EFFECTS OF BLENDED NPS FERTILIZER RATES AND INTER ROW SPACING ON YIELD COMPONENTS AND YIELD OF MAIZE (*Zea mays* L.) AT HARAMAYA, EAST ETHIOPIA

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As research Advisors, We hereby certify that we have read and evaluated this Thesis prepared under our guidance by Abdurahman Nure, entitled "**Effects of Blended NPS Fertilizer Rates and Inter Row Spacing on Yield components and Yield of Maize (*Zea mays* L.)** at Haramaya University, East Ethiopia." And we recommended that it be submitted as fulfilling the thesis requirements.

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As members of the Board of Examiners of the MSc. Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Abdurahman Nure and examined the candidate. We recommend that the Thesis be accepted as fulfilling the Thesis requirement for the degree of Master of Sciences in Agriculture (Agronomy).

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DEDICATION

This thesis manuscript is dedicated to my wife Dastu Ahmed, Abdurahman and my family for their selfless sacrifices throughout my educational career.

STATEMENT OF THE AUTHOR

First of all, I declare that this thesis is a result of my honest work and all sources of materials used for writing it have been duly acknowledged. I have submitted this thesis to Haramaya University in partial fulfillment of the Degree of Master of Science. The thesis will be deposited at the library of the University to be made available to borrowers for reference.

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BIOGRAPHICAL SKETCH

The author, Abdurahman Nure Alisho, was born at Melka Balo Woreda, East Hararghe Zone, Oromia, Ethiopia on the 12 October 1988 to his father Nure Alisho and his mother Asiya Musa. When he reached school age he attended his primary education at Harew Elementary School from 1995-2003. Then, he joined Deder Secondary School from 2004-2005 and Deder Preparatory School from 2005-2007. After completing Preparatory School education, he joined Jimma University in 2008 to pursue a study leading to the Degree of Bachelor of Sciences in Crop Science, and graduated on 11 After July 2010.

After graduation, he was employed by Melka Balo Woreda Rural Development and Agricultural Office as crop production and protection expert and then he joined Melka Balo Woreda Agriculture Office as Coordinators office and Woreda Administrator, Bale Zone coffee and tea authority until he joined Haramaya University on July 2019 to pursue a study leading to the Degree of Master of Sciences in Agriculture (Agronomy).

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ABBREVIATIONS AND ACRONYMS

AGR	Africa Agriculture Status Report
ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CGR	Crop Growth Rate
CSA	Central Statistical Agency
CV	Coefficient of Variation
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agriculture Organization Statistics
HI	Harvest Index
LSD	Least Significant Difference
m.a.s.l.	Meters above sea level
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MRR	Marginal rate of return
NB	Net Benefit
OC	Organic Carbon
OM	Organic Mater
RCBD	Randomized Complete Block Design
TV	Total Variable Cost

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ABSTRACT

Maize is becoming an important cereal crop in Ethiopia due to its use as sources of food security and generated income. However, its productivity is constrained by insufficient application of NPS fertilizer rate and different inter row spacing. Thus, afield experiment was conducted at Haramaya to assess the effects of application of different rates of blended NPS fertilizer and inter- row spacing on growth, yield components and yield of maize and to estimate the cost benefit analysis of blended NPS fertilizer application on yield of maize under main cropping season in 2019/2020. The experiment was arranged in a factorial combination of five levels of NPS fertilizer rate (0, 50, 100, 150 and 200 kg NPS ha^{-1}) and four inter- row spacing (55 cm, 65 cm, 75 cm and 85 cm) in randomized complete block design with three replications. The result revealed that main effect of blended NPS fertilizer was highly significant ($p<0.01$) effect on days to 50% anthesis, days to 50% silking, 90% physiological maturity, leaf area, leaf area index, plant stand count at harvest and number of kernel per ear. The highest days to 50% anthesis (82 days), days to 50% silking (85 days), 90% physiological maturity (128 days), leaf area (8620 cm^2), leaf area index (4.69), plant stand count at harvest (96.25%), number of kernel per ear (472.3) were recorded from the main effects of blended NPS fertilizer of 200 kg NPS ha^{-1}. NPS fertilizer rates had also significantly ($P<0.05$) effect on harvest index and thousand kernel weight. The highest harvest index (30.4%) recorded from 200 NPS kg ha$^{-.1}$ and thousand kernel weight (398.7g) where recorded from150 NPS kg ha^{-1}. The main effects of inter row spacing highly significantly ($p<0.01$) effect on days to 50% anthesis, days to 50% silking, leaf area, and plant stand count. The highest days to 50% anthesis (80.25 days), days to 50% silking (86.08 days), leaf area (8463 cm^2), and plant stand count (94%) were recorded from the 85 cm inter-row spacing. Inter-row spacing also had significant ($P<0.05$) effect on physiological maturity and number of kernel per ear, thousand kernel weight. Highest days to physiological maturity (126) and number of kernel per ear (467) were recorded 85 cm while, highest kernel weight (389 g) recorded from 75 cm. The interaction effects of NPS fertilizer and inter- row-spacing, highly significant ($p<0.01$) effects on the number of ears per plant, number of ears per hectare, ear length, agronomic efficiency and grain yield. The highest number of ears per plant (1.47),number of ears per hectare (69976), ear length (29 cm), agronomic efficiency (25.06) and grain yield (6577 kg ha^{-1}) were recorded from the application of 150 kg NPS ha^{-1} at 75 cm inter-row spacing whereas the highest plant height (265.3 cm) and above ground biomass (20667 kg ha^{-1}) were recorded from the application of 200 kg NPS ha^{-1} at 55 cm inter-row spacing. The highest economic benefit (91,608 Birr ha^{-1}) and higher acceptable MRR (1745%) was obtained from the combination of 150 kg NPS ha^{-1} and 75 cm inter-row spacing. Thus it can be concluded that application of 150 kg NPS ha^{-1} with inter-row spacing of 75 cm was found to be superior both agronomically and economically for grain yield of Melkassa-II variety under main cropping season in the study area.

Keywords: Fertility; grain yield; inter-row spacing; maize; NPS fertilizer; plant density

1. INTRODUCTION

Maize (*Zea mays* L.) is an important crop in many parts of the developing world. It occupies the third place after wheat and rice (FAO, 2018). Supplying nutritious, safe, and affordable food to a growing population is one of the far most burning issues currently facing Africa to fulfill food security in the region (AGRA, 2013). Maize is recognized worldwide as a strategic food and feed crop that provides an enormous amount of protein and energy for humans and livestock. Its advantages in the ethanol industry also keep maize in high demand.

Ethiopia is among the countries in which maize is highly cultivated and utilized for different purpose. It ranks second after teff in area coverage and first in total production and it is one of the most important cereals broadly adapted worldwide (Christian *et al.,* 2012). It is the top ranking cereal in grain yield per hectare and is the most productive species of food crops and its demand is projected to increase by 50% worldwide and by 93% in sub-Saharan Africa between 1995 and 2020 (FAO, 2016). Maize grows well below 500 to over 2400 m.a.s.l, the major production zone being between 1000 to 2000 m.a.s.l in Ethiopia. It is currently grown across 13 agro-ecological zones which together cover about 90 percent of the country.

However, there are a number of factors which are responsible for the low production and productivity of maize in Ethiopia. Among these poor agronomic practices like inappropriate seed rate, row and plant spacing, poor soil fertility, drought, insects, diseases and weeds, farmers' limited access to fertilizers, and low access to seeds of improved maize varieties (Shiferaw *et al., 2*011*)*. One of the major problems constraining the development of an economically successful agriculture is nutrient deficiency (Fageria & Baligar, 2005). In many parts of Africa including Ethiopia, repeated cultivation of land with inappropriate farming methods is causing severe depletion of nutrients and soil organic matter, posing serious threat to agricultural productivity and sustainability (Endris and Dawid, 2015).

Declining soil fertility from time to time due to natural and human made factors are serious bottle necks for crop production in Ethiopia. Besides, lack of appropriate fertilizer blends and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity (Fufa *et al*., 2011). Therefore, supply of nutrients at an appropriate amount is always imperative for better growth and development of a crop (Ali & Anjum, 2017). Application of essential plant nutrients in optimum quantity and right proportion, through correct method and time of application, is the key to increased and sustained crop production (Cisse and Amar, 2000). Chimdessa (2016) also reported that blended fertilizers increased maize productivity compared to the previously existing NP and application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production. Therefore, Nutrient inputs from chemical fertilizers are needed to replace nutrients which are removed and lost during cropping, to maintain positive nutrient balance (Buah and Mwinkaara, 2009). Nitrogen is one of chemical fertilizers plays an important role in crop life is one of the most important nutrients needed by plants in large quantities. Torbert *et al.* (2001) found that N application increased yield and yield components of maize. It plays an important role in crop life and is one of the most important nutrients needed by plants in large quantities.

It is essential to know the best level of nitrogen application for getting a higher crop yield so that maximum benefits could be achieved. Many investigators like Samira *et al*. (1998) and Torbert *et al*. (2001) found that N application increased yield and yield components of maize. Likewise (Hefny and Aly, 2008) reported that it is one of the most limiting macro nutrients to maize grain yield Worldwide. Nitrogen availability influences the uptake, not only of itself, but also of other nutrients (Onasanya *et al.,* 2009), as N-fertilized plants usually have larger root systems, which enhances the capture of other nutrient.

On the other hand, in addition to nitrogen, phosphorus and sulphur in major Ethiopian soils they studied were found very low (Bellete, 2014). This is due to loss of organic matter, macro-and micro-nutrients depletion, soil acidity, topsoil erosion and deterioration of physical soil properties (Zeleke *et al*., 2010).

Phosphorus is another important element which increases maize production (Chen *et al*., 1994). It play role in reproductive system in plants and in majority of soils. Consequently, the lack of phosphorus is as important as the lack of nitrogen in limiting maize performance. The importance of phosphorus as yield limiting factor in many Nigerian soils is well established (Adepetu, J.A., 1993). Phosphorus plays an important part in many physiological processes that occur within a developing and maturing plant. It is involved in cell division because it is constituent element of nucleoproteins which are involved in the cell reproduction processes. It is also a component of a chemical essential to the reactions of carbohydrate synthesis and degradation. Besides this, it is also important for seed and fruit formation and crop maturation.

Likewise, sulphur is recognized as the fourth major nutrient after N, P and K. On an average maize crop absorbs as much S as it absorbs P. Their deficiency results in stunted growth, reduced plant height, tillers, spikelet and delayed maturity. When S is deficient in soil, full yield potential of the crop cannot be realized regardless of other nutrients even under good crop husbandry practices (Tandon 1989). It is required for synthesis of S containing amino acid such as cysteine and methionine.

Plant density also one of the most important cultural practices determining grain yield, as well as other important agronomic attributes of this crop (Sangoi, 2000). Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Casal *et al*., 1985). At low densities, many modern maize hybrids do not tiller effectively and quite often produce only one ear per plant. Therefore, maize does not share the trait of most tillering grasses of compensating for low leaf area and small number of reproductive units by branching (Gardner *et al*., 1985). Grain yield increased with increasing plant density until production factors were not limiting (Anjum *et al.,* 1992).

Optimum inter and intra row spacing increased number of grains cob^{-1}, 1000 grain weight and grain yield of maize (Sabir *et al.,* 1987). (Muhammad *et al*., 2006) also indicated that there was maximum grain yield of 6.6 tons ha^{-1} maize against the minimum 3.28 tons ha^{-1} at narrow spacing, although narrow plant spacing (55 cm) caused substantial reduction in yield components such as grain and 1000 kernel weight compared to the wide plant spacing. On the other hand, the use of high populations enhances interplant competition for light, water and nutrients. This may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears produced per plant and kernels set per ear (Sangoi and Salvador, 1998). For each production system, there is a population that maximizes the utilization of available resources, allowing the expression of maximum attainable grain yield on that environment (Sangoi, 2000).

Haramaya where the study was conducted is one of maize producing district in East Hararghe Zone of eastern Oromia, Ethiopia. In the area, the production of maize under main cropping season a in special significance; because there is high demand for grain and fresh cob of maize consumption, stalk for feeds of animal and fuel. The gab in the study area was that most of the farmers where not using optimum fertilizer level, proper spacing when they produce maize (Haramaya agriculture and natural resource office, 2019). As result improper fertilize application and plant density makes final harvested yield is very low, and most farmers in the study area have been using different rate of NPS fertilizer rates and there is no recommendation rates for newly blended fertilizers except blanket recommendation of DAP and UREA (100 kg of urea and 100 kg of DAP per hector (MoA). Thus, there is a need to develop area specific recommendation of blended NPS fertilizer rate and inter-row spacing in order to achieve maximum and higher yield of maize crop. Therefore, the study was under taken with the objectives of:-

To determine the effect of blended NPS fertilizer rates and inter- row spacing on yield components and yield of maize and to evaluate the cost benefit of blended NPS fertilizer rates in maize grain yield production.

2. LITERATURE REVIEW

2.1. Origin, Agro-Ecologies and Maize Production in Ethiopia

Maize is a member of the grass family, Poaceae. It is believed that the crop was originated in Mexico and introduced to West Africa in the early 1500s by the Portuguese traders (Dowswell *et al*., 1996). It has never been found growing in a wild state. There is no reliable evidence that maize reached the old world prior to 1492.

Ethiopia is among the major maize producers in Sub Saharan African countries, where smallholder farmers dominate the major share of production. Maize, which is originated from South America, is first introduced in Ethiopia in the 16th to 17th Century (Abdisa *et al*., 2001).

The crop requires an average daily temperature of at least 20^{o}C for adequate growth and development; the optimum temperature for growth and development ranges between 25-30^{o}C; temperature above 35^{o}C reduces yields (Brink and Belay, 2006). Frost can damage maize at all growth stages and a frost-free period of 120 to 140 days is required to prevent damage. Leaves of mature plants are easily damaged by frost and grain filling can be adversely affected. The major maize producing regions are southern, western and southwestern Ethiopia and the highlands of Hararghe in eastern parts of the country (Assefa, 1994).

Maize is used as food for human, feed for livestock and raw material for industrial purposes (Dowswell *et al.,* 1996). Millions of people depend on maize for their daily food in sub-Saharan Africa. In Ethiopia, maize is staple food and one of the main sources of calorie in the major maize producing regions (Kebede *et al.,* 1993). Similarly, FAO (2018) reported that maize is increasingly used for human consumption and accounted for 70% of the food consumed in Sub-Saharan Africa.

Maize is a major crop in Ethiopia in production, consumption and income generation for both resource constrained men and women. In addition to the highest total production per annum and the highest per-hectare yield, maize is also the single most important crop in terms of number of farmers engaged in cultivation. It grows from moisture stress to high rainfall areas and from lowland to the highland areas (Mosisa *et al.,* 2001). Currently, maize is widely grown in most parts of the world over a wide range of environmental conditions ranging between 50 latitude north and south of the equator. It is also grown from sea level to over 3000 meters above sea level (m.a.s.l) elevation (Singh, 1987). In the tropics, maize does best with 600-900 mm well-distributed rainfall during the growing season (Brink *et al*., 2006).

The most suitable soil for maize is one with a good effective depth, favorable morphological properties, good internal drainage, and an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favorable specifically for maize production. Although large-scale maize production takes place on soils with a clay content of less than 10% (sandy soils) or in excess of 30% (clay and clay loam soils), the textural classes between 10 and 30% (clay) have air and moisture regimes that are optimal for healthy maize production and productivity.

According to CSA (2018), maize is the second important cereal after teff in terms of area coverage and volume of production in Ethiopia. According to CSA (2018), the total land areas of about 12,677,882.27 hectares were covered by grain crops, i.e. cereals, pulses and oilseeds. Out of the total grain crop area, 80.71% (10,232,582.23 hectares) was under cereals. Teff, maize, sorghum and wheat took up 23.85% (about 3,023,283.50 hectares), 16.79% (about 2,128,948.91 hectares), 14.96% (1,896,389.29 hectares) and 13.38% (1,696,907.05 hectares) of the grain crop area, respectively (CSA, 2018).

Cereals contributed 87.48% (about 267,789,764.02 quintals) of the grain production. Maize, teff, wheat and sorghum made up 27.43% (83,958,872.44 quintals), 17.26% (52,834,011.56 quintals), 15.17% (46,429,657.12 quintals) and 16.89% (51,692,525.40 quintals) of the grain production, in the same order (CSA, 2018). According to, CSA, (2018) with regard to estimated crop yield, crops such as maze, teff, and wheat within the category of cereals have shown an increment, that ranges from 7.32 quintal ha^{-1} to 28.93 quintal ha^{-1} for maize; from 5.05 qt ha^{-1} to 26.76 qt ha^{-1} for teff; and from 2.28 to 29.67 qt ha^{-1} for Wheat over the last five years (2012/13 - 2017/18).

In the country, about 2.13 million hectares of land was covered with maize with an estimated production of about 5.12 million tons during the 2017/18 cropping season (CSA, 2018).

However, the national average yield, 3.06 tons ha^{-1} (CSA, 2018) is still far below the world average 5.1 tons ha^{-1}, (FAOSTAT, 2011). Such low grain yield of maize is attributable to several production constraints, which include limited improved agronomic and other cultural practices for different agro-ecological regions, moisture stress, low soil fertility, spacing, weeds, diseases and insect pests, rodents, birds (Pswarayi and Vivek, 2007).

2.2. Importance and Uses of Maize

Maize is one of the most important cereal crops in the world. Its worldwide economic importance is due to its use as food for human, cash crop, feed for animals, and an industrial grain crop. According to FAOSTAT (2016), 1.06 billion tons of maize was produced on 188 million hectares worldwide, with a yield of over 5.64 tons ha^{-1} in the year 2016. Maize is the most important cereal crop in eastern and southern Africa accounting for over 39.5% of the total harvested area of annual cereal crops (FAOSTAT, 2016).

In Ethiopia, about 2.1 million hectares of land was covered with maize with an estimated production of about 7.8 million tons during the 2017 cropping season (CSA, 2017). However, the national average yield, 3.68 tons ha^{-1} (CSA, 2017) is still far below the world average 5.64 tons ha^{-1}, (FAOSTAT, 2016). Such low grain yield of maize is attributable to several production constraints, which include limited improved agronomic and other cultural practices for different agro-ecological regions, weeds, diseases and insect pests, rodents, birds, moisture stress, drought and low soil fertility (Pswarayi and Vivek, 2007).

In addition to the highest total production per annum and the highest per-hectare yield, maize is also the single most important crop in terms of number of farmers engaged in cultivation.
The vast majority of Ethiopian farmers are small-scale producers estimates show about 94% of the Ethiopian farmers rely on less than 5 hectares of land, of which 55% cultivate land less than 2 hectares (Rashid and Negassa, 2010). According to data from CSA, (2017), 10.9 million smallholders were involved in maize production in the country during 2017 production season.

2.3. Effects of Nitrogen on Maize Grain Yield

Nitrogen (N) is the nutrient that most often limits maize grain yield and quality (Thanki *et al*., 1988). Even under conditions where grain yield is not limited, N can affect composition and quality. Although maize is usually considered as energy food, it contains important quantity of protein. Grain yield of maize is a product of three yields components, i.e. the number of ears per unit area, the number of grains per ear and the unit grain weight (Gardner *et al.,* 1985). Increase or decrease in any one of these components, keeping the size of other components constant, contributes to increase or decrease in grain yield, respectively, and thus any exercise whether agronomic (management) or breeding type (genotype), which increase any of these components, keeping the other components constant, will increase the final grain yield.

Devi *et al.,* (2001) reported that ears per plant, ear length, number of seeds per ear and 100-seed weight directly influence the grain yield and indirectly affected several other parameters. Similarly, Sugiharto *et al.,* (1990) reported that in maturing photosynthetic leaf cells of maize lack of N causes reduced level of phospho-enol-pruvate carboxylase enzyme, which helps to replace Krebs-cycle acids used in the synthetic reactions and help to form malate needed in charge balancing functions (Salisbury and Ross, 1992).

Nitrogen plays a pivotal role in several physiological processes inside the plant. It is fundamental to establish the plant's photosynthetic capacity (Hageman and Below, 1984); it prolongs the effective leaf area duration, delays senescence (Earl and Tollenaar, 1997); and it is important for ear and kernel initiation, contributing to define maize sink capacity (Tollenaar *et al.,* 1994); and it helps to maintain functional kernels throughout grain filling, influencing the number of developed kernels and kernel final size (Jones *et al*., 1996). The percentage of nitrogen in maize actually varies according to the supply of nitrogen to the crop (fertilizer plus soil), genetic characteristics of the hybrids, planting rate and weather conditions (Pierre *et al.,* 1977). The requirement of nitrogen in the composition of the crop can set a minimum on the amount of nitrogen, which must be supplied by the soil and the fertilizer. It is a key factor in achieving optimum grain yield.

Yield is significantly affected by both N application timing and nitrogen rates. Nitrogen levels significantly increase the grain yield. Yield varying between 4744.8 kg ha^{-1} in no nitrogen application and 7355.5 kg ha^{-1} with application of 225 kg N ha^{-1} have been reported by Ali and Raouf (2012). The fact that grain yield varied significantly with timing and regimentation of nitrogen strongly underscores the necessity of fine tuning N application to match nutrient supply to crop demand. Nitrogen applied at 35 days after sowing or in equal splits at 0 and 35 day after sowing or at 35 and 70 days after sowing gave consistently more grain yield than other modes, particularly when N rate was 120 kg ha^{-1}. The findings confirm the agronomic benefits of split nitrogen application in crops reported by many researchers (Mungai *et al*., 1999).

According to Hammad *et al.* (2011) Nitrogen application had much greater effect on maize grain yield; this could be due to the fact that application of N fertilizer in plants increases uptake of other nutrients. This can be explained by the fact that the supply of N enhanced the development of small roots and root hairs which, in turn, facilitate the absorbing ability per unit of dry weight. According to Mekdad (2015) increase in yield as a result of increasing nitrogen fertilizer levels may be due to the importance of nitrogen as one of the macronutrient elements for plant nutrition and its role in increasing vegetative growth through enhancing leaf initiation and increment of chlorophyll concentration in leaves which may reflect in improving photosynthesis process.

Debebe (2010) also reported that as nitrogen increase from controlled to 105 kg N ha^{-1} plant height, ear height, leaf area and leaf area index of maize increased significantly and Leaf area influences interception and utilization of solar radiation of maize crop canopies and, consequently, maize dry matter accumulation and grain yield increased. The general conclusion of grain yield increase over control per kg N applied and time of N application in maize has been due to good synchrony if N is applied nearest to the time it is needed by the crop (Vetsch and Randall, 2004).

2.4. Effects of Phosphorus on Maize Yield and Yield Component

Phosphorus is another essential nutrient required to increase maize yield. Consequently, the lack of phosphorus is as important as the lack of nitrogen in limiting maize performance.

Phosphorus is closely concerned with many growth processes in crop plants. It is involved in many biochemical reactions and concerned with the metabolism of carbohydrates, fats and protein and play roles in the breakdown of carbohydrates.

Phosphorus significantly increases the number of cobs per plot, 1000-grain weight, and grain yield over the control (Qasim *et al.*, 2001). Adequate P results in rapid growth and earlier maturity and improves the quality of vegetative growth. Phosphorus deficiency is responsible for crooked and missing rows as kernel twist and produce small ears nubbies in maize. Deficiency symptoms of phosphorus on maize usually occur on young plants, especially under cool, wet conditions. Leaves are dark green with reddish-purple tips and margins. Phosphorus affects leaf growth and senescence dynamics in maize, and its deficiency slows down the rate of leaf appearance and reduces the final leaf area located below the main ear by 18 to 27% (Colomb *et al.*, 2000).

2.5. The Role of Sulphur in Plants and its Availability in the Soil

Sulphur is one of the essential nutrients for plant growth and it does accumulate 0.2% to 0.5% in plant tissue on dry matter basis. It requires similar amount as that of phosphorus (Ali *et al.*, 2003). Without adequate S, crop cannot reach their full potential in terms of yield or protein content (Zhao *et al.*, 1999). Due to its synergistic effect, the efficiency of these element is enhanced which result in increased crop productivity. Sulphur is attaining importance in all regions of the world because of frequent sulphur deficiencies in time and space (Khan *et al.,* 2006). Application of sulphur fertilizer is a feasible technique to suppress the uptake of undesired toxic elements (Na and Cl) because of the antagonistic relationship, thus its application is useful not only for increasing crop production and quality of the produce but also improves soil condition for healthy crop growth (Zhao *et al.*, 1999). Its fertilization helps enhancing the uptake of N, P, K and Zn in the plant. Sulfur improves K/Na selectivity and increase the capability of calcium ion to decrease the injurious effect of sodium ion in plants (Wilknson *et al.*, 2000).

In sulphur deficient condition, the use efficiency of applied NPK fertilizers, the economics of their use may be seriously affected, and high yields may not be sustained (Mazid *et al.,* 2011). The increased report on sulfur deficiency is related to the decrease in emission of oxides of S from industries, increased use of high analysis fertilizers with little S seldom addition of manures increased N fertilization with high N-efficiency cultivars (Schereer, 2001). However, S is needed in plants for the synthesis of the amino acids, cysteine and methionine, various enzymes and coenzymes, and it is an integral component of membranes, lipids and chlorophyll proteins (Schereer, 2001). It is required for plant growth in quantities equal to and sometimes exceeding those of P, which accounts about 9 - 15% of N uptake.

The sufficiency or deficiency levels of S in Ethiopian soils are little known (Kiros, 2007). Soil sulphur exists in organic and inorganic forms. From the view point of plant nutrition inorganic sulphate is the most important, since this is taken up by plant roots (Tisdale *et al*., 1985). However, sulphate-S which is the stable form of inorganic sulphur in aerobic soils-constitutes only a small part of total S in soils. Generally, more than 95% of soil sulphur is organically bonded with several hundred kilograms of organic sulphur present in the upper horizons of most soils. The sulphur supplying capacity of the soil is closely related to organic S pool and its mineralization in soil is good indicator of S supplying capacity (Ghani *et al*., 1991).

2.6. Effects of Sulphur Fertilizer on Yield of Maize

Elemental S and Sulfate fertilizer increased 36% in maize grain yield (Riyel *et al.,* 2000). In addition to organic sulfur must be mineralized to sulfate-S to be taken up by crop plant. Therefore, lower organic matter content of soil the more likely sulphur efficiency is to occur. Sulphur encourages photosynthetic activity by increasing chlorophyll pigments, synthesis of essential amino acids and proteins, translocation and utilization of starch and nitrogen and all these functions finally converge to increase maize yield. In maize the important quality parameters like carbohydrates, starch and protein yields are affected by sulphur. Currently in most of the countries, S has been identified as a limiting factor for crop quality, although maize has a relatively low sulfur requirement (Zhao *et al*., 1999). Low sulphur content in flour increase dough stage strength and reduced dough extensibility (Mac Ritchie and Gupta, 1993). In terms of disease control foliar application of S increased the effectiveness of fungicide (Zahid and Leitch, 2005). Soil application of S fertilizers increases gel protein weight in flour and the proportion of polymeric protein (Zhoa *et al.,* 1999).

Sulphur application did not affect the grain protein concentration directly, but tended to increase gel protein weight in flour and the proportion of polymeric proteins. S deficiency decreases grain size and baking quality because formation of disulfide bonds formed from the sulphydryl groups of cysteine. This affects the viscoelasticity of dough (Singh, 2002). Sulphur deficit may result in harder grains and the dough made from such grain is usually stiff and is not elastic (Ryan and Hrivna, 2004). The total uptake of N and S and concentrations of N and S in the grain were increased when sulphur was applied (Zahid and Leitch, 2005).

2.7. Effects of Spacing and Plant Density on Phenology, Growth and Yield of Maize

Maize plants are sensitive to density and increase its density to increase grain yield usually is accompanied with how to use elements such as nitrogen (Lemcuff and Lemmas, 1986). Usually seed yield will reach to maximum in range of plant density and then decreases (Lemcuff and Lemmas, 1994). Loss of seed yield in high plant density conditions may be due to infertile ears. The previous research shows that, appropriate selection of agronomic factors such as nitrogen and plant density can increase seed yield (Widdicombe, 2002).

According to Singh (2002), establishment of optimum population per unit area of a field is essential to get maximum yield. Many experiments have been conducted to determine the spacing between rows and between plants within the row that maximizes yield. Muhammad *et al*., (2006) indicated that there was maximum grain yield 6.6 tons ha^{-1} of maize against the minimum 3.28 tons ha^{-1} at narrow spacing, although narrow plant spacing (10-15 cm) caused substantial reduction in yield components such as grain cob^{-1} and 1000 kernel weight compared to the wide plant spacing, accordingly they recommend 60 cm by 10 or 15 cm plant spacing for maximum yield.

Turgut *et al*. (2005) also reported that narrow-row maize production is more efficient in utilizing soil nutrient and contributes to increased yield. Grain yield increased linearly with increasing plant density until production factors were not limiting (Anjum *et al*., 1992). Optimum plant population increased number of grains cob^{-1}, 1000-grain weight and grain yield of maize (Sabir *et al*., 1987). Rowland (1993) viewed that widely spaced maize tends to have excessive vegetative growth during early stage which may result in severe competition for water and further observed that spacing and plant population can be determined after considering a number of factors like variety, amount of water expected to be available during the growing season and its distribution through time, soil fertility especially nitrogen availability, planting, pest and disease considerations.

Wider spacing encourages growth of weed and thus, more labor and increase cost of production. Many crops are grown in wide rows to reduce seed costs, enable better stubble management, provide less soil disturbance, and facilitate weed control between rows. Furthermore, there is a large gap between the theoretical benefits of high crop densities and actual practice because farmers are reluctant to adopt higher seeding rates due to concerns about reduced yield or quality (Eddows, 1967).

Generally, wider row spacing will improve crop competition for light, soil moisture and soil borne nutrients. Time to canopy closure is an inverse function of row spacing and plant population and is also influenced by crop species and cultivar (Luque *et al*., 2006). Among various biotic and a biotic factors that affect maize yield considerably; variations in plant density affects maize yield than other members of the grass family (Vega *et al*., 2005).

High plant densities appear to affect the required period for pollen shedding and silk emergence. Higher plant density (more than 12 plants per m^2) delay time of silking and widen the time gap between silking and pollination (Carcova and Otegui, 2001). Edmeades and Daynard, (2001) stated that the required time for pollen shedding and maturity time was not influenced appreciably by plant density. However, time from sowing to silking increased from 84 to 95 days as densities increased from 5 to 20 plants m^2. Thus the duration between pollen shedding and silking increased by increasing the plant density from almost 0 to 9 days in combination with the reality that plants not shedding pollen and not silking was observed only at the higher densities of 15 and 20 plants m^2 of sterility from 0 to 26.7%. Similar results were obtained under the same plant densities by Kgasago, (2006).

Plants that grow under high plant density receive a different quality of light, enriched with far red and impoverished in red radiation. This high far red to red light ratio triggers many morphological changes in plant architecture, stimulating stem elongation, favoring apical dominance and decrease in stem diameter (Rajcan and Swanton, 2001). Such changes make maize stalks more susceptible to breakage and lodging. Plant density exerts a strong influence on maize growth and yield as a result of different competitive ability of plants at variable densities. Thus, balanced growth and development of plants need optimum plant density because optimum density enables plants efficient utilization of available nutrients, soil water and better light interception coupled with other growth influencing factors (Tinau, *et al*., 1993; Gobeze *et al*., 2012).

Plant height increased as population increase up to a certain point. Taller plants (221 cm) were observed when maize crop was raised at 60 x 15 cm spacing, which was statistically at par (218.83 cm) when the crop was grown at 60 x 20 cm. Similarly short plant (209.33cm) was recorded from the plots planted at 60 x 30 cm (Zamir *et al.,* 2011). Matthews *et al*., (2008) reported that maize planted with spacing of 50 x 30 cm had significantly taller plants than those spaced 75 x 25 cm and 100 x 50 cm. Leaf and leaf area index determines total light interception. Leaf area is an important parameter in many agronomic and ecological processes, including photosynthesis, transpiration and field energy balance. Leaf area can be increased by increasing leaf area per plant or population density by narrow spacing (Major *et al*., 1972).

The efficient interception of radiant energy incident to the crop surface requires adequate leaf area; uniformly distributed to give complete ground cover and that could be achieved by manipulating stand density and distribution over the land surface. Thus conditions favoring maximum area per leaf should optimize CO_2 (Kgasago, 2006). One of the most common explanations for narrow-row seed yield enhancement is the attainment of sufficient leaf area index (LAI) to produce maximal light interception during seed formation (Shibles and Weber, 1966; Goldsworthy and Taylor, 1990). Hussain *et al*., (2011) reported that increasing plant density increased leaf area index on account of more area occupied by green canopy of plants per unit area. Plant population of 140,000 and 120,000 plants ha^{-1} produced higher LAI of 4.77 and 4.52, respectively and the lowest LAI was obtained with population of 40,000 plants ha^{-1}.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was conducted at Haramaya University Rare Research Site. Haramaya University is located on the eastern escarpment of the Rift Valley at 9^o 26' N latitude and 42^o 03' E longitude and an altitude of 1,400 to 2026 m.a. s. l. It is situated in the semi-arid tropical belt of eastern Ethiopia and is characterized by a sub-humid type of climate with an average annual rainfall of about 600 to 1,260 mm, the minimum and maximum mean annual temperatures is 9.59^{o}C and 24.15^{o}C, (Haramaya University Meteorological Observatory, 2019).The rainy season of the area is bimodal; the short rainy season stretches from March to May and the main rainy season from July to September (Tekalign and Hammes, 2005).
The soil of the experimental site is classified as
fluvisols.

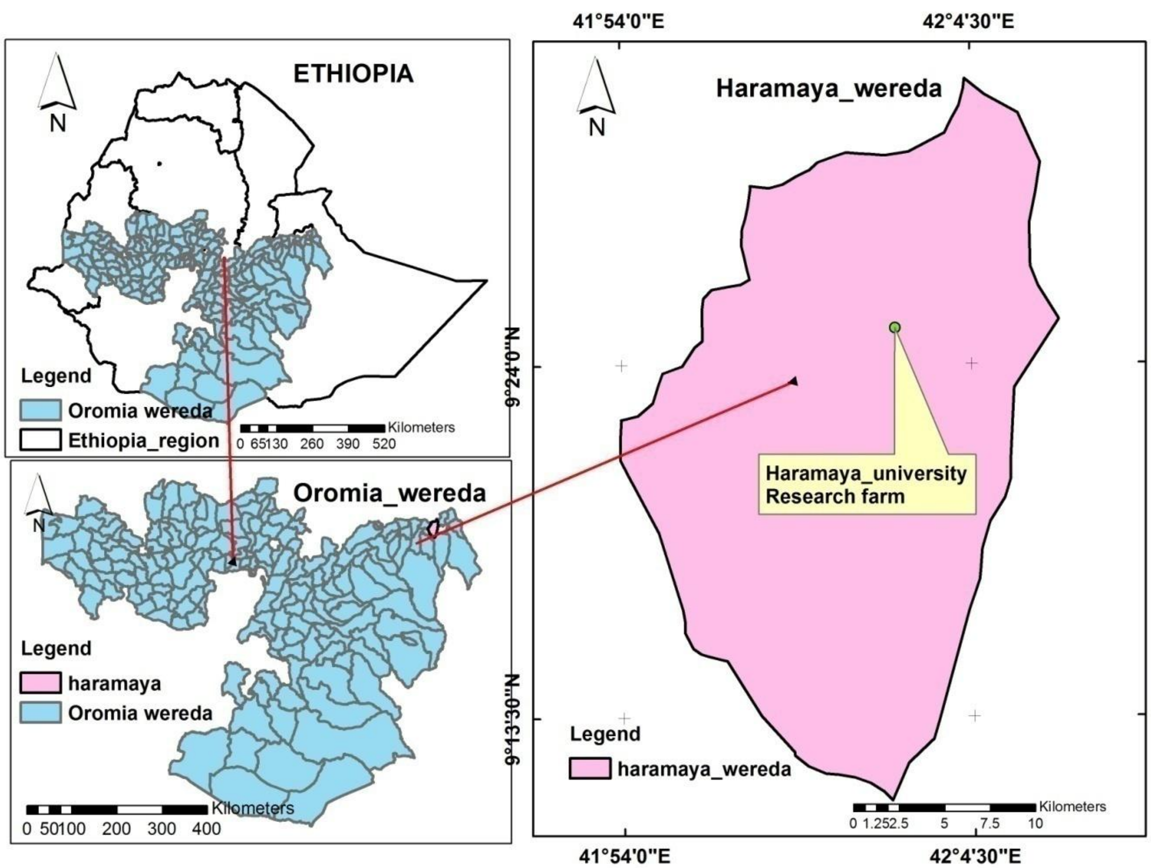

Figure 1: Map of study area

3.2. Soil Sampling and Analysis

To describe the soils of the study area, surface soil samples from 0-30 cm depth were collected in diagonal pattern using an auger based on procedures described by Munson and Nelson (1993) from five random spots in each block of experimental field before sowing, composited, air dried under shade, packed and labeled and one (1) kg of composite sample was submitted to Haramaya University soil laboratory. The sample submitted were used to analyzed for the soil cation exchange capacity (CEC), organic carbon, available phosphorus, total nitrogen (%), exchangeable bases (Na+, K+, Ca++, Mg++), soil textural class and soil pH using standard laboratory procedures.

Total nitrogen in the soil was determined by Kjeldahl method (Kenny and Nelson, 1982) and soil phosphorus was estimated by Olsen method (Olson *et al.,* 1954). Organic carbon of the soil was determined by the Walkley-Black method (1934). Available Sulfur was determined using turbid metric method (Chesnin and Yein, 1951) while soil texture was determined by Bouyoucos hydrometer method (Moodie *et al*., 1954). Soil pH was estimated in soil-water suspension (1:2.5) with the help of pH meter. Soil CEC was determined by ammonium acetate method (Cottenie, 1980).

3.3. Experimental Materials

3.3.1. Plant material

Maize variety named Melkassa-II released by Melkassa Agricultural research center was used for the study. Melkasa was released in 2004 and adapted to altitudes of 1000 - 1800 m.a.s.l. Its yield potential on research field is 5.5-6.5 tons ha^{-1} and on farmers' fields is 4.5 - 5.5 tons ha^{-1} (MoARD, 2009).

3.3.2. Fertilizer material

Blended NPS fertilizer (19% N, 38% P_2O_5 and 7% S), and Urea (46% N) were used as sources of fertilizer.

3.4. Treatments and Experimental Designs

The treatments consisted of five rates of blended NPS (0, 50, 100, 150 and 200 kg NPS ha^{-1}) and four inter- row spacing (55 cm, 65 cm, 75 cm, 85 cm). The experiment was laid out in randomized complete block design (RCBD) in a factorial arrangement and replicated three times. Thus, there are 5 x 4 = 20 treatment combinations constituting 60 plots. There were five rows for 85 cm and 75 cm row spacing, six rows for spacing of 65 and seven rows for spacing of 55 cm. Plots size was (4.25 x 3) m, (3.75 x 3) m, (3.9 x 3) m and (3.85 x 3) m for 85 cm, 75 cm, 65 cm and 55 cm inter row respectively. The spacing between plants was 30 cm, adjacent plots and blocks were separated by 1 m and 1.5 m spacing, respectively. Data was collected from central rows by excluding one row from each side of the plot and one plant from both ends of the row.

3.5. Experimental Procedure and Field Management

Prior to sowing, the land was well prepared by repeated three times ploughing using tractor plough. Plots were leveled; furrows and ridges were prepared. Thus, there were 39,215, 44,444, 51,283 and 60,606 plants per hectare, respectively under 85 cm x 30 cm, 75 cm x 30 cm, 65 cm x 30 cm and 55 cm x 30 cm inter-intra row spacing. While, one plant in both the ends of rows under all the row spacing was considered as border plants. Maize seeds was planted as per proposed inter row spacing. Initially two seeds per hill were planted and was thinned latter to one plant at the stage of 3 to 4 leaves.

At time of planting, all plots were received a basal application blended fertilizer NPS (19% N, 38% P_2O_5 and 7% S). However, 46 kg N ha^{-1} in the form of Urea at knee stage. The nitrogen were placed about 5 cm away from the plant base at knee height. All other agronomic practices like hoeing, weeding, were applied to all treatments as of it is recommendation for maize.

3.6. Crop Data Collection and Measurement

3.6.1. Crop phenological data

Days to 50% anthesis (DA): The number of days required from planting to the start of shedding of pollen by 50% of the maize plants

Days to 50% silking (DS): It was determined as the number of days taken from the date of planting to the stage when 50% of plants showed extrusion of silk.

Days to 90% Physiological maturity (PM); Was recorded when 90% of plants in a net physiologically matured (the grains formed black layer at the base of the germ at the point of attachment of the kernel on the ear).

3.6.2. Growth parameters

Leaf area: All available leaves of five plants per net plot were collected at 50% milking stage and leaf length and width was measured and leaf area were calculated as: Leaf Area (LA) = maximum leaf length (cm) x maximum width of leaf (cm) and was adjusted by a correction factor (i.e 0.75 x leaf length x maximum leaf width) as suggested by (Francis *et al.*, 1969; Pearce *et al.*, 1975).

Leaf area index (LAI): It was calculated as the ratio of total leaf area per five plants (cm^2) per area of land occupied by the plants (Diwaker and Oswalt, 1992).

Plant height: It was measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the net plot area at 75% physiological maturity.

3.6.3. Yield and yield components

Stand count: Stand count per plot was recorded after thinning and at harvest from the net plot area. The final plant stand percentage (final plant stand count at maturity/population established after thinning x 100) of the respective treatments was used to determine the stand loss due to lower spacing treatments.

Number of ears per plant: It was recorded from the five randomly taken plants in the central net plot area at crop harvest.

Number of ears per hectare: It was recorded by counting the number of ear per plot and converting to hector.

Ear length (cm): It was recorded from the measure of ten randomly taken ears per net plot at harvest.

Number of kernels per ear: It was recorded from average of five randomly taken ears per plot. This was done by manually shelling and counting the normal kernels and then averaged on per plant basis.

Thousand kernels weight (g): Thousand kernels were counted from a bulk of shelled grains from net plot and weighed using sensitive balance and the weight was adjusted at 12.5% moisture level.

Above Ground Dry biomass (AGDB): It was recorded from five plants per net plot and was weighed during harvesting and the result was converted to tons per hectare.

Grain yield (GY): It was determined from the net plot area and the result was converted to tons per hectare

Harvest index (%): It was calculated as the ratio of grain yield to aboveground dry biomass per net plot and multiplied by 100.

Agronomic efficiencies (AE)

The agronomic efficiency (kg grain kg^{-1} of NPS) was calculated using the procedures described by Craswell and Godwin (1984) as: $AE\left(\frac{Kg}{kg}\right) = \frac{Gf(kg) - Gu\,(kg)}{Na\,(kg)}$, where; AE stands for agronomic efficiency, Gf and Gu for grain yield in fertilized and unfertilized plots, respectively, and Na for quantity of fertilizer applied.

3.7. Economic Analysis

Economic analysis was done using the method described by CIMMYT (1988). The variable costs including the seed, NPS blended fertilizer, labor cost price at time of planting (May 2019) and the price of the inputs at planting (May 2019), including the cost of seed (65.00 ETB kg^{-1}), NPS fertilizer (18.00 ETB kg^{-1}), Urea (16.00 ETB kg^{-1}) at the time of planting (May 2019) and according to Haramaya, farm daily payment of labor cost for application of NPS (5 person's ha^{-1}, each 75 ETB day^{-1}). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, and harvesting, transportation, guard, etc was considered the same for all treatments or plots. The average yield was adjusted downward by 10% to reflect the farmers' field yields as described by (CIMMYT, 1988).

Unadjusted grain yield (UGY) (grain yield ha^{-1})**:** is an average yield of each treatment

Adjusted grain yield (AGY) (grain yield ha^{-1})**:** is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB) (ETB ha^{-1}**):** was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. GFB = AGCY × field/farm gate price for the crop.

Total variable cost (TVC) (ETB ha^{-1}**):** was calculated by summing up the costs that vary, including the cost of Seed Melkassa-II variety (65.00 ETB kg^{-1}), NPS (18.00 ETB kg^{-1}) and Urea (16.00 ETB kg^{-1}) fertilizers at the time of planting (May 22, 2019) and according to Haramaya, farm daily payment of labor cost for application of NPS (8 person's ha^{-1}, each 75 ETB day^{-1}).

Net benefit (NB) (ETB ha^{-1}): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment. NB = GFB – TVC

Dominance analysis: was carried out by first listing all the treatments in their order of increasing costs that vary (TVC) and their net benefits (NB) are then put aside. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D").

Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) times hundred.

3.8. Statistical Data Analysis

Data collected were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to General Linear Model (GLM) of GenStat 16thEdition (GenStat, 2013). Interpretations were made following the procedure described by Gomez and Gomez (1984). The differences between treatment means were compared using Least Significant Difference (LSD) test at 5% level of significance when the ANOVA showed the presence of significant difference

4. RESULTS AND DISCUSSION

4.1. Soil Physico-chemical Properties of the experimental Site

Physical and chemical properties of the soil were analyzed for the soil sample (0-30 cm depth) taken from the experimental field. The results of the analysis of the physical properties of the soil indicated that the sand, silt and clay contents is about 62%, 3% and 30%, respectively (Table 1). Thus, the texture of the soil was sandy clay loam according to Bouyoucos (1962) classification. The texture indicates the degree of weathering, nutrient, and water holding capacity of the soil. The high clay content might indicate high water holding capacity of the soil in the research site.

Cation exchange capacity is the capacity of the soil to hold and exchange cations. The cation exchange capacity of a soil was a measurement of the magnitude of the negative charge per unit weight of soil, or the amount of cations a particular sample of soil could hold in an exchangeable form. The result showed that the cation exchange capacity of the experimental soil was 34 cmol (+) kg^{-1} or (meq /100 g soil) (Table 1). Landon (1991) classified CEC of <6, 6-12, 12-25, 25-40, >40cmol (+)/kg very low, low, moderate, high and very high respectively.

Therefore, the CEC of the research site is rated as high. Murphy (2007) classified soil organic carbon percentages of <0.60, 0.6 – 1.0, 1.0 – 1.80, 1.80 – 3.0 and >3 as very low, low, medium, high and very high, respectively. Therefore, organic carbon content of the soil was 0.736% which was low according to the rating of Murphy (2007) indicating low potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Therefore, the soil had very low organic carbon content. Total nitrogen measures the total amount of nitrogen present in the soil, much of which is held in organic matter. The result of the analysis showed that the total nitrogen percentage was 0.05% (Table 1). Tekalign (1991) classified soil total N availability of < 0.1% as very low, 0.1-0. 2% low, 0. 2-0.5% as moderate, 0.5-1 high and >1% as very high. Therefore, total nitrogen of the research site is rated as very low.

Thus, the soil of the research site has very low in total nitrogen and requires nitrogen application as maize is highly exhaustive crop for nitrogen and the production potential of it is highly affected by N deficiency. The result of the analysis also showed that the available P level in the research site was 11.9 ppm soil. Tekalign (1991) described soils with available P <10, 11-31, 32-56, >56 ppm as low, medium, high and very high, respectively. Therefore, the result showed that the total amount of available soil P level is medium. The soil available sulfur was 3.12 ppm; therefore the result showed that the available sulfur level is low according to the classification of EthioSIS (2014).

Though the texture of the soil was suitable for maize production, it was necessary to apply in organic nitrogen as its availability was moderate and its high tendency for mobility and loss through different methods. The available sulphur of the soil was also very low and its available phosphorus was medium and this was alleviated by the application of inorganic sulphur and inorganic phosphorus in the form of blended NPS fertilizer for better production.

Table 1. Soil physical and chemical properties of the experimental site before planting maize

Properties	Result	Rating	References
1. Physical properties (%)			
Sand (%)	62	_	_
Silt (%)	3	_	_
Clay (%)	32	_	_
Textural Class	Sand clay loam	_	Bouyoucos (1962)
2. Chemical Properties	_		_
pH (1: 2.5 H_2O)	6.9	Neutral	Landon (1991)
Organic Matter /OM/ (%)	1.041	Medium	(EthioSIS, 2014)
Organic Carbon /OC/ (%)	0.736	Low	Murphy (2007)
CEC (Cmol(+)kg-1)	34.8	High	Landon (1991)
Total Nitrogen /TN/ (%)	0.05	Very low	Tekalign (1991)
Available Phosphorus /P/ (ppm)	11.9	Medium	Tekalign (1991)
Available Sulfur /S/ (ppm)	3.12	Very low	(EthioSIS, 2014)
3.Exchangeable Bases (Cmol(+)kg-1)	_	_	_
Exchangeable Na+	0.13	Low	(FAO, 2013)

4.2. Phenological and Growth Parameters

4.2.1. Days to 50% anthesis

Days to 50% anthesis was highly significantly ($p<0.01$) influenced by the main effects of blended NPS fertilizer rates and inter row spacing (Appendix Table 1). However, the interaction effect of blended NPS fertilizer rates and inter row spacing showed none significant effect on days to 50% anthesis (Appendix Table 1). It was observed that as the blended NPS fertilizer rate increased from 0 kg NPS ha^{-1} to 200 kg NPS ha^{-1} days to anthesis increased from (77 to 82.12) (Table 2). This delay in days to anthesis with the blended fertilizer might be attributed to the impact of positive interaction of nitrogen with other nutrients in the blended fertilizer enhanced more vegetative growth and larger photosynthesis than reproductive parts. This is in agreement with the findings of Mekdad (2015) who indicated that Nitrogen plays several roles in plant metabolism, and to perform these roles positively, it should interact positively with other essential nutrients and increase photosynthetic efficiency of maize.

Moges (2015) also reported that increasing N fertilizer rate from 0 to 128 kg N ha^{-1} increased duration of tasseling of maize from 74.5 days to 78.58 days. Higher nitrogenous in blended fertilizer delays the senescence of leaves and increased succulence of plants. In the case of inter row spacing the earliest days to 50% anthesis (77.80 days) was recorded at inter-row spacing of 55 cm and the delayed days to anthesis (81.20 days) was recorded from 85 cm spacing (Table 2). While, the early anthesis with less inter row spacing might be due to intense competition among plants for growth resources that might have hastened the days to anthesis. In agreement with this results Abdulatif (2002) also reported that maize at thin population density of (30,952 plant ha^{-1}) has taken longer mean days to flower followed by the intermediate (34, 111 plant ha^{-1}) of maize plant density. Similar to this result, Hamid (2001) reported that increases in plant densities and significantly delayed the duration of the vegetative and reproductive period, denser population relatively shorter period of time than those planted at lower density.

Table 2. Main effect of blended NPS fertilizer rates and inter row spacing on days to 50% anthesis, days to 50% silking of maize and days to 90% physiological maturity.

NPS rates (Kg ha^{-1})	Days to 50% Anthesis	Days to 50% Silking	Days to 90% physiological maturity
0	77.50^{d}	81.25^{e}	122.2^{d}
50	78.33^{c}	82.33^{d}	123.6^{c}
100	79.62^{b}	83.25^{c}	124.1^{c}
150	80.33^{b}	84.92^{b}	125.3^{b}
200	82.12^{a}	86.00^{a}	128.8^{a}
LSD (0.05)	1.7	1.1	0.596
Inter row spacing (cm)			
55	77.80^{d}	81.80^{c}	122.0^{d}
65	78.67^{c}	83.30^{b}	124.1^{c}
75	79.90^{b}	83.73^{b}	125.2^{b}
85	81.20^{a}	84.07^{a}	126.1^{a}
LSD (0.05)	0.3025	0.368	0.596
CV (%)	3.7	4.1	2.7

**= Significant at 1% probability levels; LSD = Least Significant Difference; CV= Coefficient of Variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.

4.2.2. Days to 50% silking

The analysis of variance revealed that the main effects of blended NPS fertilizer rates and inter-row spacing were highly significant ($p<0.01$) effect on days to 50% silking while the interaction effect was not significant (Table 2 and Appendix Table 1).

Any factor that affects silking can affect grain production directly. As the rate of blended NPS fertilizer increases from 0 kg ha^{-1} to 200 kg ha^{-1}, the days to silking was increased from (81.25 days to 86 days) (Table 2). Delayed silking in higher blended NPS fertilizer rates might be due to N fertilizers in the blended attributed to vigorous vegetative growth and increased light use efficiency. In agreement with this result, Wakjira (2018) reported that increasing the rate of NPS from 0 kg ha^{-1} to 200 kg ha^{-1} delayed days to 50% silking from 71.50 to 76.42. Similarly, Imran *et al.* (2015) also reported that increasing N rate to 210 kg ha^{-1} application delayed silking in maize by 5 days compared to control treatment. Akbar *et al.* (2002) also reported that treatments with higher nitrogen levels took more number of days to silking.

Days to 50% silking was highly significantly ($p<0.01$) affected by the main effect of inter-row spacing. Highest days to 50% silking was recorded with increasing inter-row spacing where the highest days to silking (84.07 days) was recorded at 85 cm inter-row spacing while narrowest inter-row spacing of 55 cm was earliest in days to silking (81.80 days) (Table 2). The delayed silking at the wider spacing might be due to less plant densities that enhanced less competition for growth factors more vegetative growth that ultimately delayed days to silking. Similarly, Muhammad *et al.* (2010) who reported that with increasing plant density from 57000 plant ha^{-1} to 99000 plant ha^{-1}, the number of days to 50% silking was delayed in four days and the longest days to silking (53.38) was obtained 99000 plant ha^{-1}.

4.2.3. Days to 90% physiological maturity

The main effects of NPS fertilizer application rates highly significant ($p<0.01$) influence on days to physiological maturity. However, main effect of inter row spacing and interaction had not significantly influence on days to 90% physiological maturity (Appendix Table 1).

Days to physiological maturity has a direct relationship with days to 50% tasseling and days to 50% silking. The maximum days to physiological maturity (128.8 days) was recorded from plot received 200 kg NPS ha^{-1}. However, it is not significant different with days to physiological maturity (125 days) recorded from treatment grown under 150 kg NPS ha^{-1}, whereas the lowest days to maturity (122.2 days) were recorded for the treatment without fertilizer (Table 2).

As the NPS rates increased days to physiological maturity was prolonged this might be due to the sulphur and nitrogen in the blended fertilizer that stimulate the enzymatic actions as well as chlorophyll formation that increases the amount of solar radiation intercepted, which promote the growth parameters and development of plants (Sanchez, 2007) and consequently increase days to flowering and physiological maturity. Application of N delayed leaf senescence, sustained leaf photosynthesis during active crop growth stage and extended the duration of vegetative growth and it clearly indicated that ever-increasing NPS levels have vital effect on growth, development, and yield. This result was also similar with the finding of Alemayehu (2018) who reported that the highest days to hard dough stage (150.3 days) was recorded at 150 kg NPS ha^{-1} while the earliest days to hard dough stage (139.8 days) was recorded at no NPS application (control). Similarly, Dinkinesh (2018) reported that, the highest number of days required for 90% physiological maturity (104.5 days) was recorded in the highest rate of NPSB blended fertilizer application (183 kg NPSB ha^{-1}) while the control (0 kg NPSB) showed the shortest growth period for days to 90% physiological maturity (99 days) for durum wheat. Moges (2015) also reported that as the nitrogen rates increased from 0 to 128 kg N ha^{-1}, days to physiological maturity of maize was also prolonged from 130.08 to 135.5 days consistently.

4.2.4. Leaf area and leaf area index

Analysis of variance indicated that both blended NPS rate and inter-row spacing had highly significantly ($p<0.01$) effect on leaf area and leaf area index (Table 3 and Appendix Table 1). However, the interaction effect of blended NPS fertilizer rates and inter row spacing showed none significant effect on leaf area and leaf area index of maize in this study (Appendix Table 1). The highest leaf area of plant (8620 cm^2) and leaf area index (4.157) were recorded at the highest blended fertilizer rate (200 kg ha^{-1}) and the values were statistically at par with blended NPS fertilizer rate of 150 kg ha^{-1} while the lowest leaf area (7519 cm^2) and leaf area index (3.61) were recorded at no blended NPS fertilizer application (Table 3).

In general, as the blended NPS fertilizer rate increased, the leaf area and leaf area index increased. This might be due to improved crop growth and development by blended NPS fertilizer increased utilization of applied nutrients by the crop. The result is in agreement with (Jeet *et al*., 2012) who reported that N is closely involved in the metabolism of plants which is essential for attaining the optimum leaf area, the most important indicator of size of the assimilatory system in maize to maximize harvest of the incident solar radiation. Likewise effects of high phosphorus levels on growth parameters were probably due to better development of root system and nutrient absorption (Masood *et al*., 2011) on the other hand, N deficient in plants can significantly reduce protein synthesis. Moreover, leaf area and canopy architecture, and leaf photosynthetic rate determine the rate of dry matter accumulation of the maize canopy.

In agreement with this result, Wakjira (2018) who reported that increasing the rate of NPS from 0 kg ha^{-1} to 200 kg ha^{-1} leaf area increased from 6785.5 cm^2 to 8097 cm^2. Similarly Imran *et al.* (2015) stated that increasing N application from 0 - 210 kg ha^{-1} increased leaf area of maize from 1973 cm^2 to 2757 cm^2 linearly and significantly. Applied P increased the rate of leaf appearance, the final number of leaves, and leaf area per plant (Gutierrez and Thomas, 1998). Similarly, (Sakal *et al*., 2000) reported that leaf area index, plant height and dry matter production of maize increased significantly with increasing levels of sulphur up to 60 kg S ha^{-1}.

With respect to the inter-row spacing, the highest leaf area per plant (8463 cm^2) was obtained from the 85 cm inter-row spacing and it was statistically at par with inter-row spacing of 75 cm while the lowest leaf area (7557 cm^2) was recorded under the narrowest inter-row spacing of 55 cm (Table 3). In contrast to the leaf area the narrowest inter-row spacing of 55 cm resulted in highest leaf area index (4.617) while, the lowest leaf area index (3.680) was recorded under widest inter-row spacing of 85 cm (Table 3). The higher leaf area in the wider inter-row spacing and intra-row spacing might be due to more availability of growth factors and better penetration of light, consequently increased number of leaves produced and the size of individual leaves in plants at wider row spacing.

This result was in agreement with Lakew *et al.* (2016) who reported the highest leaf area per plant of 7338.4 cm^2 was obtained from the widest intra-row spacing of 30 cm while the lowest (6732.3 cm^2) was recorded under the narrowest intra-row spacing of 20 cm of maize. Moreover, Sangoi *et al*. (2001) showed that higher leaf area of maize (7258 cm^2) was attained at row spacing of 75 cm than at 50 cm (6118 cm^2). In this study, it was generally observed that leaf area index increased as inter row spacing decreased from 85 to 55 cm owing to increasing plant density increased leaf area index on account of more area occupied by green canopy of plants per unit area. This could be due to high number of plants per unit area in narrow spacing than under wider spacing. In agreement with this result, Abuzar *et al.* (2011) reported that leaf area index of maize was significantly increased in linear fashion with increase in plant population where they reported the treatments having plant population of

120,000 plants ha^{-1} produced highest LAI of 2.77 whereas the lowest LAI (1.21) was obtained with lowest plant population density of 40,000 plants ha^{-1}.

Table 3. Main effect of blended NPS fertilizer rate and inter-row spacing on leaf area and leaf area index of maize.

NPS fertilizer rates (kg h^{-1})	Leaf Area of plant (cm^2)	Leaf Area Index
0	7519^{e}	3.610^{c}
50	7874^{d}	3.826^{c}
100	8164^{c}	3.997^{c}
150	8470^{b}	4.097^{b}
200	8620^{a}	4.157^{a}
LSD (0.05)	42.68	0.2482
Inter-row spacing (cm)		
55	7557^{d}	4.617^{a}
65	8109^{c}	4.153^{b}
75	8392^{b}	3.680^{c}
85	8463^{a}	3.680^{c}
LSD (0.05)	42.68	0.2220
CV (%)	1.8	2.3

**= Significant at 1% probability levels; LSD = Least Significant Difference; CV= Coefficient of Variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.

4.2.5. Plant height

The main effect of NPS fertilizer rate and interaction of NPS and inter row spacing were highly significant ($p<0.01$) on plant height while the main effect of inter row spacing was not significant (Table 4 and Appendix Table 1). The tallest plant (246 cm) was obtained for combination of 55 cm and 200 kg NPS ha^{-1} while the shortest plant (184 cm) was from 55 cm and 0 kg NPS ha^{-1} (Table 4).

When the rate of blended NPS was increased from 0 to 200 NPS ha^{-1} plant height was increased in most of the inter-row spacing. The result clearly indicated that plant height was increased in response to the increased levels of NPS fertilizer rate. This increment in plant height might be due to increase in cell elongation and more vegetative growth attributed to different nutrient contents containing NPS and macro nutrient. Likewise, nitrogen, phosphorus and sulfur nutrients are involved in vital plant functions and contribute to enhanced growth in the height of the crop and narrow inter-row spacing and higher density of plants brings high competition of resources resulted higher growth in height. On the other hand the least plant height in unfertilized plots might have been due to low soil fertility level in the study area.

In conformity with the results obtained from this study, Plant growth and development may be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (Landon., 1991). Thus, the results indicate that blended fertilizers application has enhanced the maize vegetative growth. Plant height increased as N increased, this could be attributed to a mere fact that higher rates of nitrogen may have caused rapid cell division and elongation (Shamim *et al*., 2015). This result was in harmonized with Workayehu (2000) who found that there was significant effect of P and N fertilizer on maize plant height. Similarly, Chimdessa (2016) also reported that application of blended fertilizer was significantly increased plant height of maize as compared to the recommended NP.

Melesse (2017) also reported that application of N and P fertilizer rates increased plant height of bread wheat and recorded the highest height of 94.18 and 90.56 cm at applications of 69 kg N ha^{-1} and 30kg P ha^{-1} respectively. In line with this result, Tilahun and Tamado (2018) also reported that the maximum application rate of blended NPS (200 kg ha^{-1}) resulted in the highest plant height wheat (79.59 cm). Tenaw (2000) also reported a significant effect of N fertilizer on maize plant height similarly; increasing P rates from 0 to 53.2 kg P ha^{-1} also increased plant height. Habtamu (2015) reported that the tallest maize crop was grown on the combined treatments of 90 kg N and 30 kg S ha^{-1} which showed an increase of 148.65% relative to the control.

In case of inter row spacing high plant density brings out certain modifications in the growth of plants such as increase in plant height, reduction in leaf thickness, alteration in leaf orientation, and leaves become erect, narrow and are arranged at longer vertical intervals to intercepts more sun light (Singh and Singh, 2002). The result also agreed with the observation of Goldsworthy and Taylor (1990) who reported increase in sorghum height with increase in plant density. In conformity with the result, Matthews *et al*. (2008) reported that maize planted with plant spacing of 25 cm and row spacing of 50 cm had significantly taller plants than those planted with 30 cm plant spacing and 75 cm row spacing. The increase in plant height at narrower inter-row spacing might be due to comparatively low solar interception through crop canopy at narrow spacing (high plant density).

Table 4. Interaction effects of blended NPS fertilizer rates and inter row spacing on plant height (m) of maize.

NPS rates (kg ha^{-1})	Inter row Spacing (cm)			
	55	65	75	85
0	1.8400^{a}	2.2167^{b}	2.2500^{c}	2.350^{ef}
50	2.2500^{c}	2.2567^{c}	2.3267^{de}	2.350^{ef}
100	2.3600^{f}	2.3533^{f}	2.3133^{d}	2.4000^{hi}
150	2.4167^{ij}	2.3433^{ef}	2.3633^{fg}	2.3867^{gh}
200	2.4633^{k}	2.4367^{j}	2.4000^{hi}	2.3567^{gh}
LSD (0.05) 0.384				
CV (%) 9.9				

LSD = Least Significant Difference; CV= Coefficient of Variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.

4.3. Yield Components and Yield of Maize

4.3.1. Plant stand count percent at harvest

The analysis of variance showed that percent stand count was highly significantly ($P<0.01$) affected by the main effects of NPS blended fertilizer rates and level of inter row spacing but their interaction was non-significant (Table 8) and (Appendix table 2). The highest stand count percent at harvest is (96.657%) was occurred for NPS blended rates at 200 kg ha^{-1} while the lowest stand count percent at harvest (92.28%) was recorded at no NPS application

Stand count at harvest increase as NPS blended fertilizer rates and inter row spacing increased might be due to positive interaction of macro nutrient in the blended (NPS) and balanced utilization of nutrients which is responsible for increase stand count at harvest. The highest stand count might be due enough root initiation that strengthened anchorage of seedlings while the lowest stand count is due to mortality from lack of nitrogen, phosphorus and sulphur fertilizer. In line with this Brady and Well. (2000) reported that plants deficient in nitrogen develop thin and spindly stems, such stems could be susceptible for lodging by wind.

Moreover, N and P deficient plants have poor development of root system which reduces their anchorage capacity. In line with this result, Sangoi *et al.* (2000) reported that ideal plant number per area depends on several factors such as water availability, soil fertility, variety, maturity group and row spacing. In agreement with this result, the minimum mean of plants ha^{-1} (3.71) was recorded in plots that received no nitrogen and increasing fertilizer doses to 60, 120, 180 kg ha^{-1} increased the number of plants at harvest (4.02, 4.03, and 4.02 respectively, but statistically par with each other.

For inter row spacing the highest plant stand count at harvest (96.35%) was obtained at 85 cm inter row spacing and the lowest stand count at harvest (89.6%) was recorded at 55 cm inter row spacing (Table 8). This might be due to at lower population comparatively availability of more space might have resulted in less competition for resources (nutrients, moisture and light) whereas at high density due to more inter specific competition the weaker plants might have died by the time the crop approached maturity. This self-thinning effect can also be attributed to increased inter plant competition for space, light, moisture and nutrients at the higher populations. In agreement with this results Kena (2014) reported that plant stands count percent increased from 90.39% to 98.26% by increasing the inter row from 55 cm to 85 cm respectively. Similarly, Eskandarnejada *et al*. (2013) reported that higher plant count percent (98%) was achieved due to the wider spacing combinations of 75 cm x 30 cm than narrower spacing of 55 cm x 20 cm.

4.3.2. Number of ears per plant

The analysis of variance showed that number of ears per plant was highly significantly ($P< 0.01$) affected by main factors and interaction of blended NPS fertilizer rate and inter-row spacing on number of ears per plant of maize (Appendix Table 2). The highest number of ears per plant (1.4767) was recorded at the application of 150 kg NPS ha^{-1} with 75 cm inter-row spacing while the lowest number of ears per plant (1.000) was for control treatment with 55 cm row spacing (Table 5). The increased number of ears per plant at the highest blended NPS rate 150 kg NPS ha^{-1} and widest inter-row spacing 75 cm might be due to provision of balanced nutrient and optimum plant density enhance better up take of all nutrient and improves NUE (Nutrient use efficiency) and positive interaction of three nutrients. And 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 facilitates 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. Similarly, Maral *et al*. (2012) reported that increasing nitrogen level from 50 to 250 kg ha^{-1} significantly increased the number of ears per plant from 1.2 to 2.05.

Closer spacing or high plant densities, there may be intense inter-specific competition among plants for growth resources like nutrients, soil moisture, and light. Thus, supply of growth resources to growing ears is reduced which in turn reduced number of ears per plant. Zamir *et al*. (2011) reported that decreasing plant spacing from 30 cm to 15 cm, the number of cobs per plant was significantly reduced from 1.42 to 1.21 possibly due to more competition for light, aeration and nutrients.

Table 5. The interaction effect of NPS and inter row spacing on number of ear per plant of maize

NPS rates (kg ha^{-1})	Inter row spacing (cm)			
	55	65	75	85
0	1.0^{a}	1.04^{abc}	1.05^{bc}	1.10^{def}
50	1.05^{bc}	1.016^{ab}	1.20^{g}	1.15^{f}
100	1.07^{cd}	1.13^{ef}	1.35^{h}	1.35^{h}
150	1.11^{def}	1.15^{f}	1.47^{j}	1.45^{j}
200	$1.11d^{ef}$	1.20^{g}	1.45^{j}	1.46^{j}
LSD (0.05) 0.04252				
CV (%) 5				

LSD = Least Significant Difference; CV= Coefficient of Variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.

4.3.3. Number of ears per hectare

Numbers of ears per hectare was highly significantly ($p<0.01$) affected both by the main effects of NPS fertilizer rate and inter-row spacing (Table 6 and Appendix Table 2). The interaction effects of NPS fertilizer rates and inter- row spacing on number of ears per hectare was also highly significant ($p<0.01$) (Table 6 and Appendix Table 2).

The highest number of ears per hectare (69,976) was recorded with the application of 150 kg NPS ha^{-1} with inter-row spacing of 75 cm followed by application of 200 kg NPS ha^{-1} with 75 cm inter-row spacing (69,317 ha^{-1}). In contrast, the lowest number of ears per hectare (43,947) was recorded from the narrowest inter-row spacing (55 cm) with 0 kg NPS ha^{-1} (Table 6). The increased in number of ears per hectare due to optimum NPS levels and optimum plant densities enhances better nutrient use efficiency might and positive interaction of all three nutrients makes rapid conversion of synthesized carbohydrates into protein and consequently increase in number and size of growing cells ultimately resulting increase number of ear per hectare.

This is due to 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 also facilitates N and P absorption, cell division, chlorophyll synthesis and photosynthesis (Rao *et al*., 2001), thus can increase significantly increase ear per hectare. Similarly, Maral *et al*. (2012) reported that increasing nitrogen level from 50 to 250 kg ha^{-1} significantly increased the number of ears per plant from 1.2 to 2.05.

Intense interplant competition for incident photosynthetic photon flux, soil nutrients and soil water, that results in limited supplies of carbon (C) and N increases in barrenness of maize (Lemcoff and Loomis, 1994). In agreement with the results of this study, Abuzar *et al.* (2011) reported that increasing plant density by reducing plant spacing significantly reduced the number of ears per hectare because of reduction in the supply of nitrogen, photosynthesis and water to the growing ear. Similarly, Wakjira (2018) also reported that number of ears per hectare increased from 30980 to 72222 by increasing inter-row spacing from 55 cm to 85 cm.

Table 6. Interaction effects of NPS fertilizer rates and inter- row spacing on number of ears per hectare of maize.

NPS rate (kg ha^{-1})	Inter row spacing (cm)			
	55	65	75	85
0	43947^{b}	55651^{bcde}	56797^{cdef}	58766^{defg}
50	45755^{bc}	60760^{defg}	66096^{fgh}	65756^{efgh}
100	46256^{bc}	62626^{defg}	68267^{gh}	69240^{h}
150	52087^{bcd}	63289^{a}	69976^{h}	69317^{h}
200	53714^{bcde}	65256^{efgh}	69000^{h}	69217^{h}
LSD (0.05)	12176			
CV (%)	4.5			

**= Significant at 1% probability levels; LSD = Least Significant Difference; CV= Coefficient of Variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance

4.3.4. Ear length

The main factors and interaction effect of blended NPS fertilizer rate and inter row spacing was highly significant ($P<0.01$) affected on ear length of maize (Appendix table 2). Accordingly, the highest ear length (29.17 cm) was recorded at the highest blended NPS fertilizer rate (150 kg ha^{-1}) with combination of the row spacing of 75 cm while the lowest ear length (17.00 cm) was recorded at the combination of the no NPS fertilizer and 55 cm narrowest inter-row spacing (Table 7).

In agreement with this result, Kena (2015) reported that the highest ear length (21.20 cm) was recorded from the interaction of the inter-row spacing 75 cm by highest nitrogen rate (180 kg ha^{-1}) while the lowest ear length (16.73 cm) was recorded from the interaction of the narrowest inter-row spacing of 55 cm by no nitrogen application.

The reason for the better ear length development at optimum input of NPS fertilizer with optimum plant density improves 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 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 also involved in the conformations and activities of many enzymes and stimulates seed production (Scherer, 2001). Mineral fertilizer better ear length growth was achieved which had impact on yield.

Orkaido Olte, (2004) also reported that application of N in combination with P showed consistent ear length increment ranging from 5.8 to 30% over the control. Lakshmi *et al*. (2010) also indicated that application of 60 kg S ha^{-1} recorded highest cob length and 100 grain weight of maize.

In the case of inter row spacing, Zamir *et al.* (2011) reported that the cob length decreased as the plant population increased significantly. The results were consistent with the finding of Gobeze *et al.* (2012) who stated that increasing plant population in density from 5 to 15 plants m^{-2} reduced the ear length from 17.0 to 12.23 cm in maize. Similarly, the result was in consistent with the finding of Donatus and Cynthia (2014) who stated that increasing plant population from 57142 to 100 000 plants ha^{-1} reduced the ear length from 18.39 to 15.64 cm in maize.

Table 7. Interaction effects of NPS fertilizer rate and inter-row spacing on ear length (cm) of maize.

NPS rate (kg ha^{-1})	Inter row spacing (cm)			
	55	65	75	85
0	17.0^{a}	18.22^{b}	23.32^{de}	24.85^{gh}
50	22.0^{c}	23.65^{d}	25.54^{gh}	27.17^{i}
100	24.0^{cf}	24.63^{fg}	28.0^{i}	28.60^{j}
150	25.0^{gh}	25.24^{gh}	29.17^{l}	28.71^{j}
200	27.0^{i}	28.0^{h}	28.50^{j}	28.40^{j}
LSD (0.05) 0.2134				
CV (%) 5.9				

**= Significant at 1% probability levels; LSD = Least Significant Difference; CV= Coefficient of Variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of Significance

4.3.5. Number of kernels per ear

Analysis of variance showed that number of kernels per ear was highly significantly ($p<0.01$) affected by NPS fertilizer rate and it was significantly ($p<0.05$) affected by inter row spacing and the interaction effect of the two factors (Appendix Table 4).

The maximum number of kernels per ears (472.3) was recorded in response to NPS applied at the rate of 200 kg NPS ha^{-1} and it was statistically at par with 150 kg N ha^{-1} which was (470.08) at all times of application (Table 8). In contrast, the lowest number of kernels per (413) recorded from control plots. Fertilizer application rates might be attributed to good physiological activities of the crop to attract assimilates. Maize intrinsic ability of the endosperm to attract assimilates (kernel sink capacity) is one of the most important physiological determinants of the grain yield of cereal crops and may be the major limitation to yield (Jones *et al*., 1996).
Similarly, Maqsood *et al*. (2001) found that number of kernels per ear was increased as P and N increased to a certain level. With increased NPS level up to 200 kg NPS ha^{-1} levels might be attributed to better uptake of all the nutrients and increased translocation of photosynthetic products from source to sink and increased photosynthetic assimilate production and its partitioning that might have favorable impacts on kernels per ear of maize.

In agreement with this result, Degefa (2016) stated that the highest number of kernels per ears (539.7) was obtained from 87 kg N ha^{-1}. In line with thus result Dinkinesh (2018) reported that the highest number of kernels (43) produced from the highest rate of NPSB fertilizers (183 kg ha^{-1} NPSB) whereas the minimum number of kernels per spike (35) was produced at nil NPSB rate.

Wider inter row spacing on the number of kernels ear^{-1} leading to low interplant competition for growth resource this manifested by high number kernel ear^{-1}. This variation might be due to the fact that widely spaced plants encountered less inter plant competition than closely spaced plants and thus exhibited better growth that contributed to more number of kernels per ear. In agreement with this result, Eskandarnejada *et al*. (2013) reported that inter-row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing. Abuzar *et al.* (2011) observed that an increase in plant density decreased the number of grains ear^{-1}.

4.3.6. Thousand kernels weight

Grain weight is an important yield component that helps a lot in the grain yield estimate. Analysis of variance indicated that thousand kernel weight of maize was highly significantly ($p<0.01$) affected by the main effect of NPS fertilizer rate and inter row spacing and significantly influenced by the interaction effect of the two factors (Appendix Table 2). The highest thousand kernels weight of (398.7 g) was recorded from 150 kg NPS ha^{-1} but it's was at par with thousand kernel weight of (392.6 g) obtained from 200 kg NPS ha^{-1}. Disparity, the lowest thousand kernels weight of (327.3 g) was recorded from plot without NPS fertilizer. Generally increasing NPS rate from 0 kg NPS ha^{-1} to 200 kg NPS ha^{-1} significantly increased thousand kernel weights (Table 8).

The more grain weight for blended fertilizer might be attributed to positive interaction of nutrients in the blended fertilizers. This result is in line with the findings of that (Zhao *et al*., 1999) and (Mekdad., 2015) Nitrogen and Sulphur is involved in the working of enzymes in photosynthesis and the movement of its products (photosynthates) to storage organs (seeds, tubers, roots and fruits) resulted increased in grain weight. The final weight of the grains is thus a result of the rate at which the kernel accumulates dry matter and the duration over which this occurs (Housely *et al*., 1982).

Phosphorus being responsible for good root growth directly affected the thousand grain weight because P at the rate of 0 kg ha^{-1} (control plots) resulted in the least thousand grain weight (Hussain *et al.,* 2006). Application of Sulphur fertilizer is also feasible for maize production and productivity by improving soil condition for healthy crop production resulted in increasing in thousand kernel weight (Zhao *et al*., 1999).

Kebede (2016) also reported the highest thousand kernel weight (391.35 g) was obtained at N rate of 92 kg N ha^{-1} followed by 69 kg N ha^{-1} (362.53 g). Widest inter row spacing of 75 cm the resulted is highest thousand seed weight of (389.4 g) and the lowest thousand seed weight (315.1 g) measured at 55 cm inter row spacing (Table 8). The decrease in 1000 seed weight could be attributed to decrease assimilate division among seeds as a result of the increased inter plant competition in utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues, hence decrease in weight. However, in wider inter row spaced plants due to availability of more resources (light, nutrient, water) for comparatively less number of plants, which they utilized efficiently to produce bigger kernels. The result was in agreement with Ogunlela *et al.* (2005), Arif *et al.* (2010) and Mukhtar *et al.* (2012) who reported that 1000 kernels weight decreased with increase in plant density.

Table 8. Main Effects of NPS fertilizer rates and Inter row spacing on thousand kernel weight, numbers of kernel per ear, stand count at harvest.

NPS rates(kg ha^{-1})	Thousand kernel weight.	Number of kernel per ears.	Stand count percent at harvest
0	327.3^{d}	413.4^{d}	0.9288^{d}
50	352.6^{c}	444.6^{c}	0.9425^{c}
100	354.2^{c}	458.7^{b}	0.9513^{cb}
150	398.7^{b}	470.8^{a}	0.9545^{b}
200	392.6^{a}	472.3^{a}	0.9657^{a}
LSD (0.05)	10.19	4.523	0.003792
Inter row spacing (cm)			
55	315.1^{d}	398.2^{d}	0.896^{d}
65	366.9^{c}	447.1^{c}	0.9437^{c}
75	389.0^{b}	461.0^{b}	0.9583^{b}
85	379.4^{a}	467.6^{a}	0.9637^{a}
LSD (0.05)	9.11	4.045	0.003792
CV (%)	3.4	7.2	3.4

LSD=least significant differences CV=Coefficient Variation Means of the same letters does not shows significant different.

4.3.7. Above ground dry biomass

The main effects of NPS level and inter-row spacing and their interaction effect highly significantly ($p<0.01$) affected aboveground dry biomass (Table 9 and Appendix Table 3). The highest above ground dry biomass yield (20,667 kg ha^{-1}) was recorded at the combination of the highest NPS fertilizer rate 200 kg ha^{-1} and 55 cm inter-row spacing followed by 200 kg NPS ha^{-1} at 65 cm spacing (23,447 kg ha^{-1}) while the lowest aboveground dry biomass (12,340 kg ha^{-1}) was recorded at 55 cm inter-row spacing without NPS fertilizer application (Table 9).

The result showed that the above ground biomass was increased by increasing rates of NPS fertilizer application due to higher LAI, number of ear per plant, number of grains per ear, ear length, 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. An 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 narrow spacing.

Moreover, the increase in dry biomass yield with the increased NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability and P also, plays a pivotal role in early root spread that might increase the nutrient up take of the plant consequently resulted in increased vegetative growth and demand for NPS increases with biomass yield, which may be enhanced by reduced row spacing and greater plant density (Jordan *et al.,* 1950).

Dinkinesh (2018) also reported that the highest aboveground dry biomass (11772 kg ha^{-1}) was obtained at the application of the highest rate (183 kg ha^{-1} NPSB) whereas the lowest aboveground dry biomass (3756 kg ha^{-1}) was produced under control treatment. Likewise, Ayman and Samier (2015) also reported the maximum above ground dry biomass of 28914 kg ha^{-1} in maize in response to the N application at the rate of 330 kg ha^{-1} and maximum of 57,124 plants ha^{-1}. The increase in biomass yield with increase in nitrogen rate is expected as nitrogen is known to promote vegetative growth (Tisdale *et al.,* 1995).

Increasing inter-row spacing from 55 cm to 85 cm decreased above ground dry biomass yield and showed consistent decrement. This might be due to higher plant population recorded at narrow inter and intra-row spacing and hence greater dry matter production. In agreement with this result Mahmood *et al.* (2001) showed that total biomass yields of maize were significantly higher in the narrow intra-row spacing (20 cm) than in wider intra-row spacing (30 cm) due to more number of taller plants per unit area and better interception of solar radiation.

Table 9. Interaction effect of NPS fertilizer rates and inter- row spacing on above ground dry biomass (kg ha^{-1}) of maize.

NPS rates (kg ha^{-1})	Inter row spacing (cm)			
	55	65	75	85
0	12340^{a}	15317^{bc}	17703^{defg}	15496^{bc}
50	14450^{b}	17178^{cdef}	18700^{fghi}	16324^{bcde}
100	16093^{bcd}	19174^{ghij}	19867^{hij}	17870^{defgh}
150	18346^{fgh}	20000^{hij}	18222^{efgh}	18519^{fgh}
200	20667^{j}	20447^{ij}	19800^{hij}	19007^{fghij}
LSD (0.05) 1915				
CV (%) 6.3				

LSD=Least significance Differences CV=Coefficient of Variations, Means in the tables indicates the same letters does not show significance differences

4.3.8. Harvest index (HI)

The harvest index indicated the physiological efficiency and ability of a crop for converting the total dry matter in to economic yield. The analysis of variance showed that harvest index was highly significantly ($p<0.01$) affected by the main effect of NPS rate and significantly ($p<0.05$) affected by main effect of inter row spacing. While the interaction of two factors none significant (Appendix Table 4). With the increase in the rate of NPS application from 0 to 200 kg NPS ha^{-1}, harvest index was increased and started to decline above this rate.

The highest harvest index (30.4%) was recorded from treatments supplied with 200 kg NPS ha^{-1}. However, it is statistically at par with harvest index (29.38%) which is recorded from treatment received 150 kg NPS ha^{-1} while lowest harvest index (24.3%) were obtained from treatments grown under control and 55 cm spacing (Table 10).

The increment in harvest index at highest rate of NPS might be adequate supply of NPS fertilizer is 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. The result was agreed with that of Addis *et al*. (2015) who reported that increasing N from 0 to 75 kg N ha^{-1} increase harvest index from 49.493% to 54.620%, but harvest index was decreased from higher dose of the treatment 100 kg N ha^{-1} to 125 kg N ha^{-1} from 50.817% to 47.663%, respectively. In line with this, Abdo (2009) reported highest harvest index (30.61%) from treatments with the lowest rate of nitrogen application 23 kg N ha^{-1}.

The highest harvesting index (30.6%) was recorded at widest spacing (85 cm), while the lowest (23%) was due to the narrowest (55 cm) spacing. Harvesting index increased as inter row spacing increased (Table 10). Plant density also affect harvest index, at the widest inter-row spacing less intra-specific competition led to greater proportional increase in grain yield than total above-ground dry matter accumulation, incidentally resulting in a higher harvest index. Maize harvest index typically decreases at above-optimum plant densities as intra-specific competition reduces biomass partitioning to the ears (Pagano and Maddonni, 2007).

4.3.9. Agronomic efficiency

The agronomic efficiency was highly significantly ($p<0.01$) affected by the main effect of NPS fertilizer rates and inter row spacing (Appendix Table 4) (Table 10). Thus, as the rate of NPS application increased from 0 to 1500 kg NPS ha^{-1}, the agronomic efficiency was increased; but increasing NPS rate from 150 to 200 kg NPS ha^{-1} did not significantly increase agronomic efficiency rather it decreased agronomic efficiency.

The highest agronomic efficiency as ratio of grain yield to rates of NPS fertilizer (25.062 kg of grain to kg of NPS) was observed in treatment that received 150 kg ha^{-1} of NPS fertilizer. In contrast to this the lowest agronomic efficiency as ratio of grain yield to NPS fertilizer rate was observed in treatment that received 200 kg ha^{-1} NPS (10.1 kg of grain to kg of NPS) which was statically at par with 100 kg ha^{-1} NPS (11.28 kg of grain to kg of NPS).

The results of agronomic efficiency for rates of NPS fertilizer showed that the efficiency was reached maximum at the application of 150 kg ha^{-1} NPS fertilizer. This result indicated that these crops got higher chance to convert nutrients in to higher economic yield when there was optimum nutrient and availability in the soil and the capacity of the maize convert nutrient in to economic yield were different with respect to their optimum spacing.

The lowest agronomic efficiency due to higher rates of NPS fertilizer rate implies that when crops have got highest nutrient beyond their requirements there was luxury consumption of nutrients rather than converting to highest economic yield they showed vegetative growth and foolishness of heights alone. These might be due to the fact that input-output relationship which follows the law of diminishing returns between fertilizer and yield and also the response of varieties to applied nutrient was varying due to their genetic makeup.

Similarly, Abebe (2012) reported that agronomic efficiency of wheat decreases with increasing N rates. Buah *et al*. (1998) also reported that when evaluating the agronomic responsiveness of 13 sorghum genotypes, differing in nitrogen use efficiency to three N rates (0, 50 and 100 kg N ha^{-1}) and observed greater yields in the high nitrogen use efficiency sorghum types than in the low Nitrogen use efficiency types.

Table 10. Harvest index and agronomic efficiency of maize as influenced by the main effects of NPS fertilizer rate and inter row spacing.

NPS Fertilizer rates (kg ha^{-1})	Harvest Index (%)	Agronomic Efficiency
0	0.2403^{b}	0.000
50	0.2467^{b}	10.340^{b}
100	0.2608^{b}	11.283^{b}
150	0.2938^{a}	25.062^{a}
200	0.3042^{a}	10.115^{b}
LSD (0.05)	0.2938	1.827
Inter row spacing (cm)		
55	0.2322^{b}	7.460^{c}
65	0.2503^{b}	11.928^{b}
75	0.2880^{a}	21.168^{a}
85	0.3061^{a}	7.884^{c}
LSD (0.05)	0.02393	1.634
CV (%)	6.3	2.5

LSD=Least significant Difference CV=Coefficient of Variations =Means of the same Letters does not show significance differences

4.4. Grain Yield

Grain yield is the end result of many complex morphological and physiological processes occurring during growth and development of the crop. The analysis of variance showed that the main factors and interaction effect of blended NPS fertilizer rates and inter row spacing of was highly significantly ($P<0.01$) (Appendix Table 3). Accordingly, the highest grain yield (6577 Kg ha^{-1}) was recorded at the combination of the highest blended NPS fertilizer rate (150 kg ha^{-1}) and the row spacing of 75 cm, while the lowest grain yield (2850 kg ha^{-1}) was recorded at the combination of the narrowest inter-row spacing of 55 cm with control plot(Table 11).

Higher grain yield at optimum blended NPS fertilizer level and widest inter row spacing might be due to optimum utilization of macro nutrient in the blended fertilizer which enhances increases uptake of other nutrients and lower competition for growth resources that allow the plants to accumulate more biomass with higher capacity to convert more photo synthesis to sink resulting in more grains yield of grain yield. It is clear from the result that grain yield increased in response to optimum rate of fertilizers application NPS possibly due to higher leaf area index (LAI), plant height, number of grain per ear, 1000 grain weight and number of cobs per plant.

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. Similarly, Hammed *et al*. (2011) suggested that N application had much greater effect on maize grain yield; this could be due to the fact that application of N fertilizer in plants increases uptake of other nutrients. The P supply is particularly important for stimulating early root formation and growth, functions in plant molecular structure as a component of nucleic acid and phospholipids, with crucial roles in energy metabolism participation in signal transduction pathways phosphorylation and controlling key enzyme reactions (Marschner, 2012). Phosphorus also significantly increases the number of cobs per plot, 1000-grain weight, and grain yield over the control (Qasim *et al*., 2001). Similarly, Olusegun (2015) reported that application of the combination of N at 90 kg h^{-1} and P at 30 kg h^{-1} gave the highest grain yield of maize.

Sulfur has the role of energy transformation, activation of enzymes which in turn enhances carbohydrate metabolism and photosynthesis activity of plant with increased chlorophyll synthesis (Juszczuk and Ostaszewka, 2011). Sulphur also encourages photosynthetic activity by increasing chlorophyll pigments, synthesis of essential amino acids and proteins, translocation and utilization of starch and nitrogen and all these functions finally converge to increase maize yield (Gahlout *et al.,* 2010*).* Similarly, increased grain yield of maize with higher sulphur application could be owing to higher availability of nutrients and development of strong source-sink relationship manifested in realization of higher productivity of maize in terms of seed yield (Tandon, 1999). The combined application of Phosphorus with nitrogen increased the yield significantly Moschler and Martens (1975). It may be due to greater contribution of N & P by producing healthy grains well filled grains and bigger grains resulted higher grain yield. The low yield in unfertilized plots might have been due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation (Sallah *et al.,* 1998).

The highest grain yield per hectare at wider inter-row spacing (75 cm) and optimum nutrient use efficiency might be due to high number of ears per plant and high leaf area because there is more availability of growth factors and better penetration of light at the widest inter-row spacing. Similarly, Sallah *et al*. (2009) reported that as plant population increased, higher nitrogen fertilizer application rates are needed for higher yields and obtained the highest grain yield of maize in plant population density of 70,000 plants ha^{-1} with 160 kg N ha^{-1}. In this study, no blended NPS fertilizer and narrowest inter-row spacing (55 cm) showed lower grain yield in most cases.

This might be due to the high plant population beyond optimum leads to intense interplant competition for incident photosynthetic photon flux density, soil nutrients and soil water. Huseyin and Omer (2010) also reported that grain yield of maize significantly increased with increasing plant population density and nitrogen fertilizer up to 88000 plants per hectare and 240 kg of nitrogen ha^{-1} in popcorn. Similar to the above authors, Cassman *et al.* (2002) reported that the greater synchrony between crop demand and nutrient supply is necessary to improve nutrient use efficiency, and split application of N during the growing season, rather than a single, more application, are known to be effective in increasing N use efficiency.

Table 11. Interaction effect of both NPS fertilizer rate and inter row spacing on grain yield.

NPS fertilizer rates (kg ha^{-1})	Inter row spacing (cm)			
	55	65	75	85
0	2850.00^{a}	3765.0^{b}	3869.2^{c}	3964.7^{d}
50	3883.0^{c}	3973.5^{d}	4200.0^{g}	4136.6^{ef}
100	4095.2^{e}	4180.8^{fg}	4478.0^{j}	5028.2^{lm}
150	4282.7^{h}	4577.7^{k}	6577^{m}	6227.8^{m}
200	4415.8^{i}	4719.8.0^{l}	6200^{m}	6120^{m}
LSD(0.05)	229.1			
CV(%)	3.9			

LSD=Least significance Differences CV=Coefficient of Variations, Means in the tables indicates the same letters does not show significance differences.

4.5. Partial Budget Analysis

The partial economic analysis was carried out by using the methodology described in CIMMYT (1988) methodology. From the final experimental data, the gross yield for 20 treatments was obtained and the recommended level of 10 % was reduced from all treatments or unadjusted grain yield (UGY) to obtain adjusted grain yield. Net benefit was calculating by subtracting the Total Variable Cost (TVC) from the Gross Field Benefit (GFB) for each treatment. Costs and benefits were calculated for each treatment. All variable costs were calculated excluding price of other agronomic practices such as weeding, protection of the farm and harvesting because it was uniform for all treatments. The cost of NPS fertilizer was ETB 18 kg^{-1}, urea was ETB 16 kg ha^{-1} variety Melkassa-II seed was ETB 65 kg^{-1}. The partial budget analysis showed that the highest net benefit of 91608 ETB Birr ha^{-1} was obtained in the treatment that received 150 kg NPS ha^{-1} and 75 cm inter row spacing while the lowest net benefit of Birr 44010 ETB ha^{-1} was from the combination of no NPS and 55 cm inter row spacing. For treatment to be considered as advisable to farmers, between 50% and 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). Therefore, 1745% was recorded from application of 150 kg NPS ha^{-1} profitable and recommended for farmers in study area and others similar agro ecology.

Table 12. Partial budget analysis of maize yield as influenced by NPS fertilizer rates and inters row spacing of maize at Haramaya University.

Treatment		AGY	AST	GFB	TVC	NB	MRR (%)
NPS	IR	(kg ha^{-1})	(kg ha^{-1})	(ETB) ha^{-1}	(ETB) ha^{-1}	(ETB) ha^{-1}	ha^{-1}
0	55	2850	10340	28500	1975	44010	2228
0	65	3765	13317	37650	1812.5	57625.5	3179
0	75	3862	15703	38620	1550	62174.5	4011
0	85	3967.4	13496	39674	1520	59918	D
50	55	3883	12450	38830	3875	57505	1484
50	65	4173.5	15178	41735	3773	64502	1709
50	75	4200	16700	42000	3450	67050	1943
50	85	4336.5	14324	43365	3220	64848	2014
100	55	4091.77	14093	40917.7	4775	62057.2	D
100	65	4147.8	17174	41478	4582.5	67239	1467
100	75	4752.5	17867	47525	4350	73325.5	1685.6
100	85	5790	15870	59900	4220	83705	1983
150	55	4282.5	16346	42825	5675	67344	D
150	65	4555.5	17000	45555	4912.5	71055.5	1446
150	75	6577.5	17222	65775	5250	91608	1745
150	85	6200	16519	62000	5220	86778.5	D
200	55	4357.9	18667	43579	6575	68579.6	1043
200	65	4735.5	18447	47455	6412.5	75125.5	1171
200	75	6200	17800	62000	6150	88700	1442
200	85	6100	17007	61000	6020	86510.5	1437

Where, NPS= Rate of NPS, IR= Inter row spacing, AGY= Adjusted grain yield, where ASY=Adjusted stalk yield, GFB= Gross field benefit, TVC = total variable cost, NB= Net benefit, MRR= Marginal rate of return, Market price of maize 10 ETB kg^{-1} , Cost of Urea = 9.8855 ETB kg^{-1}ha^{-1}; Labour cost for application of NPS =5 persons ha^{-1} at each time of application, each 75 ETB per day , Price of stalk =1.50 Birr per kg, ETB=Ethiopian birr, D: Dominated treatment.

5. SUMMARY AND CONCLUSIONS

The low yield of maize production due to poor agronomic practices like low soil fertility and plant density require special attention.

Therefore, the present experiment was conducted in 2019/2020 main cropping season at Haramaya University, eastern Hararghe Zone, Oromia Regional State, with the objectives of to determine the effect of blended NPS fertilizer rates and inter row spacing on yield components and yield of maize and to evaluate cost benefit analysis of blended NPS fertilizer rates in yield of maize in the Haramaya Research site. Factorial combinations of five levels of NPS rate (0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1}, 150 kg ha^{-1} and 200 kg ha^{-1}) and four inter row spacing (55 cm, 65 cm, 75 cm and 85 cm) were laid out in a Randomized Complete Block Design with three replications using maize variety Melkassa-II.

The main effects of NPS fertilize rate showed highly significantly ($P<0.01$) on day to 50% anthesis, 50% silking, 90% physiological maturity, leaf area, leaf area index, number of kernel per ear, above ground dry biomass, grain yield, agronomic efficiency, stand count at harvesting. The highest day to 50% anthesis (82 days), 50% silking (86 days), physiological maturity (128 day), the highest leaf area (8620 cm^2), leaf area index (4.15), number of kernel per ear (472.3), and above ground dry biomass (20667 kg h^{-1}) were recorded from 200 NPS fertilizer rates, while the lowest leaf area (6785.5), leaf area index (3.6), number of kernel per ear (413.3), and above ground dry biomass (12340 kg ha^{-1}) were recorded from 55 cm with no NPS. NPS fertilizer rates had also significantly ($P<0.05$) effect on harvest index and thousand kernel weight. Significantly the highest harvst index (30.4%) recorded from 200 NPS kg ha^{-1} and highest thousand kernel weight (398.7g) was recorded from 150 NPS kg ha^{-1}.

Main effect of inter row spacing showed highly significant ($P<0.01$) effects on 50% anthesis, 50% silking, leaf area, leaf area index, stand count, and harvest index. Among the inter-row spacing the highest 50% anthesis (81 days), 50% silking (84 days), leaf area (8463 cm^2), stand count (96.32%), and harvesting index (30.4%) were observed at widest inter row spacing (85 cm), while the highest above ground dry biomass (20,667 kg ha^{-1}) and highest leaf area index (4.617) was recorded at narrowest inter row spacing (55cm) and inter-row spacing also significant ($P<0.05$) effect on physiological maturity and number of kernel per ear, grain yield, thousand kernel weight, the highest grain yield recorded from 75 cm inter row spacing while lowest grain yield is recorded from 55 cm , the late physiological maturity (126 days), while the early maturity (122 days) was due to the widest (85 cm) and narrowest (55 cm) inter row spacing respectively and the highest number of kernels per plant (467) was at widest inter row spacing (85 cm) and the lowest number of kernel per ear (398) was recorded at (55 cm) inter row spacing.

Interactions of NPS fertilizer rates with inter row spacing showed highly significant ($P<0.01$) effect on above ground dry biomass, ear length, number of ear per hectare, plant height, Agronomic efficiency, grain yield but significant effect ($P<0.05$) on number of ear per plant, number of kernel per ear. The tallest plant (246 cm) was recorded from 200 NPS Kg ha^{-1} with (55 cm) inter row spacing, the highest number of ear per plant (1.467), highest ear length (29 cm), highest number of ear per hectare (69,999), highest grain yield per hectare (6577 kg ha^{-1}), Agronomic efficiency (30.65) were recorded from 150 NPS kg ha^{-1} at 75 cm inter row spacing.

The highest economic benefit (91,608 ETB ha^{-1}) and higher acceptable MRR (1745%) was obtained from combination of 150 kg NPS ha^{-1} and inter row spacing of 75 cm while the lowest economic benefit were (40010 ETB ha^{-1}) was from combination of control and 55 cm inter row spacing. Therefore, based on the result of the study it can concluded that application of 150 kg NPS ha^{-1} and 75 cm inter row spacing was suitable for increase the productivity of the maize variety Melkassa-II in the study area under main cropping season. However, as this result is for one season and one location; the study has to be repeated over locations and seasons to reach at a more reliable conclusion and recommendation for Haramaya university research site and around community.

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7. APPENDICES

Appendix Table 1: Mean square values of phenology and growth parameters of maize as influenced by NPS fertilizer rates and inter row spacing.

	Mean squares						
Source of variation	Degree of freedom	Days to anthesis (days)	Days to 50% silking	Days to physiological maturity	Leaf area (cm^2)	Leaf area index (%)	Plant height (cm)
Replication	2	21.763	4.17	1.817	664.3.	0.10646	0.17546
NPS rate	4	31.11**	38.35**	72.275**	2389517**	0.5908808**	0.12880**
Spacing	3	39.149*	38.06**	15.022*	2543499.1**	4.9013882**	0.02769^{ns}
Rate × Spacing	12	0.791^{ns}	1.10^{ns}	3.064^{ns}	50082.5^{ns}	0.0338586^{ns}	0.03779**
Error	38	1.736	1.48	1.799	666.8.	0.008506	0.05314
CV (%)		1.7	1.5	1.1	0.3	2.3	9.9

Where, ** = highly significant; * = significant; ns = Non-significant

Appendix Table 2. Mean square values of yield components of maize as influenced by application of NPS rate and Inter row spacing.

Mean squares					
Source of variation	Degree of freedom	Plant stands count (%)	No ear per plant	Ear length (cm)	Thousand kernel weight(g)
Replication	2	0.00010181	0.0002017	4.967	33.63
NPS rate	4	0.00150208**	0.6912892**	88.220**	10764.94**
Spacing	3	0.00557291*	0.9966683**	88.463**	687.44*
Rate × Spac	12	0.00013874^{ns}	0.1163725**	3.033**	460.03^{ns}
Error	38	0.00002631	0.0002017	2.150	57,82
CV (%)		0.5	1.1	5.9	2.1

Where, ** = highly significant; * = significant; ns = Non-significant

Appendix Table 3. Analysis of variance showing mean squares for number of kernels per ear, grain yield, above ground dry biomass yield of maize as influenced by application NPS rate and inter row spacing

Mean squares				
Source of variation	Degree of freedom	Number of kernel per ear	Grain yield (kg ha^{-1})	Dry biomass yield (kg ha^{-1})
Replication	2	2.829	1211.35	7887130
NPS rate	4	7059.202**	7435899**	417280022**
Spacing	3	3703.667*	6671986*	18299299**
Rate × Spacing	12	122.219**	671929**	4422081**
Error	38	1.430	19208.	13422081
CV (%)		0.3	3	6.3

Where, ** = highly significant; * = significant; ns = Non-significant

Appendix Table 4: Mean square values of harvest index and agronomic efficiency of maize as influenced by NPS fertilizer rate and inter row spacing.

Mean squares			
Source of variation	Degree of freedom	Harvest index (%)	Agronomic efficiency
Replication	2	0.0003527	136.89
NPS rate	4	0.004246**	927.16**
Spacing	3	0.01111032*	603.26**
NPS ×Spacing	12	0.0030845^{ns}	56.80^{ns}
Error	38	0.0002237	70.35
CV (%)		6.7	24.2

Where, ** = highly significant; * = significant; ns = Non-significant