nutrients. Vanlauwe *et al.,* (2002) stated that organic matter is a substantial reservoir for phosphorus and sulfur as well as nitrogen. According to Palm *et al.* (1997) and Hussein (2009), organic inputs influence nutrient availability by the total nutrients added through controlling the net mineralization-immobilization patterns.

Schnurer *et al*. (1985) stated that manure added to soil with N-fertilizer lead to residue decomposition rates that were two times greater than when no amendments were added. The long-term P availability is expected to be larger in combined treatments than in sole inorganic fertilizers due to microbial turnover, though the lack of crucial information on these factors will continue to lead to inefficient combinations and low productivity (Vanlauwe *et al.,* 2002).

Organic resources play a dominant role in soil fertility management in the tropics through their short-term effects on nutrient supply and longer-term contribution to soil organic matter formation (Palm *et al.,* 2001).The optimal rate of combining the organic and the inorganic fertilizers as well as the optimal rate of application needs to be investigated (Ipimoroti *et al.,* 2002 and Vanlauwe *et al.* 2002). Soil CEC and pH are the most commonly measured soil chemical properties and are the more informative. Soil pH has a profound influence on plant growth. It affects the quantity, activity and types of microorganisms in soils that in turn influence decomposition of manures and other organics (Bationo *et al.*, 2007).

Application of compost at 5 ton ha^{-1} along with inorganic fertilizers (50 kg urea ha^{-1} + 100 kg DAP ha^{-1}) improved physico-chemical properties of the soil on sustainable basis rather than using inorganic fertilizer alone (Fanuel and Gifole, 2012). Similarly, twenty years of experimental study showed that application of 50% N through FYM and 50% NPK through inorganic fertilizers improved soil fertility status (Sathish *et al*., 2011). The soil analysis after maize crop harvest revealed that soil organic matter, total N, extractable P and K, were greatest from plots receiving organic sources with 50% of recommended NPK fertilizer (60:45:30 N:P_2O_5:K_2O), suggesting integrating organic sources with 50% of recommended NPK fertilizer are appropriate for sustainable crop production on a low fertility soil (Ahmad *et al*., 2013).Other study indicated that the application of recommended dose of inorganic fertilizer along with vermicompost at 6 ton ha^{-1} to maize not only enhanced productivity of maize but also improved soil fertility in terms of higher available N, P, K and organic carbon content over the control and recommended N, P and K (Kannan *et al*., 2013).

2.7 Effect of Inorganic and Organic Fertilizers on Nutrient Uptake of Maize

Improved application and targeting of inorganic and organic fertilizer not only conserves nutrients in the soil, but makes nutrient uptake more efficient. Combined application of both inorganic and organic inputs can increase nutrient use efficiency (Nyiraneza *et al*., 2009). Study in Islamabad showed that substitution of 25 or 50% N with FYM + 4 kg Zn ha^{-1} performed better nutrient uptake than 100% N (120 kg ha^{-1}) from chemical fertilizer alone. The highest N uptake (98.7 kg ha^{-1}) was observed with 50% chemical fertilizer + 50% FYM and 8 kg Zn ha^{-1} application, while maximum Zn uptake (250.7 g/ha) was observed with 75% chemical fertilizer + 25 % FYM and 4 kg Zn ha^{-1} application (Sarwar *et. al*., 2012).

Combined application of NPK mineral fertilizer and poultry manure has significantly higher NPK uptake values of maize than the sole organic and inorganic fertilizers. Integrated applications of 60 kg ha^{-1} N as poultry manure and mineral fertilizer at 60-40-40 kg ha^{-1} NPK resulted in higher NPK uptake values than either organic or inorganic fertilizers alone (Quansah, 2010). The P recovery efficiency and NP uptake by maize following the application of poultry manure with inorganic P source showed higher values than those recorded by applying inorganic P sources alone indicating that integrated use of poultry manure with chemical P sources can save 30 to 40 kg mineral P fertilizer (Zafar *et al*., 2011). Integration of poultry waste and di-calcium phosphate in 2:1 P ratio significantly increased total P-uptake and P fertilizer use efficiency of maize by 30 to 66% over single supper phosphate alone. It was also observed that integrated use of nutrients increased P-fertilizer use efficiency from 2.8 to 59.7% over chemical fertilizer alone (Manzar-ul-Alam *et al*., 2005).

2.8 Effect of Inorganic and Organic Fertilizers on Economics

Studies on economic aspects have indicated high potential of compost and inorganic fertilizers to give higher returns in comparison to conventional farmers' practices. Combined application of both inorganic and organic inputs can reduce costs and increase profitability (Nyiraneza *et al*., 2009). Adiel (2004) reported value cost return of 3.3 for manure plus mineral fertilizers, 3.2 for sole mineral fertilizers and 2.4 for farmers' practice of no inputs. Similarly, Mutiro and Murwira (2004) reported positive returns from use of cattle manure in maize production, whereby net benefits for no inputs (i.e. control) was \$20.9 ha^{-1} while manure plus 40 kg N gave \$326.0 ha^{-1} net benefit. Bisht *et al*. (2012) found the crop receiving 125% RDF exhibited significantly more net returns (42,952 ha^{-1}) while output/input ratio with 100% RDF was significantly higher (2.95) in QPM hybrid.

A report by Jeet *et al.* (2012) on two years pooled data showed that 150 kg N ha-1 gave remarkably higher net monetary returns 48,720.39 ha^{-1} and B: C ratio 2.63 followed by 100 and 50 kg N ha^{-1}and lowest net returns 17317.86 ha^{-1} and B:C ratio 1.61 was observed with control. Singh *et al*. (2012) also revealed that the higher net returns (19,912) and B: C ratio (1.32) was obtained with combined application of 150:60:30 kg NPK ha^{-1} + 5 ton vermicompost ha^{-1} + bio-fertilizers which are significantly higher than other treatments. Sur *et al*. (1997) found that the yield targeting treatments with FYM gave 22% higher net returns than those without it.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted at Jimma zone, Kofe kebele near Jimma Agricultural Research center. The site was located at $7^0$66' 28" N latitude and $36^0$79' 45" E longitudes and at an altitude of 1728 meters above sea level. It was situated in the tepid to cool humid-mid highlands of southwestern Ethiopia. The soil type of the experimental area was Eutric Nitisols (reddish brown). The long-term (ten years) mean annual rainfall of the study area was 1714.0 mm with a maximum and minimum temperature of 26.32^0c and 12.34^0c respectively (JARC, 2017). The experiment was conducted during 2017 G.C. main cropping season from June to November.

3.2 Soil Physico-chemical Properties and Compost

The soil of the experimental field was characterized for selected physico-chemical properties before the application of the treatments (Table 1). The soil of the experimental area was found to have sand content (69%), clay content (26%) and silt content (5%) at depth of soil 0-20 cm. The soil texture of the experimental area is sandy clay loam. The soil texture controls water contents, water intake rates, aeration, root penetration and soil fertility. The average soil pH of the trial site was 5.03, which was strongly acidic (Batjes, 1995) and ideal for the production of most field crops. It affects maize growth by suppressing the root development and reducing availability of macronutrients to plants especially phosphorus (Brady and Weil, 2008). The soil total N (0.13%) and OC (3.18%) was found medium for crop growth and development. For soil to be productive, it needs to have OC content in the range of 1.8-3.0 % to achieve a good soil structural condition and structural stability (Charman and Roper, 2007). The Bray II extractable available P was 4.42 mg kg^{-1}, which is below the critical level (8 mg kg^{-1}) for most crop plants (Tekalign and Haque, 1991). This could be attributed to the uptake or utilization by crops because of continuous cultivation, low input and generally poor management practices. Also, Marschner (1995) stated in most cases, soils with pH values less than 5.5 are deficient in P. The soil bulk density (BD) of the experimental site was 1.20 (g cm^{-3}) which is ideal for crop root penetration and aeration in sandy clay loam soils (Tekalign, 1991). Hunt and Gilkes (1992) found for optimum movement of air and water through the soil, it is desirable to have soil with a low BD (<1.5 g cm^{-3}).

The chemical compositions of the compost utilized as organic source of soil fertility amendment in this study are presented in Table 1. Accordingly, the mean OC and total N contents of the compost was 6.88% and 1.00% respectively, with a resultant narrow C:N ratio of 6.88. It indicates the prepared compost was well decomposed to the level of average soil organic matter. The C:N ratio of about 30 is considered N neutral, lower ratios will release N and act as N fertilizers and higher ratios will immobilize N as microbial breakdown of the carbon component. The C:N ratio of compost should drop below 20% before application to the soil (Brady and Weil, 2002) to have expected impact from application of compost. The pH of compost (8.43) was moderately alkaline and it is capable of ameliorating the acidic content of the soil (Onwudiwe *et al*., 2014). Most finished composts will have pH values in the range of 5.5 to 8.5 (Canadian Compost Guidelines, 1996).

Table 1 Selected physico-chemical properties of the soil of the experimental site and compost before planting at Jimma in 2017

Characters	Values		Rating		Reference
	Soil	Compost	Soil	Compost	
pH	5.03	8.43	Strongly acidic	Moderately alkaline	Batjes (1995)
OC (%)	3.18	6.88	Medium	High	Tekalign (1991)
TN (%)	0.13	1.00	Medium	High	Berhanu (1980)
Av. P (mg kg^{-1})	4.42	11142.43	Low	High	Tekalign and Haque (1991)
CEC(cmol(+) kg^{-1} of soil)	15.71	24.40	Medium	Medium	Landon (1991)
C:N ratio	24.46	6.88	Medium	low	Brady and Weil, 2002
BD (g cm^{-3})	1.20	-	Medium	-	Tekalign (1991)
Soil texture					
Sand (%)	69	-	-	-	
Clay (%)	26	-	-	-	FAO(1990)
Silt (%)	5	-	-	-	
Texture Class	Sandy clay loam				

Where pH= hydrogen power, OC=organic carbon, TN=Total Nitrogen, Av. P=Available phosphorous, CEC=Cation exchange capacity and BD=Bulk density. Values are the means of duplicate samples.

3.3 Treatments and Experimental Design

The experiment has conducted with five NPS fertilizer rates (0, 45.5 kg ha^{-1} blended NPS+31.2 kg ha^{-1} urea, 91 kg ha^{-1} blended NPS+62.4 kg ha^{-1} urea, 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea, 182 kg ha^{-1} blended NPS+124.8 kg ha^{-1} urea) and five compost rates based on N-equivalence of recommended fertilizer rate (0, 2.3 ton ha^{-1}, 4.6 ton ha^{-1}, 6.9 ton ha^{-1} and 9.2 ton ha^{-1}) the details in table 2. The NPS blended fertilizer (19N–38P_2O_5-0K-7S grade) rates was set based on N and P_2O_5 recommendation for maize on Nitisols of Jimma area (92 kg ha^{-1} N and 69 kg ha^{-1} P_2O_5) (Wakene *et al*., 2011). The remaining nitrogen calculated and applied as urea at 30 days after emergence for each treatment. The N fertilizer equivalence value of applied compost at the rates of 2.3, 4.6, 6.9 and 9.2 ton ha^{-1} were 23, 46, 69 and 92 kg N ha^{-1} respectively. The compost rates were calculated on dry weight basis and applied to the respective experimental plots. It incorporated into the soil and thoroughly mixed in the upper 15 to 20 cm soil depth at time of planting using human power.

Medium maturing maize variety BHQPY545 was used for the study. It was released by Bako Agricultural Research Centre through the National Maize Research Program in 2008. It performs well in agro-ecology of 1000-2000 m.a.s.l with rainfall of 1000-1200 mm. It can give 8.0-9.5 and 5.5-6.5 t ha^{-1} grain yields under on-station and on-farm experiments, respectively. It was moderately tolerant to rust, blight and gray leaf spot with maturity date of 138 and 25 kg ha^{-1}seed rate. The seed of BHQPY 545 maize variety was obtained from Jimma Agricultural Research Center for the experiment. The treatments were arranged in Randomized Complete Block Design (RCBD) in 5 x 5 in factorial arrangements with three replications. The total treatment was 25 and there were 75 total observations in this experiment (Table 3). The net plot size of 4.5m width x 3.6 m length (16.2 m^2) and the total experimental area 33m x 58.8 m (1940.4m^2) was used.

Table 2 NPS fertilizer and compost treatment application

NPS rate %	Elemental N/P_20_5/S kg ha^{-1}	Commercial product NPS kg ha^{-1}	1st round N kg ha^{-1} in blended NPS	Urea kg ha^{-1} at 30DAE	Blended NPS gm $plant^{-1}$ at planting	2nd round Urea gm $plant^{-1}$ at 30 DAE	% Compost rate	Compost ton ha^{-1} (DB)	Compost kg $plot^{-1}$ (DB)
0	0/0/0	0.0	0.0	0.0	0.00	0.00	0	0.0	0.00
25	23/17.25/3.2	45.5	18.8	31.2	1.02	0.70	25	2.3	3.73
50	46/34.5/6.4	91	37.6	62.4	2.05	1.40	50	4.6	7.45
75	69/51.75/9.6	136.5	56.4	93.6	3.07	2.11	75	6.9	11.18
100	92/69/12.8	182	75.2	124.8	4.10	2.81	100	9.2	14.90

*DAE= Days after emergency; DB=Dry base; Compost applied based N equivalence at recommended rate (92 kg ha^{-1} N) at which 100gm dry compost gave 1gm N based on laboratory analysis

Table 3 Details of treatment combination

No.	NPS (%) x Compost (%)	Treatment description
1	Control	Control
2	0%x25%	2.3 t ha^{-1} Compost
3	0%x50%	4.6 t ha^{-1} Compost
4	0%x75%	6.9 t ha^{-1} Compost
5	0%x100%	9.2 t ha^{-1} Compost
6	25%x0%	45.5 kg ha^{-1} blended NPS+31.2 kg ha^{-1} Urea
7	25%x25%	45.5 kg ha^{-1} blended NPS +31.2 kg ha^{-1} Urea +2.3 t ha^{-1} Compost
8	25%x50%	45.5 kg ha^{-1} blended NPS +31.2 kg ha^{-1} Urea +4.6 t ha^{-1} Compost
9	25%x75%	45.5 kg ha^{-1} blended NPS +31.2 kg ha^{-1} Urea +6.9 t ha^{-1} Compost
10	25%x100%	45.5 kg ha^{-1} blended NPS +31.2 kg ha^{-1} Urea +9.2 t ha^{-1} Compost
11	50%x0%	91 kg ha^{-1} blended NPS+ 62.4kg ha^{-1} Urea
12	50%x25%	91 kg ha^{-1} blended NPS+ 62.4kg ha^{-1} Urea +2.3 t ha^{-1} Compost
13	50%x50%	91 kg ha^{-1} blended NPS+ 62.4kg ha^{-1} Urea +4.6 t ha^{-1} Compost
14	50%x75%	91 kg ha^{-1} blended NPS+ 62.4kg ha^{-1} Urea +6.9 t ha^{-1} Compost
15	50%x100%	91 kg ha^{-1} blended NPS+ 62.4kg ha^{-1} Urea +9.2 t ha^{-1} Compost
16	75%x0%	136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} Urea
17	75%x25%	136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} Urea +2.3 t ha^{-1} Compost
18	75%x50%	136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} Urea +4.6 t ha^{-1} Compost
19	75%x75%	136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} Urea +6.9 t ha^{-1} Compost
20	75%x100%	136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} Urea +9.2 t ha^{-1} Compost
21	100%x0%	182 kg ha^{-1} blended NPS +124.8 kg ha^{-1} Urea
22	100%x25%	182 kg ha^{-1} blended NPS +124.8 kg ha^{-1} Urea +2.3 t ha^{-1} Compost
23	100%x50%	182 kg ha^{-1} blended NPS +124.8 kg ha^{-1} Urea +4.6 t ha^{-1} Compost
24	100%x75%	182 kg ha^{-1} blended NPS +124.8 kg ha^{-1} Urea +6.9 t ha^{-1} Compost
25	100%x100%	182 kg ha^{-1} blended NPS +124.8 kg ha^{-1} Urea +9.2 t ha^{-1} Compost

3.4 Experimental Procedures and Crop Management

The field was prepared by plowing three times. Maize was hand planted on the 29^{th} of May 2017 on a plot size of 3.60mx4.50m =16.2m^2. Two seeds were placed per hill to ensure the desired stand in each treatment and thinned to one plant with plant population of 44,444 plants ha^{-1}. Thinning was done at 3-4 leaves stage. The outermost rows at both sides of plots were considered as borders. The path between plot and block was 1 m and 1.5 m, respectively and the planting space was 75cm x 30cm between rows and plant, respectively. In accordance with specifications of the design, each treatment was assigned randomly to experimental units within a block**.** All data were determined in the center rows of each plot. Blended fertilizer NPS was applied at spot for each plant at the time of planting. The remaining nitrogen calculated and applied in split at 30 days after emergence for each treatment. The N content of compost was determined before application to determine the application rate of compost for each treatment, which was based on recommended N equivalent rate for the test crop. The moisture content was calculated from the fresh compost after oven dried at 105^{o}C until constant weight attained to determine the different rates of compost applied for each treatment on dry weight basis.

Harvesting and threshing were done by hand. The fall army warm (FAW) pest was controlled through both manual collections of the insects and by chemical application (Diazinone 1 liter ha^{-1}) during cropping season. The chemical was applied 2 times before the crop starts tasseling at two weeks interval. Then after, all the remaining necessary agronomic practices and crop management activities were undertaken as recommended and in line with the practices followed by the Jimma Agricultural Research Center.

3.5 Compost Preparation and Laboratory Analysis

Compost was prepared from decomposable materials of soybean residue, maize straw, cow dung, desmodium biomass, ashes and top soil at Jimma Agricultural Research Center. The compost was prepared by pit method starting from January to March, 2017. Turning over of composted material from one hole to another was done 2 times at monthly interval and kept for 3 months until compost matured. After two times turning, the compost was well decomposed and ready as suggested by Solomon (2006). A fine texture, dark color, no continuous decomposition, odorless (a rich earthy odor), well cured and also a low (<20) C:N ratio after laboratory analysis was the indices that indicate the maturity of compost prepared. Then well decomposed compost was heaped under shade and covered to allow anaerobic decomposition. Nine (9) samples were collected from about 30cm depth from the sides and top of the compost and thoroughly mixed.

The compost samples were air dried and ground to pass through 2 mm sieve and analyzed for total N, available P, pH, OC and CEC. Organic carbon was analyzed by Walkley and Black method (Jackson,1973), while N content by wet digestion procedure of Kjedahl method (Bremner,1996), available P using Olsen method (Jackson,1973), CEC by ethanol 95% extraction method and pH using 1:2.5 ratio water suspension method at Jimma Agricultural Research Center Soil and Plant Tissue Analysis Laboratory.

3.6 Soil and Plant Tissue Analysis

For site characterization, the representative composite soil samples were collected in a zigzag method from various gradients using auger (0-20 cm depth) from the entire field and subjected to physical and chemical analysis before planting and from each plot after harvesting to examine the residual effect of treatments on selected soil chemical properties. The soil samples were air dried and ground to pass through 2 mm sieve and analyzed for total N, available P, pH, OC, CEC and physical properties. All samples were analyzed following standard laboratory procedures as outlined by (Sahlemedhin and Taye, 2000). The content of available P extracted by Bray II method was determined using spectrophotometer following the procedure described by Murphy (1968). Organic carbon was analyzed using digestion method as described by Walkley and Black method (Jackson,1973), total N contents of the soil was determined following the wet digestion procedure of Kjeldahl method (Bremner, 1996) and CEC by 95% ethanol extraction method. The PH of the soils was measured using 1:2.5 ratio water suspension method. Soil textures (% sand, % silt and % clay) were analyzed using hydrometer method (Gee and Bauder, 1986). Bulk density in the field at 0-20 cm depth was determined by the core sampler method described by Blake and Hartge (1986). The core was driven to the desired depth of 0-20 cm and the soil sample was carefully removed to preserve the known soil volume as existed *in situ*. A cylindrical metal sampler of 5 cm height and 2.5 cm diameter was used to sample undisturbed soil. It was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105 ^{0}C until constant weight attained and calculated by dividing weight of oven dried soil (g) to volume of the core sampler (cm^3) (Black, 1965).

Composite samples of stalk and grain were collected at harvesting per plot for analysis of N and P. The above ground parts of maize were cut at ground level at harvest stage. Six maize stands were taken in each central plot randomly for both stalk and grain nutrient content. The collected plant samples were washed by distilled water and subjected to air drying. The air dried plant tissues were ground into 0.25 mm size and analyzed for total nitrogen and available P. Nitrogen was determined by the modified Kjeldahl method (Van Reeuwijk, 1992), whereas the P content was measured using spectrophotometer after its extraction by the wet digestion method (Olsen and Dean, 1965). The soil and plant tissue analysis were carried out at Jimma Agricultural Research Center Soil and Plant Tissue Analysis Laboratory.

3.7. Data Collected

3.7.1 Phenological and growth parameters

3.7.1.1 Days to 50% tasseling: The number of days counted from planting time to 50% tassel production in each plot.

3.7.1.2 Days to 50% silking: The number of days counted from planting time to 50% silk production in each plot.

3.7.1.3 Days to 90% physiological maturity: The number of days counted from planting time to when 90% of plants formed black layer at the base of the kernel.

3.7.1.4 Number of leaves per plant: total number of green leaves per plant at tasseling was counted from six randomly selected plants and their averages were taken as the number of leaves per plant.

3.7.1.5 Leaf area index: it was calculated as the ratio of total leaf area per area of land (cm^2) occupied by the plant (Sestak *et al*., 1971) from six randomly selected plants.

3.7.1.6 Stem diameter (girth): it was measured at 50cm from the ground level on six randomly selected plants using caliper.

3.7.1.7 Plant height (cm): it was measured at ground level to terminal stem using measuring stick at the point where the tassel starts branching from six randomly selected plants.

3.7.2 Data on yield and yield components

3.7.2.1 Number of ear per plant: it was obtained by counting total number of ears in each plot and divided to total number of plant stand harvested.

3.7.2.2 Ear length (cm): it was measured for six randomly selected ears from the base to the tip of the ear at harvesting.

3.7.2.3 Number of grain rows per ear: six ears were selected randomly from each plot and grain rows per ear of each ear were counted and averaged at harvesting.

3.7.2.4 Number of grains per row-six ears were collected randomly from each plot and number of grains per row in each ear were counted and averaged at harvesting.

3.7.2.5 Number of grains per ear: were obtained by multiplying number of grain rows per ear and number of grains per row from six randomly selected ears in each plot.

3.7.2.6 Ear diameter (cm): was measured for six randomly selected plants at approximately the middle of the ear at harvesting.

3.7.2.7 Thousand Seed weight (g): ears were selected randomly from six plants and thousand seed weight was measured by counting a thousand seeds using a seed counter and weighed it using sensitive balance at harvest and adjusted at 12.5% moisture.

3.7.2.8 Grain yield (kg ha^{-1}): grain yield per plot was recorded using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis.

3.7.2.9 Above ground biomass (kg ha^{-1}): all above ground biomass was harvested from net plot and weighted, ears were removed and weighted separately, six plants were selected, chopped and oven dried till get uniform weight.

3.7.2.10 Harvest index: was calculated as the ratio of grain yield to above ground biomass yield on dry weight basis (Donald, 1962). $\mathrm{HI}(\%) = \frac{\text{Economic yield (kg/ha)}}{\text{Total biological yield (kg/ha)}} \mathrm{x}100$

3.8 Statistical Data Analysis

The data were subjected to Analysis of variance (ANOVA) using SAS software version 9.3. Least significant difference (LSD) at 5% level of significance was used to separate treatment means. Correlation and regression analysis were performed to determine the association among studied variables.

Model for the experiment

$$Y_{ijk} = \mu + \alpha_i + \beta_j + r_k + (\alpha\beta)_{ij} + e_{ijk}$$

Where, μ = the overall mean effects

α_i = the effect of i^{th} level of NPS level i=1-5

β_j= the effect of j^{th} level of compost level j=1-5

r_k=the effect of k^{th} replication

$(\alpha\beta)_{ij}$=the interaction effect of NPS and compost fertilizer

e_{ijk}=the random error compared for the whole factor

k=number of replications

3.9 Partial Budget Analysis

Partial budget analysis was performed to investigate the economic feasibility of the treatments and assess the costs and benefits associated with different treatments of NPS fertilizer and compost levels. The partial budget technique as described by CIMMYT (1988) was applied. The partial budget analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross field benefit (GFB) ha^{-1} (the product of field price and the mean yield for each treatment), the field price of blended NPS and urea kg^{-1} (the nutrient cost plus the cost of transportation from the point of sale to the farm), cost of labor spent on compost preparation, transportation and incorporation, the total costs that varied (TVC) which included the sum of field costs of fertilizers and their application.

The net benefit (NB) was calculated as the difference between the GFB and the TVC. The marginal rate of return (MRR %) were also calculated. To obtain an estimate of these returns the MRR (%) was calculated as changes in NB divided by changes in cost. Thus, a minimum acceptable MRR of 100% was used indicating, for every one ETB expended there is a return of one ETB for a given variable input (CIMMYT, 1988), which is suggested to be realistic. This enables' to make farmer recommendations from marginal analysis. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested.

Sensitivity analysis for different interventions was also carried out to test the recommendation made for its ability to withstand price changes. Sensitivity analysis simply implied redoing marginal analysis with the alternative prices. Through sensitivity analysis, maximum acceptable field price of an input was calculated with the minimum rate of return as described by Shah *et al*. (2009).

4. RESULTS AND DISCUSSIONS

The effect of different rates of NPS fertilizer and compost on phenological and growth parameters, yield and yield components, nutrient uptake of the crop, soil nutrient status after harvest and cost benefit analysis were presented and discussed with available literatures as follows.

4.1 Effect of NPS Fertilizer and Compost on Phenological and Growth Parameters

4.1.1 Days to 50 % tasseling

The number of days required for 50% tasseling was significantly ($P < 0.05$) affected by the interaction of NPS fertilizer and compost, while highly significantly ($p < 0.01$) affected by both NPS fertilizer and compost (Appendix Table 2). The shortest days to 50% tasseling (81.33 days) was recorded from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea with 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost; 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea with 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost which were statistically at par with all treatments, except with 2.3, 4.6, 6.9, 9.2 ton ha^{-1} compost and the control. Whereas, the longest days to reach 50% tasseling (90.0 days) was recorded from the control treatment which was statistically at par with 2.3 ton ha^{-1} compost (Table 4). Days to 50% tasseling was delayed by 8.67 days (10.7%) in the control treatment compared to treatments those needed 81.33 days to 50% tasseling (Figure 1).

The higher fertilizer use of the crop leads the crop to vigorous growth and ultimately the crop tassel early instead of prolonged vegetative growth. The nutrients in the compost gradually mineralized and become available for the crop. Despite that, the application of compost delays days to tasseling compared to combined application of NPS fertilizer and compost and NPS fertilizer only. Maize crop accumulates more heat units (thermal time) to tasseling with increasing the rate of N and vice versa (Amanullah *et al.*, 2009). Increase in N rate might have increased the rate of photosynthesis in the plant (Oikeh *et al.,* 1997). Sufficient nitrogen results in rapid growth and hastened tasseling, while too little or no N, resulted in slow growth and delayed tasseling (Cock and Ellis, 1992). These results are in line with those of Ayoola and Makinde, (2009) and Uwah *et al.*, (2011) who observed a reduction in number of days to 50% tasseling in maize with increased rates of fertilizers.

4.1.2 Days to 50% silking

The interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost were highly significantly ($P < 0.01$) affected days to 50% silking (Appendix Table 2). The shortest period required to reach days to 50% silking (83.33 days) was recorded from treatment combination of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea with 9.2 ton ha^{-1} compost; 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea with 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost which are statistically at par with all treatments except with 2.3, 4.6, 6.9, 9.2 ton ha^{-1} compost and the control. Whereas, the longest days to reach 50% silking (94.0 days) was recorded from the control treatment which was statistically at par with 2.3 ton ha^{-1} compost (Table 4). Days to 50% silking delayed by about 10.67 days (12.81%) in the control treatment as compared with treatments those recorded 83.33 days to 50% silking (Figure 1).

The significant difference among the treatments might be attributed to the N, P and S nutrients in combination with compost which enhanced vegetative growth of the crop, high photosynthetic activity and vigorous vegetative growth of the crop thus results in shorter days to silking. These findings were in line with the report of Dagne (2016) who reports the application of blended fertilizer and recommended NP significantly decreased days to silking as compared to control. Also Habtamu (2015) found that plots treated with fertilizer rates of 60 kg N and 15 kg S ha^{-1} showed earlier silking relative to the control.

Figure 1 Days to tasseling and silking of maize from fertilized and unfertilized (low nutrient) input plots

* Shorter days to tasseling and silking for more fertilized plot

4.1.3 Days to 90% maturity

The number of days required for 90% maturity was significantly (P <0.05) influenced by the interaction of NPS fertilizer and compost, and highly significantly (P <0.01) affected by both main NPS fertilizer and compost (Appendix Table 3). The combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) with 9.2 ton ha^{-1} (100%) and 6.9 ton ha^{-1} (75%) compost took minimum days to physiological maturity (142.33 days). But its effect was not statistically significant from all the treatment, except 2.3, 4.6, 6.9, 9.2 ton ha^{-1} compost; combined application of 45.5 kg ha^{-1} bended NPS fertilizer+31.2 kg ha^{-1} urea and 2.3 ton ha^{-1} compost and 45.5 kg ha^{-1} bended NPS fertilizer+31.2 kg ha^{-1} urea. Whereas, the maximum (153.00 days) was recorded from control treatment which was not statistically significant from 2.3 ton ha^{-1} (25%) and 4.6 ton ha^{-1} (50%) compost (Table 5). The combined application of 182 kg ha^{-1} blended NPS+124.8 kg ha^{-1} urea with 9.2 and 6.9 ton ha^{-1} compost hastened days to maturity by 6.97% (10.67 days) as compared to control.

Plants in the higher nutrient application rates matured early because of vigorous growth of fertilized treatments, early tasseling and silking of the crop, while plants at the lower nutrient application matured lately because of insufficient nutrients. Maize crop accumulate more heat units (thermal time) to physiological maturity with increasing the rate of N and vice versa (Amanullah *et al.,* 2009). This result is in line with the report by Dagne (2016) who reports early maturity days were recorded with the application of blended fertilizer whereas the longest days to maturity were recorded for control.

Table 4 Interaction effects of NPS fertilizer and compost on days to 50% tasseling, days to 50% silking and days to 90% maturity at Jimma in 2017

Blended NPS + Urea kg ha^{-1}	Compost ton ha^{-1}	Days to tasseling	Days to silking	Days to maturity
	0	90.00a	94.00a	153.00a
	2.3	88.00ab	91.67ab	152.67a
0+0	4.6	86.67b	90.00bc	150.67ab
	6.9	86.00bc	88.67cd	149.00bc
	9.2	84.33cd	87.00d	146.67cd
	0	82.00e	84.33e	145.67de
	2.3	82.00e	84.00e	145.00def
45.5+31.2	4.6	82.00e	84.00e	144.33defg
	6.9	81.67e	84.00e	144.67defg
	9.2	81.67e	84.00e	144.67defg
	0	82.33de	84.00e	144.33defg
	2.3	82.00e	83.67e	144.00efg
91+62.4	4.6	81.67e	83.67e	143.67efg
	6.9	81.67e	84.00e	143.33efg
	9.2	81.67e	83.67e	143.00fg
	0	82.00e	84.00e	144.00efg
	2.3	81.67e	83.67e	143.33efg
136.5+93.6	4.6	81.67e	83.67e	143.33efg
	6.9	81.33e	83.33e	143.00fg
	9.2	81.33e	83.33e	142.67fg
	0	82.00e	84.00e	143.00fg
	2.3	82.00e	83.67e	142.67fg
182+124.8	4.6	81.67e	83.67e	142.67fg
	6.9	81.33e	83.67e	142.33g
	9.2	81.33e	83.33e	142.33g
Mean		82.80	85.08	144.96
LSD (0.05)		2.074	2.358	2.447
CV (%)		1.19	1.38	0.81

*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

4.1.4 Leaf area index (LAI)

Leaf area index was highly significantly (P <0.01) affected by the interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 2). Numerically treatment combination of 182 kg ha^{-1} blended NPS+124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} (100%) compost were gave higher LAI (3.61). But its effect was not statistically significant from combined application of 182 kg ha^{-1} blended NPS+124.8 kg ha^{-1} urea with 6.9 and 4.6 compost ton ha^{-1}, 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea with 9.2 and 6.9 compost ton ha^{-1}. The lowest LAI (1.72) was obtained from the control treatment (Table 4). The LAI was increased by 15.33% and 109.88% at 182 kg ha^{-1} blended NPS+124.8 kg ha^{-1} urea combined with 9.2 ton ha^{-1} compost when compared with recommended NPS fertilizer only and control respectively.

The leaf area index was increased with increased NPS fertilizer and compost rate because of vigorous growth of the crop and leaf expansion in length and width. Leaf area index has primary importance in increasing the yield of crop. The reason for an increase of leaf area index could be attributed to more production of leaves with expanded leaves produced in response to nitrogen. Phosphorous promotes rapid canopy development and contributing to root cell division. Sulfur also involved in various metabolic and enzymatic processes including photosynthesis and respiration (Rao *et al*., 2001). The compost also possibly improved soil physical properties such as bulk density and porosity, moisture holding capacity there by, promoted early root growth, which enhanced ability of plants to access nutrients and promotes leaf area expansion and more number of leaves per plant. Leaf expansion was improved in plants by giving chemical and organic fertilizers and leaf expansion was illustrated in terms of leaf length and width (Valero *et al*., 2005). Kumar *et al*. (2005) reported that growth and yield of maize plants in terms of leaf area index varied significantly due to various fertility levels. He also reported that the maximum leaf area index was recorded from application of 100% NPK (120N:26.2P:33.2K) with 10 ton FYM ha^{-1} over control.

This funding was in agreement with Mahmood *et al.* (2017) who investigated that integrated use of chemical fertilizer with poultry manure (NPK150-85-50 + 7.0 ton ha^{-1}) resulted in maximum LAI. Also Oscar and Tollenaar (2006) concluded that LAI of maize increased with the application of higher rate of N and decline in LAI was much prominent in low doses of N. Greater LAI in NPK + FYM treatment was attributed to production of new leaves and also increase in size of the existing leaves (Bandyopadhyay *et al*., 2010). Superior growth and LAI under combined high rates of organic and inorganic fertilizers obtained in this study have been also reported by other workers (Ayoola and Makinde, 2009; Efthimiadou *et al.,* 2009).

4.1.5 Number of leaves per plant

Number of leaves per plant was significantly ($P < 0.05$) affected by the interaction of NPS fertilizer and compost, whereas highly significantly ($P < 0.01$) affected by NPS fertilizer and compost (Appendix Table 2). Numerically the maximum leaf number (15.47) was recorded from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and 4.6 ton ha^{-1} (50%) compost. But its effect was not significantly different from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea with 9.2, 6.9 and 2.3 compost ton ha^{-1}; 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea with 9.2, 6.9, 4.6, 2.3 compost ton ha^{-1}, and 91 kg ha^{-1} blended NPS fertilizer + 62.4 kg ha^{-1} urea with 9.2 compost ton ha^{-1}. The minimum leaf number (12.40) was recorded from the control, which was not significantly different from 2.5 ton ha^{-1} compost alone (Table 4). The combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and 4.6 ton ha^{-1} (50%) compost increased the number of leaves per plant by 24.76% and 4.98% when compared with the control and full NPS fertilizer without compost respectively.

An increase in the number of leaves could positively affect the photosynthetic activity of the plant since leaf number is a growth index that could enhance crop yields. Higher photosynthetic activity and chlorophyll synthesis due to N, P and S nutrients with combined application of compost seemed to have a favorable effect on number of leaves per plant. The reduction of leaf number with low nutrient management might be due to high nutrient use of the crop for vigorous growth. These findings are in line with Qasim *et al*. (2001) who reported that the higher rates of the soil amendments produced more leaves per plant. Also Uwah *et al*. (2011) reported that number of leaves per plant significantly influenced by poultry manure and N fertilizers. The author found that the highest number of green leaves were recorded under 10 ton ha^{-1} poultry manure and 80 kg ha^{-1} N and lowest under control plots. Adamu *et al.* (2015) also reported that highest number of leaves (10.50) was achieved with application of 150 kg N ha^{-1} + 80 kg P ha^{-1} + 10 ton FYM ha^{-1}.

4.1.6 Stem diameter (stem girth)

The stem girth was significantly (P <0.05) affected by the interaction of NPS fertilizer and compost, and highly significantly (P <0.01) affected by both NPS fertilizer and compost (Appendix Table 3). Numerically the highest stem diameter of 2.49 cm was recorded from the treatments having combined application of 136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} urea (75%) and 9.2 ton ha^{-1} (100%) compost. Whereas, the lowest stem diameter (1.71cm) was obtained from the control treatment which statistically at par with 2.3 ton ha^{-1} (25%) compost (Table 5). The stem girth at combined application of 136.5 kg ha^{-1} blended NPS +93.6 kg ha^{-1} urea (75%) and 9.2 ton ha^{-1} (100%) compost was 45.61% thicker than the control. The significant difference among treatments might be attributed to application of nutrients from both NPS fertilizer and compost which enhanced vegetative growth of crop and have a positive effect on maize stem girth.

These findings were in line with findings of Adamu *et al.* (2015) who reported that highest stem girth (4.90 and 5.85 cm) were achieved with application of 150 kg N ha^{-1} + 80 kg P ha^{-1} + 10 ton FYM ha^{-1} in 2014 and 2015 respectively and the control had the lowest stem girth. Also Gonzalez *et al.* (2001) reported that NPK (15-15-15 kg ha^{-1}) fertilizer and organic manure which was supplied as essential nutrition at initial establishment stage recorded the best results for width of the stem.

4.1.7 Plant height

Plant height was highly significantly (P <0.01) affected by the interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 3). Numerically the longest plant height (242.77cm) was recorded from combined application of

182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} (100%) compost. But its effect was not statistically significant from the combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea with 6.9, 4.6, 2.3 and 0 compost ton ha^{-1}; 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea with 9.2, 6.9, 4.6, 2.3 and 0 compost ton ha^{-1}; 91 kg ha^{-1} blended NPS fertilizer + 62.4 kg ha^{-1} urea with 9.2 and 6.9 compost ton ha^{-1}; and 45.5 kg ha^{-1} blended NPS fertilizer + 31.2 kg ha^{-1} urea with 9.2 compost ton ha^{-1}. While the shortest plant height (158.17cm) was recorded from the control treatment which was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Table 5). The plant height was increased by 53.49% at combined application of 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} compost as compared to control.

The increase in plant height with increasing rate of NPS fertilizer and compost could be due to their synergistic effects. Nitrogen is considered as one of the major limiting nutrients in plant growth and adequate supply of it promotes the formation of chlorophyll which in turn resulted in higher photosynthetic activity, vigorous vegetative growth and taller plants. P is required for shoot and root development where metabolism is high and cell division is rapid. Similarly, sulfur promotes formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth and taller plants (Rao *et al*., 2001). Also the compost acted as the store house of different plant nutrients, reduce P fixation, and improve CEC, aeration, root penetration and water storage capacity of the soil (Rahman *et al.*, 2012).

These results were in line with the findings of Adekayode and Ogunkoya (2010) who explained that there was very high significant difference in maize plant height in plots treated with high fertilizers compared with nil application. Similar results were reported by Ghafoor and Akhtar (1991) who stated that application of high N rates had significant effect on plant height of maize. Also Kumar *et al*. (2005) reported that growth and yield of maize plants in terms of plant height varied significantly due to various fertility levels. He reported the highest plant height was recorded from application of 100% NPK (120N:26.2P:33.2K) with 10 ton FYM ha^{-1} over control. The plant height were found highest under combined application of poultry manure, FYM and recommended dose of fertilizers (RDF) which are statistically at par but comparatively higher than 100% RDF (Wailare and Kesarwani, 2017).

Table 5 Interaction effects of NPS fertilizer and compost on leaf area index, number of leaves per plant, stem diameter and plant height at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	Compost (ton ha^{-1})	LAI	Number of leaves plant^{-1}	Stem diameter(cm)	Plant height (cm)
	0	1.72l	12.40g	1.71f	158.17g
	2.3	2.02k	12.80g	1.89f	168.90g
0+0	4.6	2.34ij	14.13ef	2.20de	195.00f
	6.9	2.28j	14.03f	2.16e	195.90f
	9.2	2.63h	14.20ef	2.20de	210.97def
	0	2.59hi	14.13ef	2.27bcde	208.50ef
	2.3	2.94efg	14.23ef	2.24cde	209.37ef
45.5+31.2	4.6	2.95efg	14.27ef	2.36abcd	221.10bcde
	6.9	2.90fg	14.63cdef	2.34abcde	220.83bcde
	9.2	2.97efg	14.63cdef	2.34abcde	224.43abcde
	0	2.79gh	14.33def	2.26cde	214.73cdef
	2.3	2.91efg	14.60cdef	2.33abcde	219.63bcde
91+62.4	4.6	3.17cde	14.70cde	2.26cde	222.07bcde
	6.9	3.09def	14.77bcde	2.29bcde	226.47abcde
	9.2	3.33bcd	15.23abc	2.43abc	232.77abc
	0	3.07def	14.63cdef	2.22de	226.97abcde
	2.3	3.12cdef	14.93abcd	2.23de	231.17abcd
136.5+93.6	4.6	3.15cdef	15.03abc	2.32abcde	236.00ab
	6.9	3.45ab	15.43a	2.37abcd	236.67ab
	9.2	3.38abc	15.37ab	2.49a	236.43ab
	0	3.13cdef	14.67cdef	2.33abcde	230.40abcd
	2.3	3.11def	15.13abc	2.37abcd	236.87ab
182+124.8	4.6	3.48ab	15.47a	2.37abcd	236.77ab
	6.9	3.55ab	15.40ab	2.43ab	239.43ab
	9.2	3.61a	15.40ab	2.46ab	242.77a
Mean		2.95	14.58	2.28	219.29
LSD (0.05)		0.255	0.658	0.198	20.265
CV (%)		4.18	2.42	4.88	5.64

*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

4.2. Effect of NPS Fertilizer and Compost on Yield and Yield Related Parameters

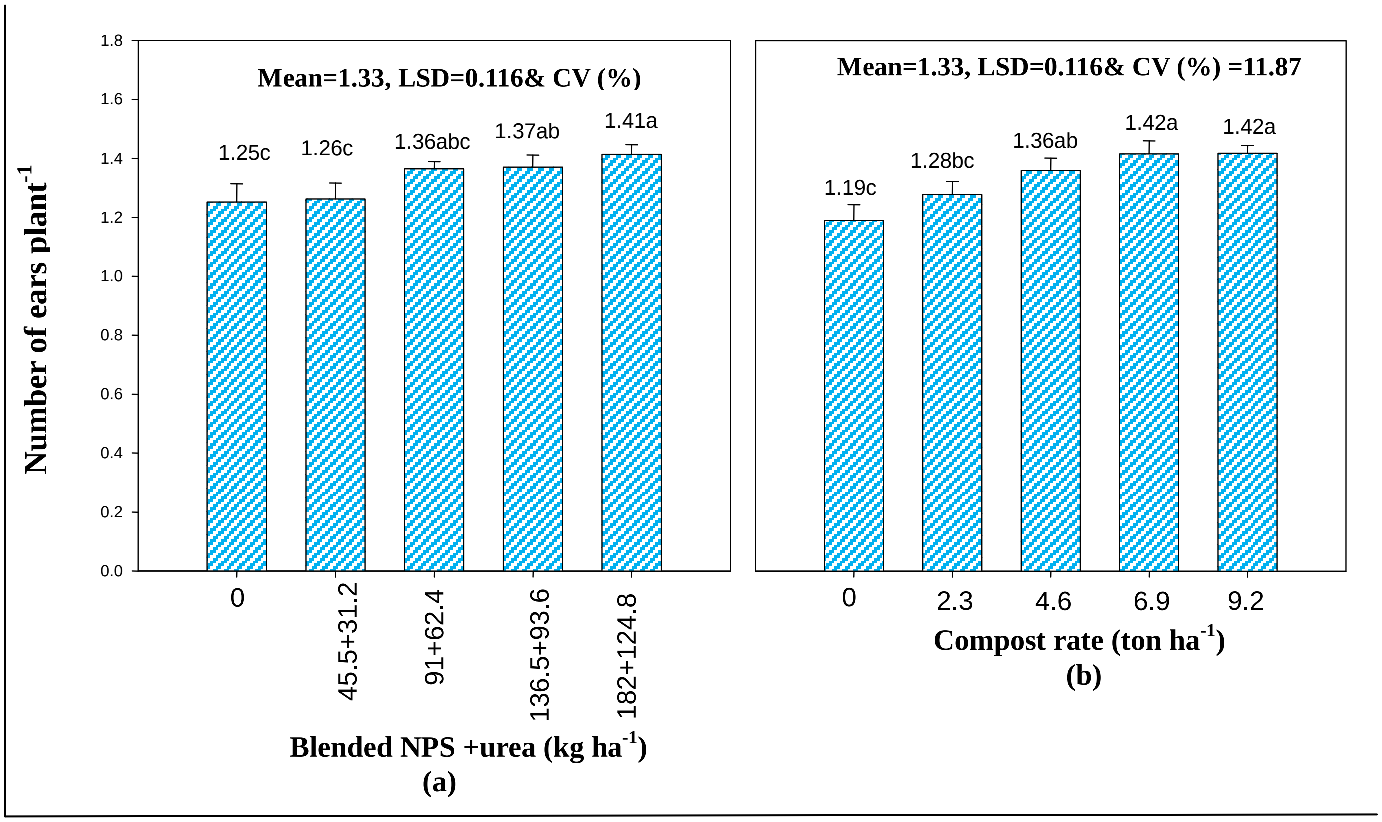
4.2.1 Number of ear per plant

The number of ear per plant was not significantly ($P > 0.05$) affected by the interaction of NPS fertilizer and compost. However, it was significantly ($P < 0.05$) influenced by NPS fertilizer and highly significantly ($P<0.01$) affected by compost (Appendix Table 3). Numerically the maximum number of ear per plant (1.41) was recorded at 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%). But its effect was not statistically significant from 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea (75%) and 91 kg ha^{-1} blended NPS+62.4 kg ha^{-1} urea (50%), while the minimum number of ear per plant (1.25) was recorded from the control, which was not statistically significant from 45.5 kg ha^{-1} blended NPS+ 31.2 kg ha^{-1} urea (Figure 3a). Application of 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea increased number of ears per plant by 12.80% over the control. On the other hand, numerically the maximum number of ear per plant (1.42) was recorded at 9.2 ton ha^{-1} (100%) and 6.9 ton ha^{-1} (75%) compost which was not statistically significant from 4.6 ton ha^{-1} (50%) compost, while the minimum number of ear per plant (1.19) was recorded under control which was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Figure 3b). The compost at the rate of 9.2 and 6.9 ton ha^{-1} increased 19.33% number of ear per plant over the control. This might be due to release of nutrient slowly from the compost that increased the ears harvested per plant. Also it could be related to improved soil fertility, which in turn had increased the nutrient availability for vigorous plant growth thus might have increased the number of ears $plant^{-1}$.

Number of ear per plant was determined by prolific ability of the BHQPY545 maize variety (Figure 2) as described by Adefris *et al*. (2015) and the growth behavior of the crop which is dependent upon management practices and edaphic and climatic factors. This is considered a main yield component as it defines the yield potential of a crop. The improvement of the soil conditions or enrichment with nutrients and organic matter due to soil-added materials might be responsible for better cob production under plots treated with NPS fertilizer and compost. Nitrogen can trigger vegetative growth and development and it is an integral part of chlorophyll, which is the primary absorber of light energy needed for photosynthesis. Sulfur facilitate N and P absorption, cell division, chlorophyll synthesis and photosynthesis (Rao *et al*., 2001), thus can increase number of ear per plant in maize.

These results were in line with the findings of Dagne (2016) who indicated that the application of blended fertilizer increased the number of cobs harvested compared to the control plot. Also, Amanullah *et al.* (2015) found that application of compost was most beneficial in terms of higher yield and yield components of maize over the control. Singh and Nepalia (2009) also reported that application of 125% RDF improved the number of cobs plant^{-1} (1.17) in QPM hybrid significantly over 100% RDF and 75% RDF.

Figure 2 Prolificacy of BHQPY545 maize varieties at Jimma in 2017



*LSD = Least Significant Difference; CV = Coefficient of Variation; Values followed by the same letter(s) within main treatment rates are not significantly different at 0.05 probability level.

Figure 3 Effect of NPS fertilizer (a) and compost (b) on number of ears per plant at Jimma in 2017

4.2.2 Ear length

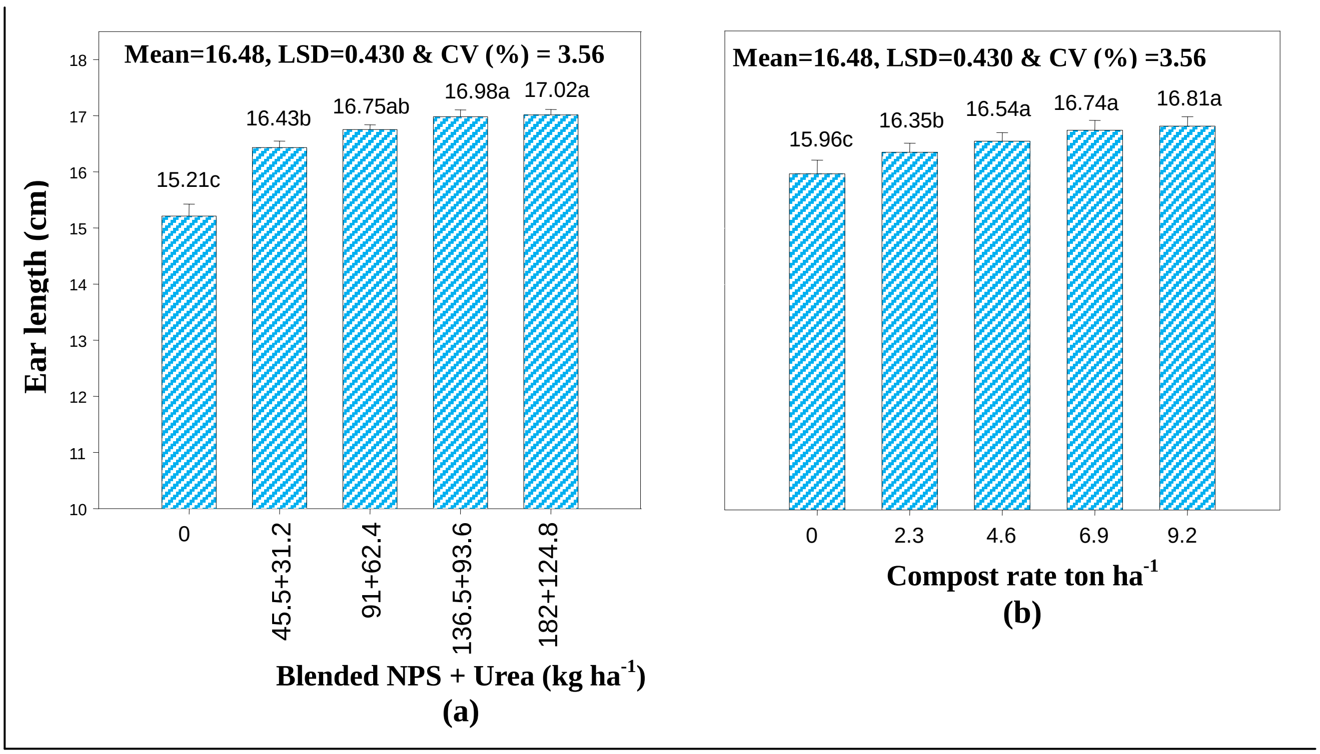
The interaction of NPS fertilizer and compost was not significantly (P>0.05) affected ear length, while NPS fertilizer and compost highly significantly (P <0.01) influenced the ear length (Appendix Table 3). Numerically the maximum ear length (17.02 cm) was recorded at 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%). But its effect was not statistically significant from 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea (75%) and 91 kg ha^{-1} blended NPS+62.4 kg ha^{-1} urea (50%), while the minimum ear length (15.21cm) was recorded under the control (Figure 5a). The application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea increased ear length by 11.90% when compared with the control. On the other hand, numerically the maximum ear length (16.81cm) was recorded at 9.2 ton ha^{-1} (100%) compost which was not statistically significant from 6.9 ton ha^{-1} and 4.6 ton ha^{-1} compost while, the minimum (15.96 cm) was recorded under the control which was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Figure 5b). The application of 9.2 ton ha^{-1} compost increased ear length by 5.33% over control treatment. The application of NPS fertilizer and compost affected the ear length of the maize variety used when compared with control as indicated in figure 4.

The reason for the better ear length development at higher input of both NPS fertilizer and compost was due to increase in photosynthetic activities of the plant on the account of adequate supply of nitrogen and phosphorous (Jan *et al.,* 2002). Nitrogen is also an essential requirement of ear growth so if the soil was nourished by compost and mineral fertilizer better ear length growth was achieved which had impact on yield. Increase in ear length at higher N and P could be due to good photo-assimilates supply which facilitates photosynthesis and S aids in seed formation. The compost also contains different nutrients that used for growth and development of the crop. The maximum assimilate supply should be available during maize grain filling with split application of N (Arif *et al*., 2010).

These results were in agreement with that of Rajeshwari *et al*. (2010) who reported a significant increase in ear length with increased rates of nitrogen fertilizer application from different sources. The result is also in line with that of Masresha (2014) who found significance in ear length with application of N fertilizer and compost. Maral *et al*. (2012) also reported that with increasing nitrogen level from 50 to 200 kg ha^{-1} significantly increased the ear length of maize from 10.17 to 15.69 cm. Similarly, Imran *et al*. (2015) reported that ear length increases with increased in nitrogen level of 210 kg ha^{-1}.

(a) **(b)**

Figure 4 Ear length of maize from nil (a) and higher nutrient (b) input plot

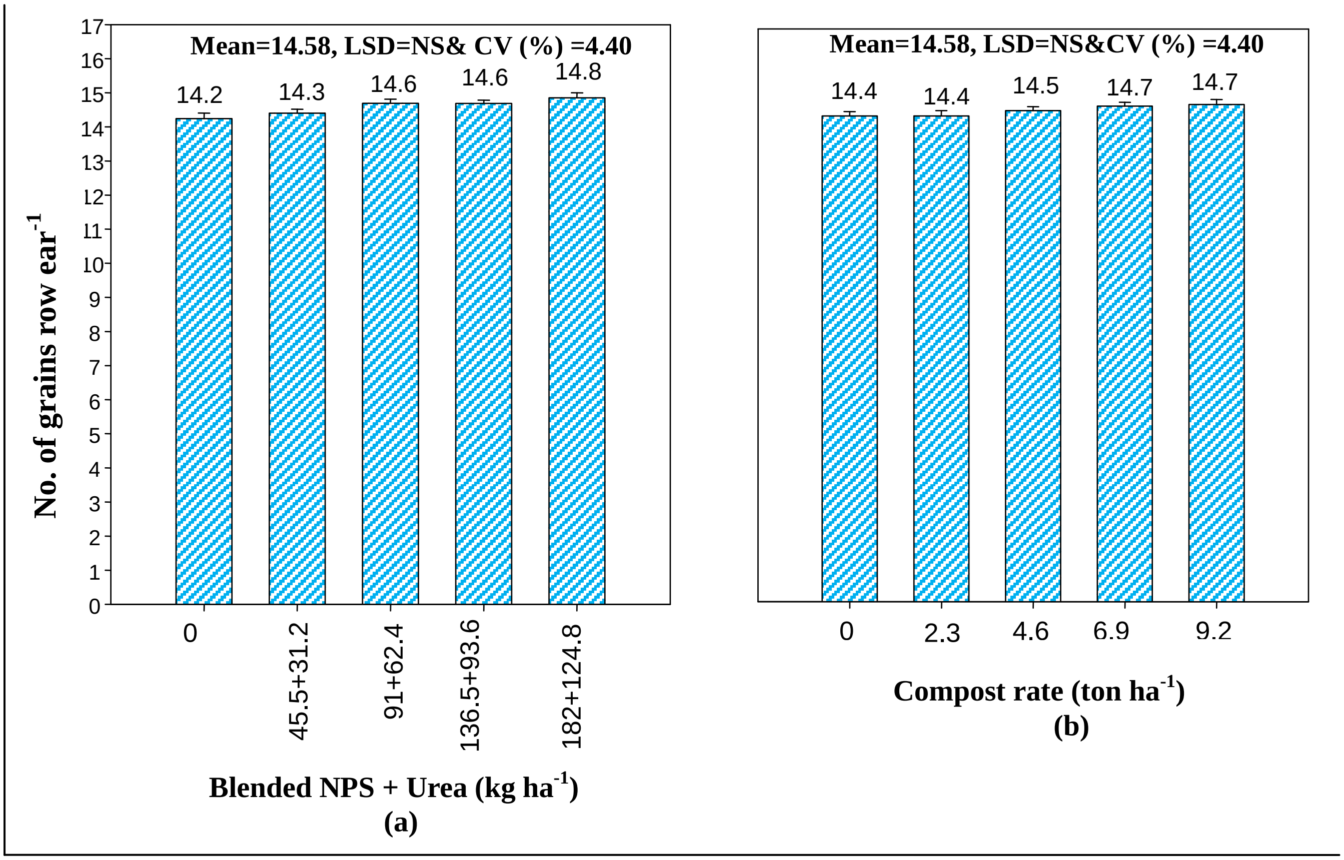


*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within main treatment rates are not significantly different at 0.05 probability level.

Figure 5 Effect of NPS fertilizer (a) and compost (b) on ear length at Jimma in 2017

4.2.3 Number of grain row per ear

The interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost on number of grain row per ear were non significant (P>0.05) (Appendix Table 3).



*LSD = Least Significant Difference; CV = Coefficient of Variation; Ns= Non significant

Figure 6 Effect of NPS fertilizer (a) and compost (b) on number of grains row per ear at Jimma in 2017

4.2.4 Number of grains per row

The number of grains per row was highly significantly (p<0.01) affected by interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 3). Numerically the highest number of grains per row (37.00) was recorded from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and

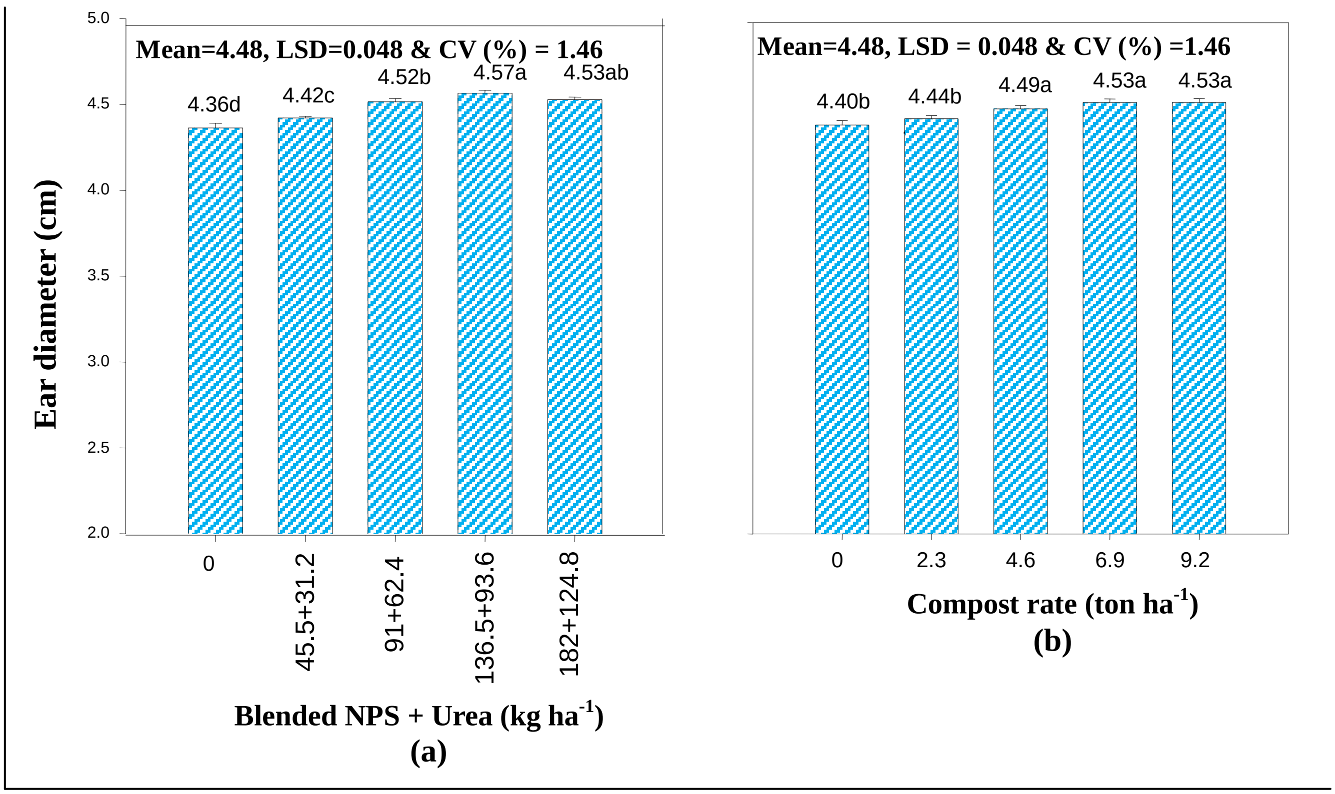
6.9 ton ha^{-1} (75%) compost. Whereas, the lowest number of grains per row (29.90) was recorded from the control treatment (Table 6). Compared to the control treatment, the number of grains per row was increased by 23.75% at combined application of 182 kg ha^{-1} blended NPS +124.8 kg ha^{-1} urea and 6.9 ton ha^{-1} compost.

The significant increase in number of grains per row might be due to the significant increase of ear length with application of both NPS fertilizer and compost that results better vegetative growth which in turn enabled the crop to produce greater photo assimilate. Compost supply major and micronutrients which led to adequate supply of photo assimilates for development of ears and grains (Radhakrishnan, 2009). N and P availability in sufficient quantity throughout the growing season are essential for optimum maize growth (Kogbe and Adediran, 2003) and leads for grain productions. Sulfur is involved in the conformations and activities of many enzymes and stimulates seed production (Scherer, 2001). Grain number is strongly associated with assimilate availability at flowering (Tollenaar and Dwyer, 1999). These findings were in line with finding of Baharvand *et al*. (2014) who reported integrated use of vermicompost and inorganic chemical fertilizers management increased grain number in row of maize.

4.2.5 Ear diameter

The interaction of NPS fertilizer and compost had non significant ($P > 0.05$) effect on ear diameter. However, NPS fertilizer and compost had highly significant ($P < 0.01$) effect on ear diameter (Appendix Table 3). The highest ear diameter (4.57cm) was recorded from 136.5 kg ha^{-1} blended NPS fertilizer +93.6 kg ha^{-1} urea, but its effect was not statistically significant from 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea. On other hand, the lowest (4.36cm) was recorded from the control (Figure 7a). The ear diameter at 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea was 4.82% higher than control treatment. With regard to compost, numerically the highest ear diameter (4.53 cm) was recorded at 9.2 ton ha^{-1} (100%) and 6.9 ton ha^{-1} (75%) compost which was not statistically significant from 4.6 ton ha^{-1} (50%) compost. While, the lowest (4.40cm) was recorded under the control at which its effect was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Figure 7b). The ear diameter at 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost was 2.96% thicker than the control.

The availability of sufficient essential nutrients from both NPS fertilizer and compost lead to improved cell activities, enhanced cells multiplication and enlargement and luxuriant growth. These findings were in agreement with Baharvand *et al*. (2014) who reported that ear diameter increased on account of chemical fertilizer and vermicompost application.



*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within main treatment rates are not significantly different at 0.05 probability level.

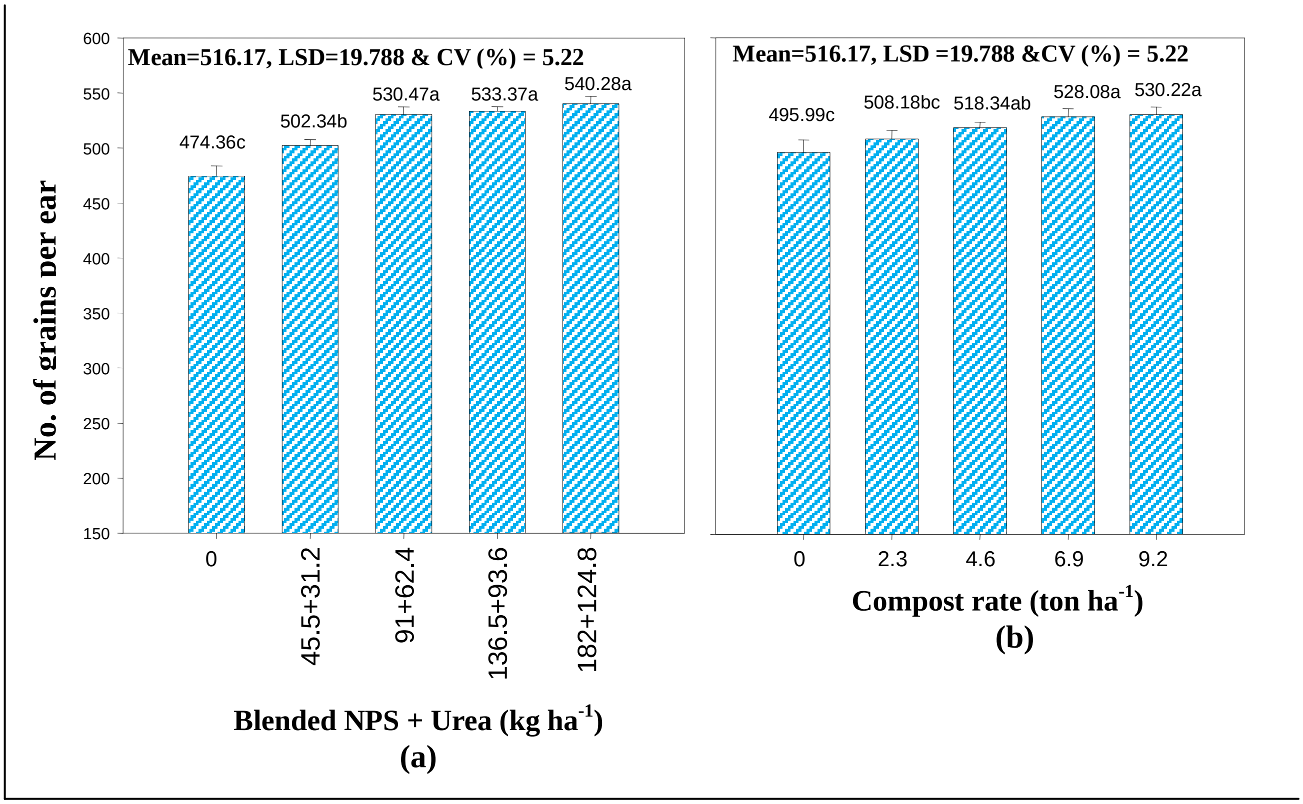
Figure 7 Effect of NPS fertilizer (a) and compost (b) on ear diameter at Jimma in 2017

4.2.6 Number of grains per ear

The interaction of NPS fertilizer and compost had non significant (P >0.05) influence on number of grains per ear. On other hand, the main effect of NPS fertilizer and compost were highly significantly ($P<0.01$) influenced number of grains per ear (Appendix Table 3). Numerically the highest (540.28) number of grains per ear was recorded from 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) which was not statistically significant from 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea (75%) and 91 kg ha^{-1} blended NPS+62.4 kg ha^{-1} urea (50%), while the lowest (474.36) number of grains per ear was recorded from the control (Figure 8a). There was an increase of 13.90% number of grains per ear when 182 kg ha^{-1} NPS fertilizer +124.8 kg ha^{-1} urea applied as compared with control. On the other hand, the highest grains per ear (530.22) was recorded at 9.2 ton ha^{-1} (100%) compost which was not statistically significant from 6.9 ton ha^{-1} (75%) and 4.6 ton ha^{-1} (50%) compost while, the lowest (495.99) was recorded under the control, which was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Figure 8b).There was an increase of 6.90% number of grains per ear at 9.2 ton ha^{-1} (100%) compost applied when compared with the control.

The increase in number of grains per ear might be due to availability of N at proper time which is required for better growth and development of plants, P for seed development and sulfur for seed production whereas compost improved soil fertility, moisture retention and soil structure which in turn had increased the nutrients availability for improved plant growth. This might be also due the split application of nitrogen to reduce nitrogen losses through leaching and volatilization. An increase in number of grains per ear was also due to an increase of number of grains per row, ear length and number of rows per ear with higher nutrient supply from both NPS fertilizer and compost.

The optimum availability of synthetic fertilizer as well as compost which might boost growth indices as a consequent increased the ear length (Chapagain and Gurung, 2010) and thus resulted in more grains per ear of maize. These results are in line with the findings of (Farooqi, 1999) who reported that more grains per ear associated with increased ear length, mainly due to the adequate chemical fertilizer and organic N sources. Also Ali *et al.* (2012) reported application of compost at the rate of 5 ton ha^{-1} has 24 % higher number of grains ear^{-1} than no application of compost. This encouraging effect of blended NPS fertilizer was also in accordance with the findings of Maqsood *et al.* (2001) who reported that increased rate of NPK, increased the number of grains per ear. Also Habtamu *et al*. (2015) found that the highest mean grain number per ear was counted in plots treated with high doses of N and compost together with medium S fertilizers, whereas the lowest was recorded in the control.



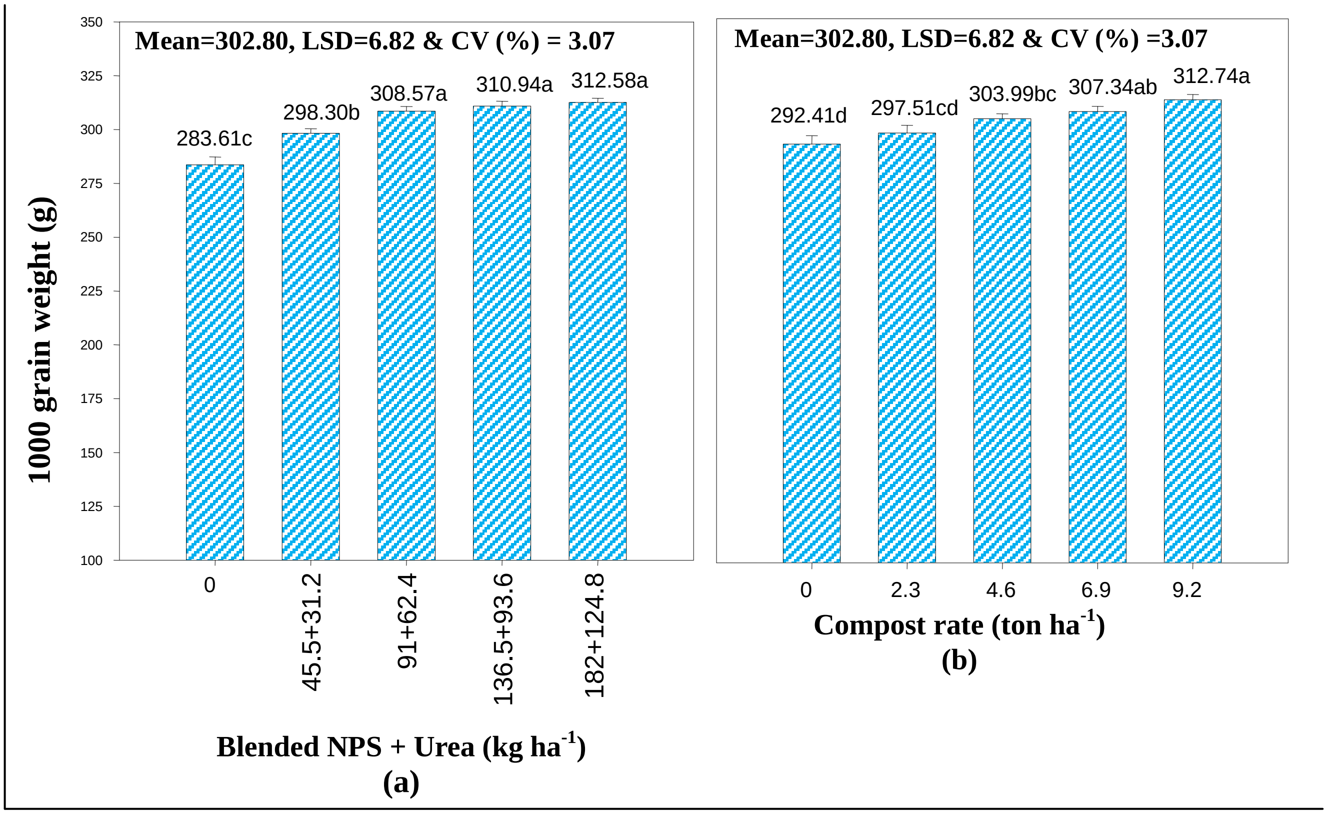
*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter within main treatment rates are not significantly different at 0.05 probability level.

Figure 8 Effect of NPS fertilizer (a) and compost (b) on number of grains per ear at Jimma in 2017

4.2.7 Thousand grain weight

Thousand grain weight was not significantly (P>0.05) affected by the interaction of NPS fertilizer and compost. However, it was highly significantly (P<0.01) affected by both NPS fertilizer and compost as main factors (Appendix Table 4). The heavier (312.58 g) thousand grain weights were recorded from 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea (100%) which was not statistically significant from 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%) and 91 kg ha^{-1} blended NPS fertilizer+62.4 kg ha^{-1} urea (50%), while the lighter (283.61g) thousand grain weights were recorded from the control (Figure 9a). There was an increase of 10.22% thousand grain weight at 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea application when compared with the control. On the other hand, the higher thousand grain weight (312.74 g) was recorded from 9.2 ton ha^{-1} (100%) compost which was not statistically significant from 6.9 ton ha^{-1} compost. While, the lower (292.41g) thousand grain weight was recorded under the control which was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Figure 9b).There was an increase of 6.95% thousand grain weight at 9.2 ton ha^{-1} compost application when compared with control.

An increase in thousand grain weights were due to the effects of N for grain filling and increases the plumpness of grains, P for cell division, seed formation and development, S for seed production and compost in addition to source of nutrient, it improves soil structure and water absorption which helps for heavier grain weight of maize. Availability of sufficient light and moisture to an individual plant at higher nutrient proportion leads to enhanced plant growth and might have led to better grain development which ultimately increased grain weight. Bigger sized ear might have accommodated more number of grains providing sufficient space for development of an individual grain, leading to higher 1000 grain weight at sufficient NPS fertilizer and compost. The weight of grains depend on flabbiness of grains and transport of assimilates to the seed (Siam *et al*., 2008). In addition the sufficient availability of nutrients from both inorganic and organic sources at critical growth stages especially at grain filling and development (Mohsin *et al*., 2012) and thus resulted in properly filled grains. These results were in line with report of Onasanya *et al*. (2009) who reported that higher values of 1000 grain weight with higher doses of inorganic fertilizers.



*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within main treatment rates are not significantly different at 0.05 probability level.

Figure 9 Effect of NPS fertilizer (a) and compost (b) on thousand grain weight at Jimma in 2017

4.2.8 Grain yield

There was highly significant (P <0.01) effect due to interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost on grain yield (Appendix Table 4). Numerically the highest grain yield (8453.2 kg ha^{-1}) was recorded from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) with 9.2 ton ha^{-1} (100%) compost which was statistically at par with combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea with 6.9 and 4.6 compost ton ha^{-1}; 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea with 9.2, 6.9 and 4.6 compost ton ha^{-1}. On the other hand, the lowest mean grain yield of 2612.7 kg ha^{-1} was recorded from the control (Table 6). Grain yield of maize was increased by 223.54% due to the combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} compost over the control. This combination also resulted in 24% higher than 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea without compost application. Also a 160.8% of grain yield advantage was obtained due to the application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea over the control. On the other hand, grain yield advantage of 113.7% was obtained due to application of full rate of compost over the control treatment. Reduction of grain yield in unfertilized plots might be due to nutritional imbalance and deficiency of certain important plant growth elements at various important growth stages and also due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation.

It is clear from the result that grain yield increased in response to increasing rate of fertilizers application both NPS and compost possibly due to higher LAI, plant height, number of grain per ear, 1000 grain weight and number of cobs per plant. The increase in grain yield could be attributed to beneficial influence of yield contributing characters and positive interaction of NPS fertilizer with compost. These increase the nutrients in the soil and modification of soil environments that resulted in better vegetative growth which in turn enabled the crop to produce greater photo-assimilate. The N has synergistic effects on growth and yield attributes resulting in greater translocation of photosynthates from source to sink, beneficial effect on physiological process, plant metabolism, growth and it is the major ingredient of proteins, enzymes, amino acids, amides and nucleic acids (Yayock *et al*., 1988) and there by leading to higher grain yield. The P supply is particularly important for stimulating early root formation and growth, functions in plant macromolecular structures as a component of nucleic acids and phospholipids, with crucial roles in energy metabolism, participation in signal transduction path ways via phosphorylation and controlling key enzyme reactions (Marschner 2012). Although the sulfur in the blended NPS have the role for energy transformation, activation of enzymes which in turn enhances carbohydrate metabolism and photosynthesis activity of plant with increased chlorophyll synthesis (Juszczuk and Ostaszewka, 2011).

Mugwe *et al*. (2007) reported the higher grain yield of maize was recorded in treatments of compost either alone or in combination with mineral fertilizer when compared to the control. The increase in yield of maize with combined application of P and compost were due to the increase in P availability (Biswas, 2011). Higher doses of N and compost fertilizers increased grain yield as N is the main driving force to produce high yield of maize (Nivong *et al*., 2007) and compost is responsible in improving soil physical, chemical and microbial conditions in addition to giving different macro and micro nutrient to the plant.

These results were supported by the findings of Nagassa *et al*. (2005) who revealed that grain yield was significantly affected by N fertilizer in combination with FYM. Also the result was in line with findings of N'Dayegamiye *et al*. (2010) who reported that application of compost with 120 kg N ha^{-1} led to higher maize grain yields. The highest grain yield of 7179 kg ha^{-1} was produced with application of FYM 10 t ha^{-1} + 100% RDF in QPM maize hybrid, which was significantly superior to the other treatments as revealed by Ravi *et al.* (2012). Verma (1991) on a clay soil found that increasing the rate of farmyard manure from 5.0 to 10.0 ton ha^{-1} and fertilizer application from 50 to 100% recommended dose of N, P and K increased the grain yield of maize.

4.2.9 Above ground biomass

The interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost were highly significantly ($P<0.01$) influenced above ground biomass of maize (Appendix Table 4). Numerically the highest above ground biomass yield 15387.2 kg ha^{-1} was recorded from 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} (100%) compost which was statically at par with combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea with 6.9, 4.6 and 2.3 compost ton ha^{-1}; 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea with 9.2, 6.9 and 4.6 compost ton ha^{-1}. On the other hand, the lowest above ground biomass yield 5139.9 kg ha^{-1} was obtained from the control (Table 6). Above ground biomass yield advantage of 199.37% and 21.44% were obtained due to combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} (100%) compost when compared to the control and 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea respectively. On the other hand, above ground biomass yield advantage of 103.68% was obtained due to application of full rate of compost over the control.

Table 6 Interaction effects of NPS fertilizer and compost on number of grains per row, grain yield and above ground biomass at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	Compost (ton ha^{-1})	Number of grains per row	Grain yield (Kg ha^{-1})	AGB (kg ha^{-1})
	0	29.90h	2612.7n	5139.9o
	2.3	33.53g	3878.1m	7499.5n
0+0	4.6	34.17fg	4664.5lm	8858.7mn
	6.9	34.40defg	5165.3jkl	9616.9lm
	9.2	34.27efg	5583.9ijkl	10469.1klm
	0	34.40defg	4727.2lm	9122.9mn
	2.3	34.53cdefg	4923.8klm	9177.9m
45.5+31.2	4.6	34.73bcdefg	5883.6hijk	10990.1jkl
	6.9	34.80bcdefg	6093.9ghij	11680.3hijk
	9.2	36.00abc	6287.0fghij	12029.0ghijk
	0	35.67abcde	5910.5hijk	11134.6ijkl
	2.3	35.80abcd	6370.7fghi	11922.5hijk
91+62.4	4.6	36.07ab	7067.3cdefg	13314.3cdefgh
	6.9	36.40a	6913.9defgh	13220.0defgh
	9.2	36.57a	7203.6cdefg	13635.5bcdefg
	0	35.57abcdef	6425.3efghi	12163.4ghij
	2.3	36.10ab	6648.2efghi	12598.9fghij
136.5+93.6	4.6	36.67a	7549.6abcde	14304.7abcde
	6.9	36.77a	8384.9ab	15148.1ab
	9.2	36.50a	8138.5abc	15088.1ab
	0	36.10ab	6814.3efgh	12670.6efghi
	2.3	36.13ab	7304.4bcdef	13859.0abcdef
182+124.8	4.6	36.20ab	8120.1abc	14913.5abc
	6.9	37.00a	7974.9abcd	14472.4abcd
	9.2	36.30a	8453.2a	15387.2a
Mean		35.38	6363.97	11936.69
LSD (0.05)		1.498	1141.1	1677.6
CV (%)		2.29	10.93	8.57

*AGB= above ground biomass; LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

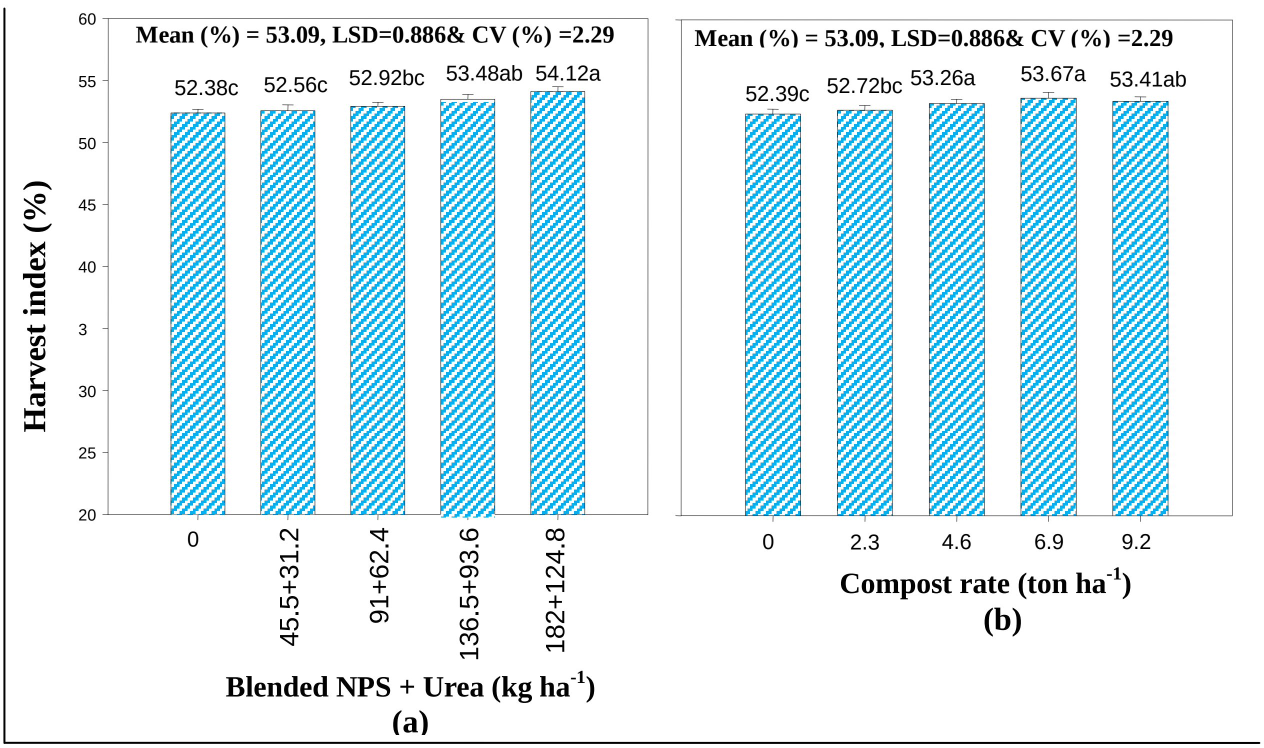
The result showed that the above ground biomass was increased by increasing rates of NPS fertilizer and compost application due to higher LAI, number of ear per plant, number of grains per ear, ear length, stem girth, plant height and grain. An increase in the number of leaves as well as increase in the LAI, may have promoted photosynthetic production to enhance high biomass yield in the combined treatments. Adequate supply of nutrients to the crop helps in the synthesis of carbohydrates, which are required for the formation of protoplasm, thus resulting in higher cell division and cell elongation. Thus an increase in biomass yield might have been on account of overall improvement in the vegetative growth of the plant due to the application of NPS fertilizer in combination with compost. The high crop above ground biomass improvements with compost than those obtained with the control was probably attributed to the improvement of the physical conditions and biological activity of the soil (Chang *et al*., 1990). Similar results were obtained by Makinde and Ayoola (2010) who reported that conjunctive application of organic and inorganic fertilizers is effective for the growth of maize and improving the yields.

4.2.10 Harvest index (HI)

Harvest index was not significantly ($P > 0.05$) affected by the interaction of NPS fertilizer and compost, while highly significantly ($P < 0.01$) effected by NPS fertilizer and significantly ($p < 0.05$) affected by compost (Appendix Table 4). Numerically the highest harvest index (54.12%) was recorded from application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%). But its effect was not statistically significant from 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea (75%) and 91 kg ha^{-1} blended NPS+62.4 kg ha^{-1} urea (50%), while the lowest harvest index (52.38%) was recorded under the control (Figure 10a). On the other hand, the highest harvest index (53.67%) was recorded from 6.9 ton ha^{-1} (75%) compost which was not statistically significant from 9.2 and 4.6 ton ha^{-1} compost, while the lowest (52.39%) was recorded under the control (Figure 10b).

As harvest index is the ratio of grain yield to total above ground biomass, the highest harvest index was recorded from higher NPS fertilizer and compost. The higher harvest index indicates the proportion of economical yield to total above ground biomass was higher than that of the control treatment. Harvest index obtained were in the acceptable range of 0.4 - 0.6 for maize (Hay, 1995).

Adequate supply of NPS fertilizer and compost are essential for optimizing partitioning of dry matter between grain and other parts of the maize plant. Optimum utilization of solar radiation, higher assimilates production and its conversion to starch results in higher biomass, grain yield leading to higher harvest index. These findings were in line with results by Kumar and Puri (2001) who observed that the highest HI of 37.11% and 37.54% was recorded with 90 kg N ha^{-1} in 1996 and 1997 compared to 45 kg N ha^{-1} (35.82% and 35.81%) and control (33.33% and 34.63%). Also Jat *et al.* (2010) found that the highest HI 42.4% and 42.6% was recorded from application of 120 kg ha^{-1} compared to 60 kg N (41.8% and 41.9%) and control (40.6% and 40.6%) in 2006 and 2007.



*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within main treatment rates are not significantly different at 0.05 probability level.

Figure 10 Effect of NPS fertilizer (a) and compost (b) on harvest index at Jimma in 2017

4.3 Correlation Analysis

Grain yield was highly and positively correlated with above ground biomass (r = 0.99**), plant height (r = 0.91**), leaf area index (r = 0.91**), leaf number (r = 0.87**), thousand seed weight (r = 0.80**), number of ears per plant (r = 0.62**), ear diameter (r = 0.80**), number of grains per ear (r = 0.72**), number of grains per rows (r = 0.82**), ear length(r = 0.77**) and harvest index (r = 0.62**), but negatively correlated with days to silking (r = -0.75**), days to tasseling (r = -0.75**) and days to maturity (r = -0.82**) (Table 7). Similar findings were reported by Yihenew (2015) and Habtamu *et al*. (2015) that grain yield of maize were positively and significantly correlated with yield components.

The above ground biomass yield was highly and positively correlated with plant height (r = 0.91**), leaf area index (r = 0.91**), leaf number (r = 0.88**), girth(r = 0.75**) thousand seed weight (r = 0.81**), number of ears per plant (r = 0.60**), ear diameter (r = 0.81**), number of grains per ear (r = 0.73**), number of grains per rows (r = 0.83**), ear length(r = 0.78**) and harvest index (r = 0.51**) but negatively correlated with days to silking (r=-0.77**), days to tasseling (r=-0.77**) and days to maturity(r=-0.83**) (Table 7).

Generally, Pearson's moment correlation coefficients between grain yield and sixteen other agronomic traits considered in the study are shown in Table 9. The current investigation was in line with the previous studies made by Pearl**,** (2012) that certain plant characters such as thousand kernel weight and ear length highly significant and positively correlated with grain yield. Therefore, significant and positively correlated parameters moves in the same direction this means that as one variable increases, so does the other one while significant and negatively correlated parameters moves in the inverse or opposite direction. In other words as one variable increases the other variable decreases.

Table 7 Pearson Correlation Coefficients among different growth, yield and yield component parameters of maize

	DT	DS	DM	LN	PH	GIR	LAI	GR	EL	ED	GPE	TSW	EPP	GY	AGB	HI
DT	1	0.97**	0.80**	-0.77**	-0.86**	-0.77**	-0.82**	-0.71**	-0.75**	-0.64**	-0.66**	-0.69**	-0.49**	-0.75**	-0.77**	-0.34**
DS		1	0.83**	-0.80**	-0.87**	-0.77**	-0.83**	-0.74**	-0.75**	-0.64**	-0.68**	-0.70**	-0.49**	-0.75**	-0.77**	-0.33**
DM			1	-0.79**	-0.86**	-0.75**	-0.86**	-0.75**	-0.73**	-0.62**	-0.61**	-0.76**	-0.36**	-0.82**	-0.83**	-0.44**
LN				1	0.84**	0.74**	0.88**	0.74**	0.74**	0.71**	0.63**	0.72**	0.55**	0.87**	0.88**	0.45**
PH					1	0.79**	0.89**	0.83**	0.81**	0.74**	0.77**	0.80**	0.62**	0.91**	0.91**	0.51**
GIR						1	0.78**	0.69**	0.66**	0.68**	0.70**	0.70**	0.45**	0.75**	0.75**	0.43**
LAI							1	0.81**	0.81**	0.77**	0.71**	0.80**	0.47**	0.91**	0.91**	0.48**
GR								1	0.82**	0.79**	0.85**	0.80**	0.52**	0.82**	0.83**	0.46**
EL									1	0.72**	0.71**	0.73**	0.49**	0.77**	0.78**	0.45**
ED										1	0.76**	0.68**	0.51**	0.80**	0.81**	0.40**
GPE											1	0.73**	0.52**	0.72**	0.73**	0.42**
TSW												1	0.43**	0.80**	0.81**	0.39**
EPP													1	0.62**	0.60**	0.56**
GY														1	0.99**	0.62**
AGB															1	0.51**
HI																1

* = Significant at P < 0.05; ** = Significant at P < 0.01; ns=non-significant; DT=Days to tasseling; DS=Days to silking; DM=Days to maturity; LN=leaf number; PH=plant height; GIR=girth; LAI=leaf area index; GR= number of grain per row; EL=Ear length; ED=Ear diameter; GPE=number of grain per ear; TSW= Thousand seed weight; EPP= number of ear per plant; GY=grain yield; AGB=Above ground biomass yield and HI= Harvest index

4.4 Effect of NPS Fertilizer and Compost on Nutrient Uptake of Maize

4.4.1 Effects of NPS fertilizer and compost on nitrogen uptake

Maize grain, straw and total N uptake was highly significantly (P<0.01) affected by NPS fertilizer and compost (Appendix table 5). Numerically the highest grain N and total N uptakes (8.93 and 14.49 kg ha-1) were recorded at 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea (100%). respectively, while the highest straw N uptake (5.79 kg ha^{-1}) was recorded at 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%). The lowest grain, straw and total N uptake (3.35, 2.75 and 6.10 kg ha^{-1}) were recorded at the control respectively (Table 8). Accordingly application of full NPS fertilizer increased grain and total N uptakes by 166.57% and 137.54% respectively, above control. The straw N uptake was increased by 110.55% in response to 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%) when compared with the control treatment. The result clearly showed the positive effects of N on maize grain and straw yields and the improvement of grain and straw N uptake by application of NPS fertilizer. On other hand, numerically the highest grain, straw and total N uptake (7.61, 5.76 and 13.37 kg ha^{-1}) was recorded at 9.2 ton ha^{-1} respectively. While the lowest grain, straw and total N uptake (4.09, 3.59 and 7.68 kg ha^{-1}) was recorded at the control respectively (Table 8). Application of 9.2 ton ha^{-1} compost increased grain N and straw N uptake by 86.06% and 60.45% respectively, while total N uptake increased by 74.09% when compared to the control treatment.

The N uptake of grain and straw at harvest depending on the rate of N supply from both NPS fertilizer and compost indicate the ability of the crop to translocation of nutrients to grain and straw at the expense of the vegetative part of the plant. Furthermore, a positive linear response was also noted for total N uptake with NPS fertilizer and compost rates. Soheil *et al*. (2012) observed a rise in N nutrient concentration in the plant tissue as the compost application rates were increased.

As a consequence of the increased plant N uptakes by both NPS fertilizer and compost nutrient sources, the maize N uptake exhibited positive relationship with grain yield. The maize grain yield was positively and highly significantly correlated with total N uptake (r = 0.87**), grain N uptake (r = 0.76*) and straw N uptake (r = 0.64**) (Figure 11).

Table 8 Effect of NPS fertilizer and compost on nitrogen concentration and uptake of grain and straw of maize at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	Grain N concentration (%)	Straw N concentration (%)	Average concentration (%)	Grain N uptake (kg ha^{-1})	Straw N uptake (kg ha^{-1})	Total N uptake (kg ha^{-1})
0+0	0.07b	0.07	0.07b	3.35c	2.75c	6.10d
45.5+31.2	0.09ab	0.08	0.09a	5.42b	4.25b	9.67c
91+62.4	0.09ab	0.09	0.09a	5.81b	5.35a	11.15bc
136.5+93.6	0.09ab	0.09	0.09a	6.80b	5.79a	12.59ab
182+124.8	0.12a	0.09	0.11a	8.93a	5.56a	14.49a
Mean	0.09	0.08	0.09	6.06	4.74	10.80
LSD (0.05)	0.023	NS	0.016	1.50	0.917	1.924
Compost (t ha^{-1})						
0	0.07b	0.07b	0.07b	4.09c	3.59b	7.68c
2.3	0.08ab	0.07b	0.08b	5.09bc	3.62b	8.71c
4.6	0.09ab	0.09a	0.09a	6.42ab	5.46a	11.88b
6.9	0.10a	0.09a	0.10a	7.09a	5.27a	12.36a
9.2	0.11a	0.09a	0.10a	7.61a	5.76a	13.37a
Mean	0.09	0.08	0.09	6.06	4.74	10.80
LSD (0.05)	0.023	0.016	0.016	1.50	0.917	1.924
CV (%)	33.74	25.44	24.42	33.68	26.35	24.27

*LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

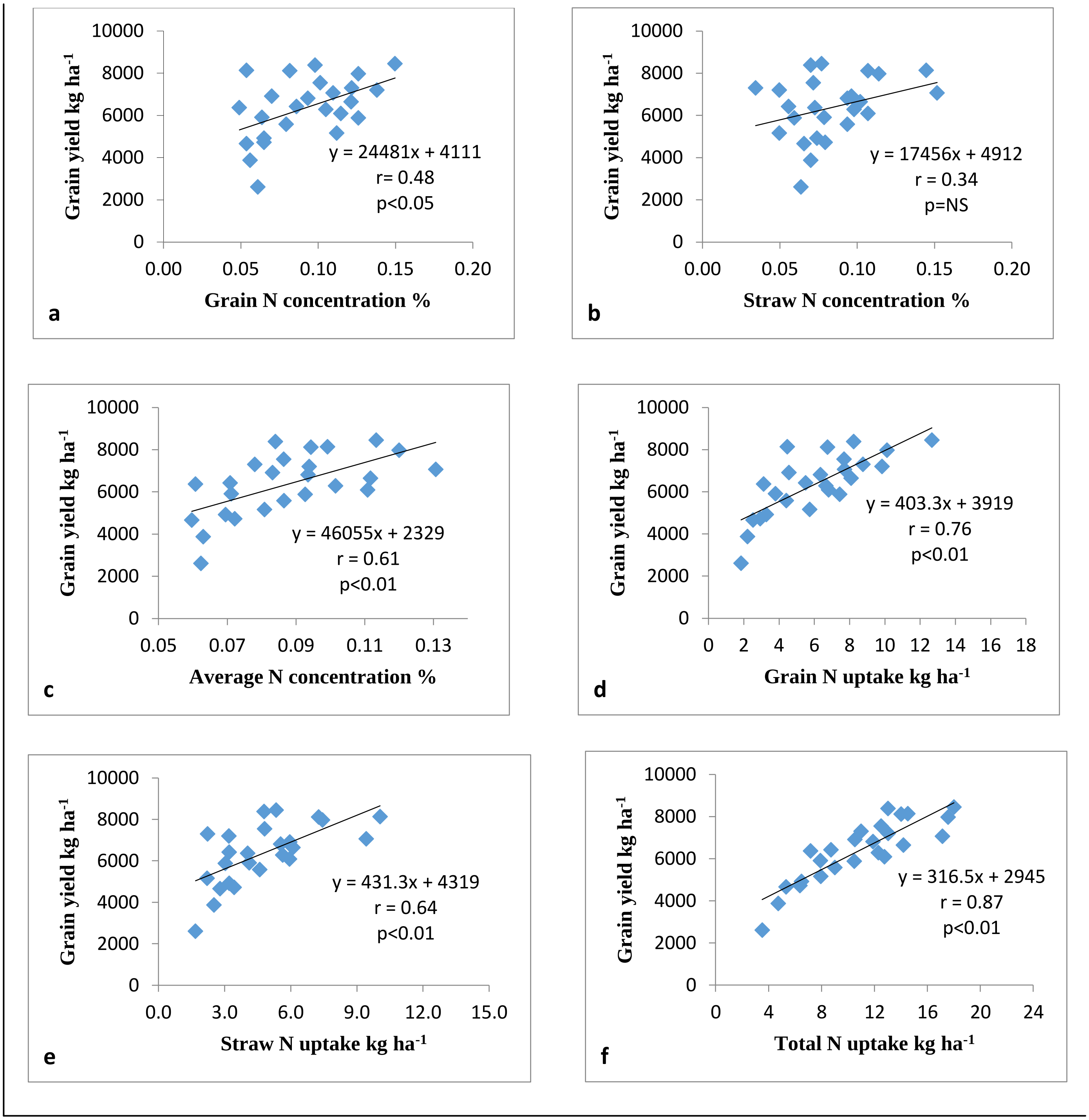


Figure 11 Relationships between grain concentration, straw concentration, average concentration, grain uptake, straw uptake and total N uptake of N and maize grain yield at Jimma in 2017

4.4.2 Effects of NPS fertilizer and compost on phosphorous uptake

The grain, straw and total P uptakes of the crop had significantly ($p<0.01$) affected by applications of NPS fertilizer and compost (Appendix table 5). The highest grain P, straw P and total P uptakes (71.19, 26.57 and 97.76 kg ha^{-1}) were recorded at 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea (100%) respectively and the lowest uptakes (31.91, 12.93 and 44.84 kg ha^{-1}) were recorded at control respectively (Table 9). The grain, straw and total P uptakes were increased by 123.10%, 105.49% and 118.02% respectively, in response to full recommended NPS fertilizer relative to the control. The result clearly showed the positive effects of P on maize grain and straw yields and the improvement of grain and straw P contents by application of NPS fertilizer. On other hand, the highest grain P, straw P and total P uptakes (62.32, 24.01, and 86.33 kg ha^{-1}) were recorded from application of 9.2 ton ha^{-1} compost respectively, while the lowest grain P, straw P and total P uptake (41.07, 15.55 and 56.62 kg ha^{-1}) were recorded at the control treatment respectively (Table 9). Generally, application of 9.2 ton ha^{-1} compost increased grain P and straw P uptake by 51.74 and 54.41% respectively and total P uptake by 52.47% when compared with the control.

Table 9 Effect of NPS fertilizer and compost on phosphorous concentration and uptake of grain and straw of maize at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	Grain P concentration (%)	Straw P concentration (%)	Average P concentration (%)	Grain P uptake kg ha^{-1}	Straw P uptake kg ha^{-1}	Total P uptake kg ha^{-1}
0+0	0.73c	0.30c	0.52b	31.91d	12.93c	44.84e
45.5+31.2	0.80bc	0.30c	0.55b	44.84c	14.66c	59.50d
91+62.4	0.85ab	0.37a	0.61a	57.00b	22.13b	79.13c
136.5+93.6	0.89a	0.33bc	0.61a	66.58a	20.95b	87.53b
182+124.8	0.92a	0.41a	0.67a	71.19a	26.57a	97.76a
Mean	0.84	0.34	0.59	54.30	19.45	73.75
LSD (0.05)	0.084	0.043	0.051	5.814	2.484	6.887
Compost (t ha^{-1})						
0	0.76	0.30c	0.53b	41.07c	15.55c	56.62d
2.3	0.85	0.36ab	0.61a	50.74b	19.34b	70.08c
4.6	0.88	0.31c	0.59a	59.87a	18.05b	77.92b
6.9	0.83	0.34bc	0.59a	57.52a	20.32b	77.84b
9.2	0.86	0.39a	0.63a	62.32a	24.01a	86.33a
Mean	0.84	0.34	0.59	54.30	19.45	73.75
LSD (0.05)	NS	0.043	0.051	5.814	2.484	6.887
CV (%)	13.68	17.16	11.75	14.58	17.40	12.72

*LSD = Least Significant Difference; CV = Coefficient of Variation; Values followed by the same letter(s) within the column are not significantly different at 0.05 probability level

As reported by Bereket *et al*. (2014), application of N fertilizer at the rate of 69 kg ha^{-1} resulted in significantly higher total P uptake compared to the nil N rates. Amsal and Tanner (2001) also reported that the grain P and straw P uptakes of crop increased in response to applied N rate by 45% at 164 kg N ha^{-1} relative to the control treatment. Getachew and Tekalign (2003) also noted increased P removal with increased N application, where nitrogen appeared to have stimulated root absorption of both native and fertilizer P. Likely, Sarwar *et al*. (2009) observed application of organic materials in the form of compost at the rate of 12 and 24 ton ha^{-1} enhanced the total phosphorus uptake in straw and grain.

As a consequence of the increased plant P uptakes by both application of NPS fertilizer and compost, the maize P uptake exhibited positive relationship with grain yield. The maize grain yield was positively and highly significantly correlated with total P uptake (r = 0.97**), grain P uptake (r = 0.94*) and straw P uptake (r = 0.79**) (Figure 12).

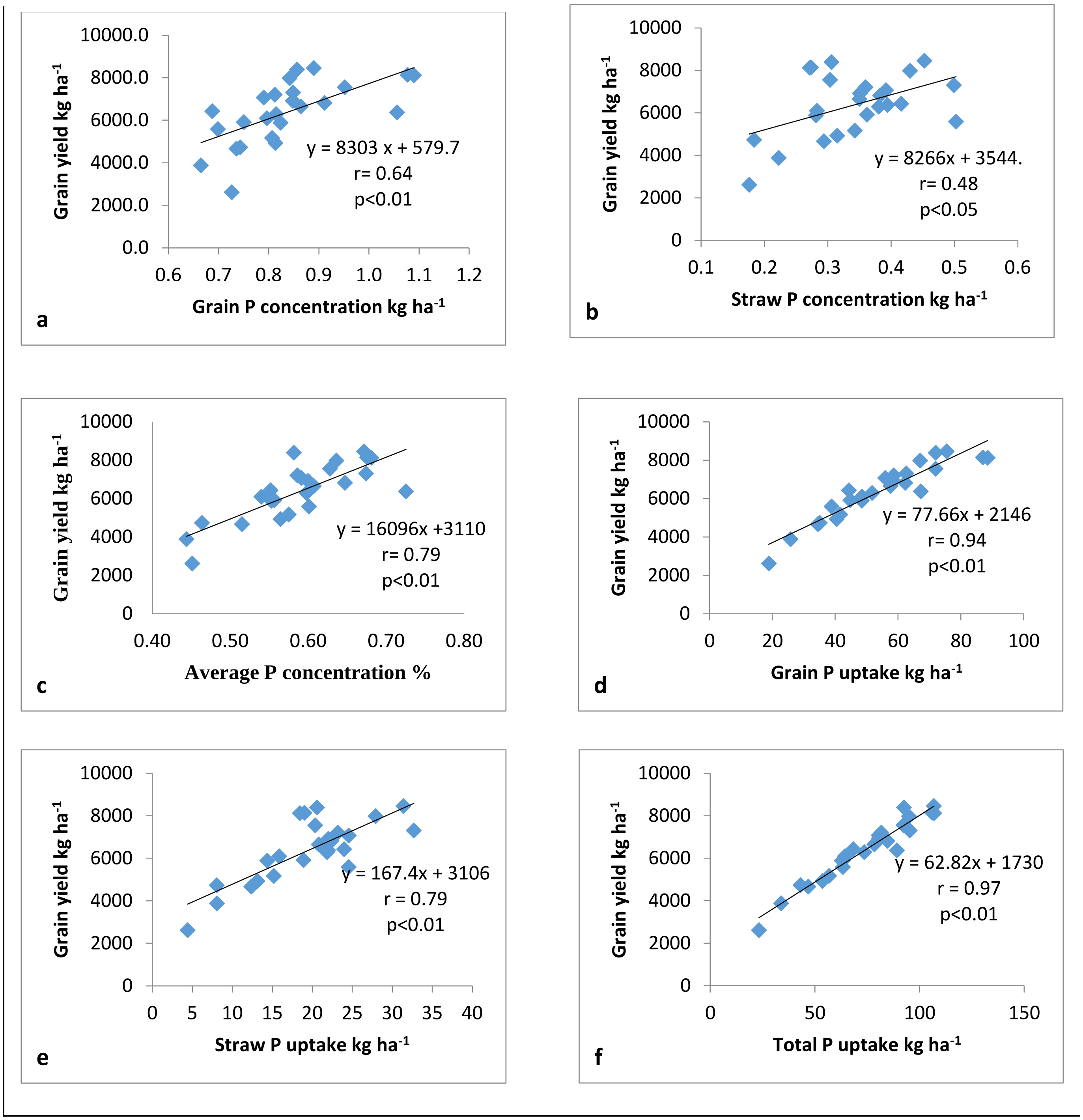


Figure 12 Relationships between grain P concentration (a), straw P concentration (b), average P concentration (c), grain P uptake (d), straw P uptake (e) and total P uptake (f) and maize grain yield at Jimma in 2017

4.5 Effect of NPS Fertilizer and Compost on Soil Nutrient Status after Harvest

The soil pH was not significantly (P>0.05) affected by interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 6). The soil pH after harvest was decreased under all treatments when compared to the initial soil pH (5.03). High manure in soil has the capacity to absorb or bind hydrogen ions in its humus forms while application of N fertilizers add hydrogen ions to the soil, hence, high acidity. There was a drop in the soil pH after harvest indicating an increase in soil acidity, with high NPK chemical fertilizer (Quansah, 2010).The decrease of soil pH resulted with higher doses of NPS fertilization was in line with the findings of Chodak *et al*. (2015) and Simansky *et al*. (2017).These results were also in line with finding of Goyal *et al*. (1999) who said there was no significant change in the pH of the soils in various treatments with different doses of inorganic fertilizers and organic amendments.

The soil total nitrogen was not significantly (P >0.05) affected by interaction of NPS fertilizer and compost, while highly significantly (P <0.01) affected by NPS fertilizer and compost as main factors (Appendix Table 6). Numerically among the treatments, the highest soil total nitrogen (0.192%) was recorded from full NPS fertilizer, which was statistically at par with 136.5 kg ha^{-1} +93.6 kg ha^{-1} urea (75%) and 45.5 kg ha^{-1} blended NPS fertilizer +31.2 kg ha^{-1} urea (25%) and the lowest total N (0.158%) was recorded from control (Table 10). The soil total nitrogen was increased by 21.5% from control treatment when full recommended NPS fertilizer applied. On other hand, numerically the highest total soil nitrogen (0.192%) was recorded from 9.2 ton ha^{-1} compost, which was not statistically significant from 6.9, 4.6 and 2.3 ton ha^{-1} compost, whereas the lowest soil total nitrogen (0.151%) was obtained from control treatment. The total soil nitrogen content was increased by 27.15% when 9.2 ton ha^{-1} compost applied when compared with no input of the compost.

The soil N after harvest was increased in all treatments of NPS fertilizer and compost when compared to the initial soil N (0.13%).The soil N content was increased by 21.54%, 38.46%, 24.62%, 40.00% and 47.69% at control, 45.5 kg ha^{-1} blended NPS fertilizer+31.2 kg ha^{-1} urea, 91 kg ha^{-1} blended NPS fertilizer+62.4 kg ha^{-1} urea, 136.5 kg ha^{-1} blended NPS fertilizer

+93.6 kg ha^{-1} urea and 182 kg ha^{-1} blended NPS fertilizer +124.8 kg ha^{-1} urea respectively. Also the soil N content after harvest was increased by 16.15%, 41.54%, 33.85%, 33.08% and 47.69% at 0, 2.3, 4.6, 6.9 and 9.2 ton ha^{-1} compost respectively. Synergistic effects of organic manures with inorganic fertilizers accumulate more total nitrogen in soils (Huang *et al.,* 2007).The higher concentrations of available N in soils after nitrogen dose has been emphasized by Dubey *et al*. (2012) who reported that continuous use of nitrogenous fertilizers increased the available N status of the soil. Organic fertilizers typically release nutrients (macro and micro-nutrients) gradually and supply the crop throughout the growing period (Adediran *et al*., 2005).

Available soil phosphorus was highly significantly ($P<0.01$) affected by interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 6). Numerically, the highest 9.76 mg kg^{-1} available P was obtained from the plot with combined applications of 136.5 kg ha^{-1} blended NPS+93.6 kg ha^{-1} urea (75%) and 9.2 ton ha^{-1} (100%) compost, whereas the lowest available P 2.40 mg kg^{-1} was obtained from the control plot (Table 11). The available soil P was increased by 306.67 % as compared to control treatment. When compared with initial soil available P (4.42 mg kg^{-1}), it was decreased in all treatments after harvest, except at 136.5 kg ha^{-1} blended NPS fertilizer +93.6 kg ha^{-1} urea (75%) combined with 4.6, 6.9, 9.2 ton ha^{-1} compost and full rate of NPS fertilizer combined with 6.9 ton ha^{-1} compost with an increase of 16.06%, 86.65%, 120.82%, 3.17% respectively. Changes in soil available P was generally low in all plots due to P is relatively immobile and strongly adsorbed by soil particles (Ige *et al*., 2005), P uptake of the crop and its transformation in the soil (Singh *et al*., 2011; Sharma *et al*., 2012). Also this situation can be attributed due to the high phosphorous fixing capacity of acid soil. Marschner (1995) stated in most cases, soils with pH values less than 5.5 are deficient in P. The use of organic manure has been shown to increase the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and thus improves the available P content in the soil (Zsolnay and Gorlitz *et al*., 1994). The decomposition of organic inputs produces organic acids that may dissolve (solubilize) phosphate rock. The combination of phosphate rock with compost has been shown to increase the availability of phosphorus (Negassa *et al.*, 2003).

Soil organic carbon (SOC) was not significantly (P>0.05) affected by interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 6). In all treatments the SOC was decreased when compared to the initial SOC (3.18%). It was in range of 1.93%-2.11% for NPS fertilizer application rates and 2.02%-2.09% for compost application rates (Table 10) which was in the range of 1.8-3.0% to achieve a good soil structural condition and structural stability (Charman and Roper, 2007). An increase chemical fertilizer dose can be enhanced mineralization and resulted in unstable organic compounds. The application of compost increase soil organic matter content and the effect was more pronounced in the third year than the first and second year (Zhang *et al*., 2016). Organic manures play a dominant role in soil fertility management in the tropics through their short-term effects on nutrient supply and longer-term contribution to soil organic matter formation (Palm *et al.*, 2001). Munkholm *et al*. (2002) also stated that under some conditions, fertilizers may decrease SOC concentration. In the long-term, inorganic fertilization alone proved unable to increase SOC concentration (Chandel *et al*., 2010). Simansky *et al*. (2017) showed that there were no statistically significant differences between the SOC due to N fertilization. Application of fertilizer to the soil can increase mineralization (Jagadamma *et al*., 2007) and this negatively affects the stability of organic substances and overall quality of SOM (Zalba and Quiroga, 1999).

Cation exchange capacity (CEC) of the soil had not significantly (P>0.05) affected by the interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost (Appendix Table 6).

Soil bulk density had not significantly (P>0.05) affected by the interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer, while highly significantly (P<0.01) affected by compost (Appendix Table 6). The lowest bulk density (1.12g cm^{-3}) was recorded at 9.2 ton ha^{-1} compost, while the highest (1.20 g cm^{-3}) was obtained from the control treatment (Table 10). By application of 9.2 ton ha^{-1} compost the soil bulk density was decreased by 6.67% as compared to the control treatment. The soil bulk density after harvest was decreased in all treatments of compost application when compared to the initial soil bulk density (1.20 g cm^{-3}) and it was decreased by 4.17%, 5.00%, 5.00% and 6.67% at 2.3, 4.6, 6.9

and 9.2 ton ha^{-1} compost respectively. The soil bulk density is an indicator of soil compaction and soil health. It affects infiltration, rooting depth/restrictions, available water capacity, soil porosity, plant nutrient availability and soil microorganism activity, which influence key soil processes and productivity. The soil with organic manure had lower bulk density and higher porosity values, porous and buffering capacities (Edmeades, 2003). This finding was in line with finding of Rong *et al*. (2016) who said soil bulk density has a lower value under high organic manure treatment. The highest value of bulk density was obtained for recommended dose of NPK (1.46 g cm^{-3}) and lowest value was obtained for control treatment (Malik *et al*., 2014). Also Mahmood *et al*. (2017) found that plots treated with organic manures substantially reduced soil bulk density. Values of soil bulk density ranges from less than 1 g cm^{-3} for soils high in organic manure, 1.0 to 1.4 g cm^{-3} for well- aggregated loamy soils and 1.4 to 1.8 g cm^{-3} for sands and compacted horizons in clay soils (White, 1997).

The maize grain yield was significantly and positively correlated with soil available P (r = 0.58**), total N (r = 0.49**), but it was negatively and not correlated with soil bulk density (r=-0.15) (Figure 13). The positive correlations between soil total N and available P with grain yield indicates the soil nutrient status may affect grain yield and its components directly. These results were in confirmatory with Lima *et al.* (2009) who stated that incorporation of organic manures improves soil physico-chemical properties that may have a direct or indirect effect on plant growth and yield attributes. These findings were also in line with finding of Mahmood *et al*. (2017) who said a significant positive correlation was found among grain yield, soil total N and available P, whilst the negative and non-significant correlation was found among maize grain yield and soil bulk density.

Table 10 Effect of NPS fertilizer and compost on some chemical and physical properties of soil after harvest at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	pH	Total N (%)	Organic Carbon (%)	CEC(cmol(+) kg^{-1} of soil)	Bulk density (g cm^{-3})
0+0	4.78	0.158c	1.93	13.49	1.14
45.5+31.2	4.73	0.180ab	2.07	13.44	1.14
91+62.4	4.71	0.162bc	2.07	14.00	1.16
136.5+93.6	4.70	0.182a	2.11	13.54	1.14
182+124.8	4.65	0.192a	2.09	14.06	1.17
Mean	4.71	0.175	2.05	13.71	1.15
LSD (0.05)	NS	0.0195	NS	NS	NS
Compost (ton ha^{-1})					
0	4.69	0.151b	2.02	13.48	1.20a
2.3	4.68	0.184a	2.04	13.67	1.15b
4.6	4.74	0.174a	2.09	13.69	1.14bc
6.9	4.73	0.173a	2.05	13.92	1.14bc
9.2	4.72	0.192a	2.09	13.77	1.12c
Mean	4.71	0.175	2.05	13.71	1.15
LSD (0.05)	NS	0.0195	NS	NS	0.029
CV (%)	3.15	15.21	8.21	10.06	3.38

*CEC= Cation exchange capacity; LSD = Least Significant Difference; CV = Coefficient of Variation; Ns= Non significant; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

Table 11 Interaction effects of NPS fertilizer and compost on soil available phosphorous at Jimma in 2017

Blended NPS+ Urea (kg ha^{-1})	Available Phosphorous (mg kg^{-1})				
	Compost rate (ton ha^{-1})				
	0	2.3	4.6	6.9	9.2
0+0	2.40f	3.02cdef	2.68def	3.19cdef	3.07cdef
45.5+31.2	3.39bcdef	2.61def	3.80bcdef	2.65def	4.37bcd
91+62.4	2.56ef	2.49f	4.33bcde	3.83bcdef	4.32bcde
136.5+93.6	3.16cdef	3.31cdef	5.13b	8.25a	9.76a
182+124.8	2.93cdef	3.79bcdef	3.01cdef	4.56bc	4.00bcdef
Mean			3.86		
LSD (0.05)			1.804		
CV (%)			28.49		

*LSD = Least Significant Difference; CV = Coefficient of Variation. Means values followed by the same letter(s) within the column or row are not significantly different at 0.05 probability level

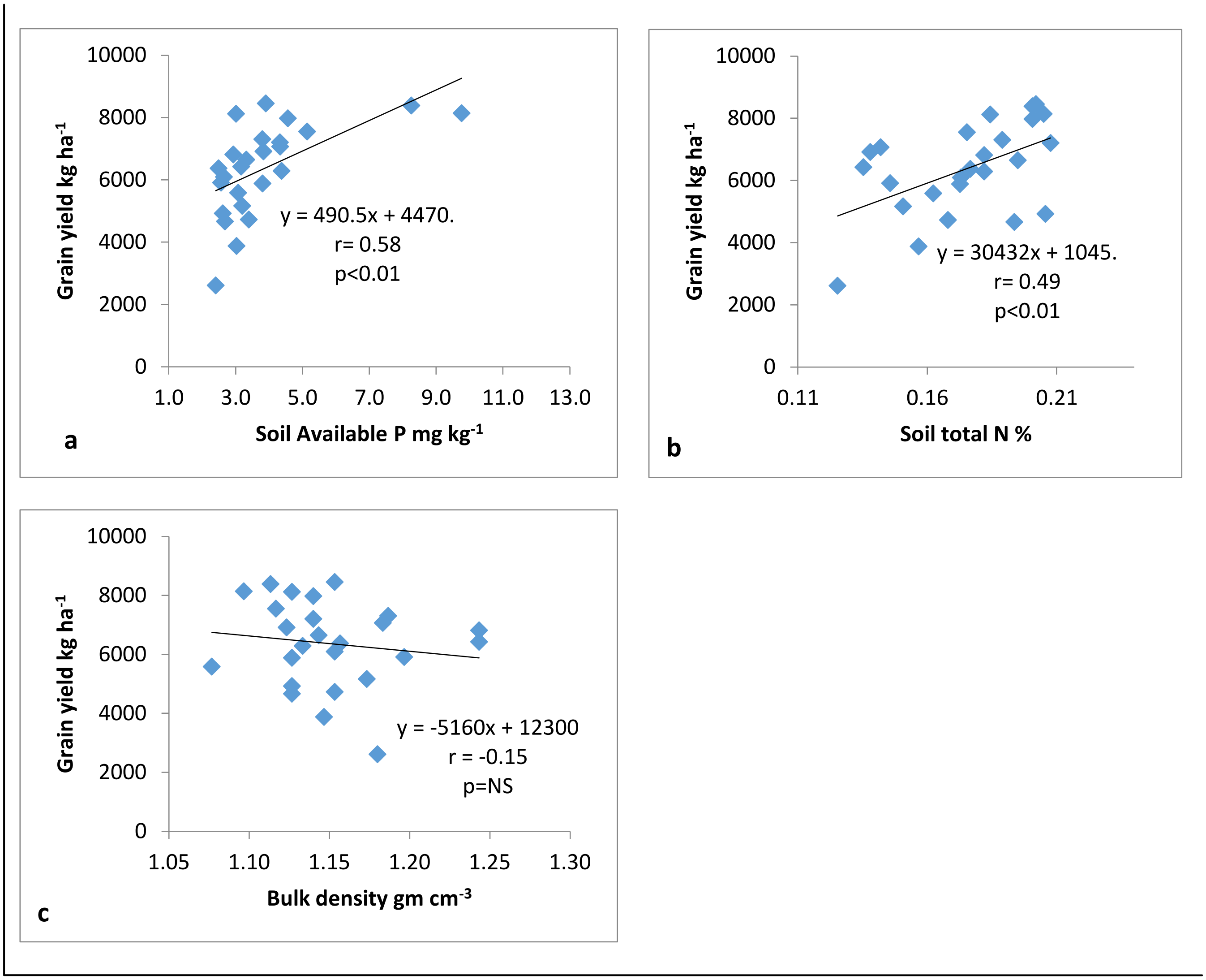


Figure 13 Relationships between soil available P (a), total N (b) and bulk density (c) with maize grain yield at Jimma in 2017

4.6 Economic Analysis

The open market price (6 birr kg^{-1}) for maize crop and the official prices of NPS (13 birr kg^{-1}), urea (10 birr kg^{-1}) and the cost of labor spent on compost preparation, transport and incorporation were used for analysis. The cost of application and transport for fertilizer was taken to be 15 birr 100 kg^{-1}. Grain yield was adjusted by 10% for management difference to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment (Getachew and Taye, 2005, CIMMYT, 1988). The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments. Dominance analysis led to the selection of treatments ranked in increasing order of total variable costs (Table 12). For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of un-dominated treatments was the return per unit of investment in fertilizer (both NPS fertilizer and compost). It was calculated by dividing the change in net benefit to the change in variable costs. 100% MRR means for every 1 birr invested in fertilizer cost, cost of application and transportation for both NPS fertilizer and compost, farmers can expect to recover 1 birr and obtain an additional 1 birr (CIMMYT, 1988).

The highest net benefit (40925.46 ETB) with MRR 1228.61% was obtained from combined application of 136.5 kg ha^{-1} blended NPS fertilizer +93.6 kg ha^{-1} urea (75%) and 6.9 ton ha^{-1} (75%) compost followed by a net benefit of (36754.34 ETB) with MRR 645.87% by combined application of 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%) and 4.6 ton ha^{-1} (50%) compost (Table 13). On other hand, the lowest net benefit (14,108.58 ETB) was obtained from the control treatment. Due to application of 136.5 kg ha^{-1} blended NPS fertilizer +93.6 kg ha^{-1} urea (75%) with 6.9 and 4.6 ton ha^{-1} compost, there was net benefit increase by 188.26% (25,085.22 birr) and 158.84% (21,164.69 birr) when compared with control respectively, whereas 24.11% (7950.24 birr) and 11.46% (3779.12 birr) net benefit increase over the full rate of NPS fertilizer respectively.

Since the minimum acceptable rate of return assumed in this experiment was 100%, therefore 2.3, 6.9, 9.2 ton ha^{-1} compost; 45.5 kg ha^{-1} blended NPS fertilizer+31.2 kg ha^{-1} urea, 91 kg ha^{-1} blended NPS fertilizer+62.4 kg ha^{-1} urea; combined application of 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%) with 6.9 and 4.6 ton ha^{-1} compost; 91 kg ha^{-1} blended NPS fertilizer+62.4 kg ha^{-1} urea (50%) with 4.6 and 2.3 ton ha^{-1} compost had met the requirement (Table 13). The highest MRR 1719.50% was obtained from application of 45.5 kg ha^{-1} blended NPS fertilizer+31.2 kg ha^{-1} urea (25%). But the recommendation is not (necessarily) based on the highest MRR, because when farmers stopped there, they would miss the opportunity for further earning, at an attractive rate of return, so the farmers will continue to invest as long as the returns to each extra unit invested (measured by MRR) are higher than the cost of extra unit invested (measured by minimum acceptable rate of return) (CIMMYT, 1988).

Market prices are ever changing and as such a recalculation of the partial budget using a set of likely future prices *i.e*., sensitivity analysis, was essential to identify treatments which may likely remain stable and sustain satisfactory returns for farmers despite price fluctuations. The sensitivity analysis study indicates an increase in the field price of blended NPS fertilizer, urea, labor costs for transportation and application of inorganic fertilizers as well as the labor costs for compost preparation, transportation and incorporation, and a fall in the price of maize grain, which represented a price variation of 15% (Table 14).

The price changes are realistic under market conditions prevailing at Jimma area which were above the minimum acceptable MRR of 100% for application of 2.3, 6.9, 9.2 ton ha^{-1} compost; 45.5 kg ha^{-1} blended NPS fertilizer+31.2 kg ha^{-1} urea (25%) and 91 kg ha^{-1} blended NPS fertilizer+62.4 kg ha^{-1} urea (50%); 91 kg ha^{-1} blended NPS fertilizer combined+62.4 kg ha^{-1} urea (50%) with 2.3 and 4.6 ton ha^{-1} compost; and 136.5 kg ha^{-1} blended NPS fertilizer +93.6 kg ha^{-1} urea (75%) combined with 4.6 and 6.9 ton ha^{-1} compost (Table 14). Thus, those treatments were above the minimum acceptable marginal rate of return, those treatments could be recommended as alternative sources for users (CIMMYT, 1988). These results agree with Saha *et al*. (1994) whose findings from coastal Kenya on maize showed that the application of 30 kg N ha^{-1} consistently gave acceptable economic returns.

Table 12 Partial budget with dominance analysis for the combined effects of NPS fertilizer and compost on maize grain yield at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	Compost (ton ha^{-1})	GY (kg ha^{-1})	Adj.GY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Dominance
0+0	0	2612.70	2351.43	14108.58	0.00	14108.58	
0+0	2.3	3878.10	3490.29	20941.74	781.50	20160.24	
45.5+31.2	0	4727.20	4254.48	25526.88	1033.50	24493.38	
0+0	4.6	4664.50	4198.05	25188.30	1121.00	24067.30	D
0+0	6.9	5165.30	4648.77	27892.62	1460.50	26432.12	
0+0	9.2	5583.90	5025.51	30153.06	1800.00	28353.06	
45.5+31.2	2.3	4923.80	4431.42	26588.52	1815.00	24773.52	D
91+62.4	0	5910.50	5319.45	31916.70	1963.00	29953.70	
45.5+31.2	4.6	5883.60	5295.24	31771.44	2154.50	29616.94	D
45.5+31.2	6.9	6093.90	5484.51	32907.06	2494.00	30413.06	
91+62.4	2.3	6370.70	5733.63	34401.78	2744.50	31657.28	
45.5+31.2	9.2	6287.00	5658.30	33949.80	2833.50	31116.30	D
136.5+93.6	0	6425.30	5782.77	34696.62	2892.50	31804.12	
91+62.4	4.6	7067.30	6360.57	38163.42	3084.00	35079.42	
91+62.4	6.9	6913.90	6222.51	37335.06	3423.50	33911.56	D
136.5+93.6	2.3	6648.20	5983.38	35900.28	3674.00	32226.28	D
91+62.4	9.2	7203.60	6483.24	38899.44	3763.00	35136.44	
182+124.8	0	6814.30	6132.87	36797.22	3822.00	32975.22	D
136.5+93.6	4.6	7549.60	6794.64	40767.84	4013.50	36754.34	
136.5+93.6	6.9	8384.90	7546.41	45278.46	4353.00	40925.46	
182+124.8	2.3	7304.40	6573.96	39443.76	4603.50	34840.26	D
136.5+93.6	9.2	8138.50	7324.65	43947.90	4692.50	39255.40	D
182+124.8	4.6	8120.10	7308.09	43848.54	4943.00	38905.54	D
182+124.8	6.9	7974.90	7177.41	43064.46	5282.50	37781.96	D
182+124.8	9.2	8453.20	7607.88	45647.28	5622.00	40025.28	D

*GY= Grain yield; GFB = Gross field benefit; TCV = Total cost that varied; NB = Net benefit; D=Dominated treatment; ETB = Ethiopian Birr; Price of NPS = 13birr kg^{-1}; Price of Urea = 10 birr kg^{-1}, Wage rate = 26 Birr man-day^{-1}; Retail price of grain = 6 birr kg^{-1}; 1USD = 27.51 ETB.

Table 13 Partial budget with estimated marginal rate of return (%) for combined application of NPS fertilizer and compost on maize grain yield at Jimma in 2017

Blended NPS + Urea (kg ha^{-1})	Compost (ton ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Raised cost	Raised benefit	MRR (%)
0+0	0	0.00	14108.58	-	-	-
0+0	2.3	781.50	20160.24	781.50	6051.66	774.36
45.5+31.2	0	1033.50	24493.38	252.00	4333.14	1719.50
0+0	6.9	1460.50	26432.12	427.00	1938.74	454.04
0+0	9.2	1800.00	28353.06	339.50	1920.94	565.81
91+62.4	0	1963.00	29953.70	163.00	1600.64	981.99
45.5+31.2	6.9	2494.00	30413.06	531.00	459.36	86.51
91+62.4	2.3	2744.50	31657.28	250.50	1244.22	496.69
136.5+93.6	0	2892.50	31804.12	148.00	146.84	99.22
91+62.4	4.6	3084.00	35079.42	191.50	3275.30	1710.34
91+62.4	9.2	3763.00	35136.44	679.00	57.02	8.40
136.5+93.6	4.6	4013.50	36754.34	250.50	1617.90	645.87
136.5+93.6	6.9	4353.00	40925.46	339.50	4171.12	1228.61

*TCV = Total cost that varied; NB = Net benefit; ETB = Ethiopian Birr; MRR= Marginal rate of return; Price of NPS = 13 birr kg^{-1}; Price of Urea = 10 birr kg^{-1}, Wage rate = 26 Birr man-day^{-1}; Retail price of grain = 6 birr kg^{-1}; 1 USD = 27.51 ETB.

Table 14 Sensitivity analysis of maize production based on a 15% rise in total cost and maize price of gross field benefit fall

Blended NPS + Urea (kg ha^{-1})	Compost (ton ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Raised cost	Raised benefit	MRR (%)
0+0	0	0.00	11992.29	-	-	-
0+0	2.3	898.73	16901.75	898.73	4909.46	546.27
45.5+31.2	0	1188.53	20509.32	289.80	3607.57	1244.85
0+0	6.9	1679.58	22029.15	491.05	1519.83	309.51
0+0	9.2	2070.00	23560.10	390.43	1530.95	392.12
91+62.4	0	2257.45	24871.75	187.45	1311.64	699.73
91+62.4	2.3	3156.18	26085.34	898.73	1213.59	135.03
91+62.4	4.6	3546.60	28892.31	390.43	2806.97	718.95
136.5+93.6	4.6	4615.53	30037.14	1068.93	1144.83	107.10
136.5+93.6	6.9	5005.95	33480.74	390.43	3443.60	882.01

*TVC = Total cost that varied; NB = Net benefit; ETB = Ethiopian Birr; MRR= Marginal rate of return

5. SUMMARY AND CONCLUSION

Declining soil fertility aggravated the challenge of agriculture to meet the world's increasing demand for food in a sustainable way. The information on the application of integrated NPS fertilizer and compost for maize production is lacking at Jimma condition. Therefore, this study was conducted to investigate the effect of integrated application of NPS fertilizer and compost on growth, yield and yield related parameters of quality protein maize at Jimma, southwestern Ethiopia.

The results revealed that individual as well as combined application of NPS fertilizer and compost improved growth, yield and yield components of the maize. The improvement was mainly due to availability of nutrients from both sources for plant development up to cob formation. The combined application of NPS fertilizer and compost increased grain yield mainly due to higher LAI, number of leaves per plant, stem girth, plant height, number of grains per row and better grain development. On other hand, application of NPS fertilizer and compost individually can uplift the number of ear per plant, ear length, ear diameter, number of grains per ear and 1000 grain weight which were contributed for overall higher grain yield and above ground biomass of maize.

The highest grain yield (8453.2 kg ha^{-1}) was recorded from full recommended NPS fertilizer combined with 9.2 ton ha^{-1} compost. This combination was statistically at par with combined application of full recommended NPS fertilizer with 4.6 and 6.9 ton ha^{-1} compost; 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%) with 4.6, 6.9 and 9.2 ton ha^{-1} compost. On other hand the lowest grain yield (2612.7 kg ha^{-1}) was recorded under the control. The shortest mean days to 50% tasseling (81.33 days), silking (83.33 days) and maturity (142.33 days) of maize were recorded from full recommended NPS fertilizer combined with 9.2 ton ha^{-1} compost, whereas the longest days (90.00, 94.00 and 153.00 days) were obtained from the control respectively.

The maize grain yield and above ground biomass was positively and highly significantly ($p<0.01$) associated with all growth, yield and yield parameters of maize. However, it was negatively and highly significantly ($p<0.01$) correlated with days to 50% silking, days to 50% tasseling and days to 90% maturity. The higher LAI, number of ears per plant, number of grains per ear, longer ear length, taller plant height, higher number of grains per cobs and heavier 1000 grain weight were the traits associated with good performance of maize.

The soil total N was significantly affected by NPS fertilizer and compost, soil available P was significantly affected by their interaction, whereas soil bulk density was significantly affected by compost application rates. The total N and available P were positively and highly correlated with maize grain yield, while soil bulk density was negatively and not correlated. Hence, NPS fertilizer and compost in nutrient deficient soils can increase crop productivity through improved soil physico- chemical properties.

The results of growth, yield, yield components and soil physico-chemical properties indicated the fertility of the soil at Jimma area was low because all fertilized treatments (NPS fertilizer, compost or combinations of the two) gave higher grain yield than control treatment which gave very low yield. Combined application of NPS fertilizer and compost gave better result than application of either of one. This indicated integrated nutrient management is the best approach for soil fertility management.

In conclusion, combined application of NPS fertilizer and compost improved soil physicochemical properties and performance of maize. Accordingly, the highest grain yield was obtained from combined application of 182 kg ha^{-1} blended NPS fertilizer+124.8 kg ha^{-1} urea (100%) and 9.2 ton ha^{-1} compost. From economic point of view, combined application of 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea and 6.9 ton ha^{-1} compost gave higher net benefit with acceptable MRR. However, this treatment was at par with combined application of 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea and 4.6 ton ha^{-1} compost. So farmers can integrate and apply 136.5 kg ha^{-1} blended NPS fertilizer+93.6 kg ha^{-1} urea (75%) with 4.6 ton ha^{-1} (50%) compost to sustain maize production. As this study was conducted for one season and at one location further study should be done to determine optimum rate of NPS fertilizer and compost integration to increase the crop production and further ascertain their effects on physico-chemical properties of the soil.

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7. APPENDIX

Appendix Table 1 Meteorological data during crop growth period at Jimma in 2017

Month	Rainfall (mm)	Min. Temp. (°C)	Max. Temp. (°C)	Mean Temp. (°C)
January	88.2	11.5	26.7	19.1
February	83.8	9.9	26.0	18.0
March	87.2	10.3	24.7	17.5
April	76.6	10.4	25.6	18.0
May	281.3	10.4	25.6	18.0
June	158.4	10.2	26.6	18.4
July	187.3	10.7	24.6	17.7
August	99.6	11.5	28.0	19.8
September	350.0	11.2	26.8	19.0
October	262.0	10.8	26.6	18.7
November	53.0	10.2	28.3	19.3
December	20.0	9.4	28.2	18.8
Mean		10.5	26.5	18.5

Source: Jimma Agricultural research center meteorology department, Melko.

Appendix Table 2 ANOVA table showing mean square values of growth parameters as influenced by NPS fertilizer, compost and their interaction at Jimma in 2017

		Mean Square			
Source	Df	DT	DS	Total leaf	LAI
NPS	4	82.900**	126.580**	6.9389**	3.1597**
Compost	4	5.867**	6.847**	2.2509**	0.6364**
NPS*Compost	16	2.183*	3.905**	0.2618*	0.0455**
Error	48	0.9717	1.3711	0.1242	0.0152

DF = degree of freedom; DT = Days to tasseling; DS = Days to silking and LAI = Leaf Area Index;*Significant ($P < 0.05$); ** highly significant ($p<0.01$) difference.

Appendix Table 2 (Continued)

Source	Df	Mean Square		
		SG	MD	PH
NPS	4	0.2997**	148.9200**	6247.7531**
Compost	4	0.1198**	10.6867**	1137.4545**
NPS*Compost	16	0.0241*	3.1950*	1345.0098**
Error	48	0.0123	1.3928	152.6968

DF = degree of freedom; SG = Stem Girth; MD = Maturity Date; PH = Plant Height;*****Significant (P < 0.05); ** highly significant (p<0.01) difference.

Appendix Table 3 ANOVA table showing mean square values of yield parameters as influenced by NPS fertilizer, compost and their interaction at Jimma in 2017

Source	Df	Mean Square					
		EP	EL	GRE	GR	GE	ED
NPS	4	0.077*	8.322**	0.925ns	26.610**	11328.886**	0.105**
Compost	4	0.143**	1.738**	0.372ns	6.421**	3054.911**	0.052**
NPS*Compost	16	0.032ns	0.295ns	0.301ns	1.815**	1195.507ns	0.006ns
Error	48	0.025	0.343	0.411	0.6543	726.441	0.004

DF = degree of freedom; EP = Number of ear per plant; EL= Ear length; GRE = Number of grain row per ear; GR = Number of grain per row; GE = Number of grain per ear; ED = Ear diameter; Ns= non-significant; *****Significant (P < 0.05);** highly significant (p<0.01) difference.

Appendix Table 4 ANOVA table showing mean square values of yield and yield parameters as influenced by NPS fertilizer, compost and their interaction at Jimma in 2017

Source	Df	Mean Square			
		TSW	GY	AGB	HI
NPS	4	2188.550**	28728692.6**	91852472.5**	7.8172647**
Compost	4	963.234**	8995671.0**	27872311.9**	4.0121447*
NPS*Compost	16	108.523ns	6476318.2**	20529826.0**	2.5922913ns
Error	48	86.358	484178.4	1046442.7	1.4723154

DF = Degree of freedom; TSW = Thousand seed weight; GY = Grain yield; AGB = above ground biomass; HI = Harvest Index; ns = non-significant; *****Significant (P < 0.05); ** highly significant (p<0.01) difference.

Appendix Table 5 ANOVA table showing mean square values of crop nutrient uptake as influenced by NPS fertilizer, compost and their interaction at Jimma in 2017

Source	Df	Mean Square					
		GNU	SNU	TNU	GPU	SPU	TPU
NPS	4	62.2996**	23.7260**	151.0966**	3877.630**	471.339**	6879.199**
Compost	4	31.6314**	16.5685**	91.2472**	1100.784**	145.139**	1871.320**
NPS*Compost	16	10.9455**	11.2852**	12.4013ns	164.160**	59.785**	124.317ns
Error	48	4.1672	1.5599	6.8684	62.716	11.447	87.992

DF = degree of freedom; GNU= Grain N uptake; SNU= Straw N uptake; TNU=Total N uptake; GPU= Grain P uptake; SPU= Straw P uptake; TPU=Total P uptake; Ns = non-significant; *****Significant (P < 0.05); ** highly significant (p<0.01) difference.

Appendix Table 6 ANOVA table showing mean square values of selected physico-chemical properties of soil as influenced by NPS fertilizer, compost and their interaction at Jimma in 2017

Source	Df	Mean Square					
		pH	Total N	Av. P	OC	CEC	BD
NPS	4	0.03696ns	0.00309**	21.21762**	0.06971ns	1.33825ns	0.00288ns
Compost	4	0.00847ns	0.00354**	13.18304**	0.01287ns	0.37869ns	0.01512**
NPS*Compost	16	0.01658ns	0.00108ns	8.92676**	0.04407ns	3.14541ns	0.00257ns
Error	48	0.02203	0.00071	1.20949	0.02844	1.90222	0.00151

DF = degree of freedom; Total N= Total Nitrogen; Av. P= Available phosphorus; OC = Organic carbon; CEC = Cation exchange capacity; BD = Bulk density; Ns = non-significant;*****Significant (P < 0.05);** highly significant (p<0.01) difference.

Appendix Figure 1 Different pictures during research period