# VALIDATION OF RECOMMENDED NP FERTILIZER RATES ALONG WITH POTASIUM APPLICATION FOR WHEAT PRODUCTION IN OMO NADA DISTRICT, SOUTHWEST ETHIOPIA

**M.Sc. THESIS**

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# Validation of Recommended NP Fertilizer Rates along with Potassium Application for Wheat Production in Omo Nada District, Southwest Ethiopia

**M.Sc. Thesis**

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**By**

**AyanaEtanaTerfa**

**July, 2020**
**Jimma, Ethiopia**

# DEDICATION

This thesis has been dedicated to my children and wife who deprived the lovely time that was shifted to study this M.Sc.

# STATEMENT OF AUTHOR

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

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# BIOGRAPHY

The author, AyanaEtanaTerfa, was born on November 06, 1978 in HorroGuduruWollega, GuduruDistrict from his mother BasheGelan Abaya and his father EtanaTerfaGalata. He completed his high school education at Shambo Senior Secondary, School. After passing the Ethiopian School Leaving Certificate Examination (ESLCE) in 1996, he joined Debub (now Hawassa) University College of Agriculture and graduated with B.Sc degree in Plant Production and Dryland Farming (PPDF) on July 15, 2000. Up on his graduation, the author was employed as Fruit and Vegetables Expert in WonchiWereda, south-west Shewa Zone in December 2000. Later, on March, 2002 he was employed inOromiya Agricultural Research Institute (OARI),AdamiTullu Agricultural Research Center (ATARC) as junior researcher of Forage Agronomy. After serving for 5 years in the same organization at various positions, he joined Addis Ababa University in 2007 to pursue his M.Sc. study in Biology (Botanical Sciences). He graduated his M.Sc. on July, 24, 2009; and rejoined horticulture research team in the same center and served at various managerial and research positions until 2016. On October 22, 2016 he joined an Ethio-Netherland project called JU-CASCAPE (Capacity Building for Scaling up of Evidence – Based Practices in Agricultural Production in Ethiopia hosted By Jimma University) as research Expert of Agronomy. Besides his regular duty of project work, he followed his M.Sc. in Agronomy at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM)

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ATA | Agricultural Transformation Agency |
| CSA | Central statics Agency |
| ha | Hectare |
| JU-CASCAPE | Jimma University-Capacity Building for Scaling up of Evidence Based Practices in Agricultural production in Ethiopia |
| LAI | Leaf Area Index |
| Mha | Million hectare |
| MoA | Ministry of Agriculture |
| MoANR | Ministry of Agriculture and Natural Resources |
| Mt | Metric tonne |
| SOC | Soil Organic Carbon |

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# ABSTRACTS

*Inorganic fertilizer application is among the major factors help to improve crop productivity. Use of fertilizersfor major cereal crops, including wheat, was started in Ethiopia before forty years; even though the recommendation still remained more general. The current scenario of fertilizer requirement is moving towards soil and crop specific recommendations. This study was conducted to evaluate the feasibility of previous and current NP blanket recommendations for wheat production on Andosol. It was carried out in Cheleleka Donga kebele ofOmo Nada district in Jimma zone, Oromia Regional State, south western Ethiopia during the crop season of 2019 on farmers' field. N and P rates recommended at various times were used as a base for treatment setting. Accordingly, two rate of N (64 and 73 kgN/ha), three rates of* $P_2O_5$ *(37.7, and 69 kg /ha) and three rates of* $K_2O$ *(0, 18 and 36kg/ha)were used.The experiment was laid downin a randomized complete block (RCB) design with a 2*3*3 factorial treatment arrangement in four replications.The soil analysis result showed that it is strongly acidic, deficient in available phosphorus, optimum in total nitrogen and organic carbon and high in available potassium. The differences among fertilizer treatments were not significant for plant height(PH), leaf area index(LAI) and biomass yield (BMY). Spike length was significantly influenced* ($P < 0.05$) *by nitrogen rate. Spikelet per spike was significantly affected by the interaction of Pand K. Number of seeds per spike was significantly influenced* ($P < 0.05$) *by the interaction of N and K. Thousand seed (kernel) weight was significantly affected* ($P < 0.05$) *by K rate. Grain yield was only significantly affected*($P < 0.05$) *by P rate and the maximum value (4574 kg/ha)was obtained when 69kg/ha* $P_2O_5$ *was applied, followed by 46 kg/ha* $P_2O_5$ *with grain yield of 4323kg/ha , with the respective yield advantage of 12.74% and 6.56% over the minimum rate (37.7 kg* $P_2O_5$*/ha). The maximum net benefit was recorded for plots which received 69kg/ha* $P_2O_5$ *with MRR of 258%. In general, Phosphorus was found to be the major limiting nutrient and, hence, improving its availability through improving soil pH and applying enough amount of fertilizer would enhance wheat production in the area.*

KEY WORDS:Soil Fertility; DAP; Blended Fertilizer;Grain Yield

# 1. NTRODUCTION

Wheat is among the principal cool-weather grain crops grown in Ethiopia between an altitudinal range of 1,900 and 2,700 meter above sea level (masl) and is produced exclusively under rain fed conditions (White *et al.,* 2001) on an estimated area of 1266Mhawith a total production of 4.3Mt each year (CSA, 2016). On the other hand, Ethiopia is a net importer of grains among which more than 59% of wheat demand is imported every year (FAO, 2013). This is as a result of low mean productivity of wheat in farmer's fields (2.54 t/ha), in contrast to its productivity on research stations (over 5 t/ha)(Mann and Warner, 2015). Such a low yield is primarily allied with depletion of soil fertility due to continuous nutrient uptake by crops, low fertilizer use and insufficient organic matter application (Kidane, 2015). These indicate that major nutrients outflows far exceed inflows in a range of soil types which results in negative nutrient balances, particularly in the intensively cultivated high-potential areas that are mainly concentrated in the highlands of Ethiopia (Hillette*et al*., 2015).

Soils of the Ethiopian highlands are the outcome of decomposition of the volcanic material. They are derived from lava rocks, which are clayey in texture and are basically quite fertile. However, growing population pressure, increasing number of livestock and failure to return organic matter to the soil has reduced soil fertility (CSA, 1993). Because of severe shortage of fuel wood, both straw and manure are used as fuel rather than returned to the soil. Consequently, intensification is the major option to increase production, and this inevitably means an increase in the use of inorganic fertilizers (FAO, 1992). Among the inorganic fertilizers imported every year, over 80% is applied to cereals and 45 to 50% of this is estimated to be used for the major staple, teff, with the remainder being applied to wheat, barley, maize and sorghum(IFDC, 2015).

Fertilizer was first introduced to Ethiopia in 1967 following four years of trial carried out by the government with the assistance of FAO's Freedom from Hunger Campaign. Later on, fertilizer trials have been conducted by few research stations and recommendations were drawn. Based on the results of those trials, the National Fertilizer Input Unit (NFIU) recommended 100 kg urea/ha (46 % N) and 100 kg DAP/ ha (18 % N and 46 % $P_2O_5$) as blanket fertilizer recommendation for the country, which waslater on revised and 150 kg DAP/ha and 100 kg urea/ha has been adopted. Currently, with the introduction of blended fertilizer concept and based on the soil fertility map developed by EthioSIS(EthioSIS, 2014)a compound fertilizer NPS (19% N, 38%$P_2O_5$ and 7% S) replaced DAP with similar rate of application (100 kg NPS/ha).

Study reports indicated that wheat grain yield has shown an improvement of 80-300% on Vertisols, and 45 to 15% on Nitisols through the application of higher rates of N. Although it has been observed that wheat yields increasewith application of the recommended rate, some studies confirmed that most of the highland farmers use very limited amount of fertilizer, compared to the midland farmers (Yirga and Hassan, 2013),and apply only 37 to 40kg/ha of the recommended rate (MoA, 2012).

Experiments conducted across the major wheat production belts of the Ethiopian highlands indicated that N and P are the two major plant nutrients that limit wheat productivity, although there is growing evidence that other nutrients such as K and some micronutrients also constrain wheat production. The recommendation for N and P fertilizers vary from 30 to 138 N kg/ha and 0 to 115 $P_2O_5$ kg/ha, respectively (Abdulkadir*et al.*, 2016). Such huge differences in NP fertilizer requirement across the testing sites highlight the need to target the right fertilizer and application rate~~s~~for specific location to improve both fertilizer use efficiency and productivity of crops, as well as to prevent negative environmental consequences. In addition, wheat response to K was observed in some testing locations in contrary to the long-standing assumption~~s~~ that Ethiopian soils are rich in K (Abdulkadir*et al*., 2016). There are also research reports explaining that as application of potassium sulphate on highland vertisols in central Ethiopia resulted in about 1t/ha of wheat yield advantage compared to untreated plots (Astatke*et al*., 2004). On the other hand, study results obtained from Enderta district, Tigiray region showed declining return when the rate of K exceeds 30kg/ha (Brhane, *et al*, 2017).

The current scenario of fertilizer requirement is moving towards soil and crop specific fertilizer recommendations. Previous study results are showing that most of the fertilizer rate trials conducted in Ethiopia was preferentially to south-eastern, northern central, north-west, and southern Ethiopia, disregarding the western part of the country, which has also high potential for wheat production. As a result, farmers of southwestern part of the country have been obliged to use fertilizer recommendations not based on their soil and crop requirements.

This study was designed to fill the information gap on fertilizer demand for wheat production on Andosols of Omo Nada district and similar agro-ecologies in southwestern Ethiopia.

## 1.1.Objectives

### 1.1.1. General objective:

- To evaluaterationalityof NP rate recommendation trend for optimum wheat production and K fertilizerapplication feasibility on Andosols of south-western highlands of Ethiopia.

### 1.1.2. Specific objectives

- To validate previous NP fertilizer recommendations under Andosolcondition
- To indicateoptimum N, P and K application rates for economically profitable wheat production in the area.

# 2. LITERATURE REVIEW

## 2.1. Wheat Production in Ethiopia

Wheat (*TriticumaestivumL.*) is the most important cereal crop in the world and is the staple food for humans. Ethiopia is the second largest wheat producer in Sub-Saharan Africa next to South Africa. Oromia accounts for over half of national wheat production (54 percent), followed by Amhara (32 percent); Southern Nations, Nationalities and Peoples (SNNP) (9 percent); and Tigray (7 percent) (CSA, 2013). Of the current total wheat production area, about 75 percent is located in the Arsi, Bale and Shewa wheat belts (MOA, 2012).

Wheat is one of the major staple crops in the country in terms of both production and consumption. In terms of caloric intake, it is the second most important food in the country behind maize (FAO, 2014). There are two types of wheat grown in Ethiopia: durum wheat, accounting for 60 percent of production, and bread wheat, accounting for the remaining 40 percent (Bergh *et al*., 2012).

## 2.2. Nature and Properties of Andosol

The land around volcanic eruption is intermittently covered by volcanic ash deposition. This volcanic ejecta or tephras contain various silicates and minerals of different sizes such as volcanic glass, feldspars, quartz, hornblend, hypersthense, augite, magnetites, biotites and apatite. After tephra deposition, soil formation starts, the tephra's elemental and mineralogical composition changes and volcanic ash soils (Andosols) having unique properties are formed. During this time many plant nutrient elements provided to the soil environment.

Some physical properties of Andosols are directly visible to the eye and sensible to the touch. Surface soils are rich in humus and black in color, soil clods are light, fluffy and easy to break in to small pieces. Chemical and mineralogical characteristics of

Andoslosare reflected in their physical properties and biological activities and affect the utilization of it. The unique chemical properties of Andosols are basically due to Aluminum rich elemental composition, the highly reactive nature of their colloidal fraction and their high surface area. Inferior agricultural crops growth observed when planted in young alluvial soils due to low content of plant available nutrient elements, especially P and some micronutrients, sometimes their high toxic Alcontent, the highly sorptive properties of the nutrient ions and stabilization of soil organic N.Both major and minor minerals are important in volcanic ash due to the essential element they contain. Apatite contains phosphorus tourmaline and boron. Potassium can be supplied from various minerals like biotite from which it released easily.

Morphological properties of matured Andosol profiles are quite different from those of new airborne ash deposits, lahar deposits and pyroclastic flow deposits. There is no horizon development in new tephra deposits as in Andosols. The new tephra deposits will be converted to Andosols over time which can be identified by seeing the buried multi-sequun profile underlining the new tephra deposit. The most abundant mineral in volcanic ash is volcanic glass.

Matured Andosols typically have a low bulk density of about 0.9 or lower and are lowest among mineral soils. The low bulk density of Andosols can easily be recognized if an air-dried clod picked-up by hand. Only organic soils or organic horizons have lower bulk density than Andosols. The low bulk density is due to high porosity caused by well-developed aggregate structure made of noncrystalline structure. In nonallophanicAndosols low bulk density is due to the accumulation of large amount of humus which is making high porous aggregates.The humus content of matured Andosolis mostly less than 30% with the bulk density still remaining 0.9 or lower. In Andosols with advancement in formation of noncrystalline materials macropores distribution decreases and micropores increase to the level it contributes permeability of air and retention of plant available water.

Allophane, imogolite and Al-humus are basically the major component characterizing Andosols. They show variable charge characteristics, high phosphate retention capacity, high affinity for multi-valentcations and contrasting effect on KCl-exchangeable and water-soluble Al at an acid pH range. Ferrihydrite also has variable charge characteristics and high phosphate retention capacity. The negative and positive charges amount on Andosol soil colloids depends on pH and salt accumulation in the equilibrating liquid phase. The functional groups contributing to variable negative charges are carboxyl groups of humus and silanol groups of allophane and imogolite. The variable positive charges are due to protonated hydroxyl groups bound to aluminum of allophane and imogolite and those bound to iron minerals(Nanzyo, 2002).

Cambisols, Vertisols, Luvisols, Solonchaks, Regosols, and Andosols are among the most dominant major soil types in Ethiopia. Andosols and Phaeozems are limited to high altitude landscapes such as in Arsi and Jimma (Omonada) areas. UmbricAndosols are those having a thick dark-coloured surface horizon rich in organic matter but depleted of exchangeable bases. Sizeable areas of UmbricAndosols (about 13, 000 ha) are found in Omonadaworeda frequently occurring on the high to mountainous relief hills (Eyasu. 2016).

## 2.3. Inorganic Fertilizer Use and Trend in Ethiopia

In Ethiopia, fertilizer use was started in the 1960 after the result obtained from demonstrations about fertilizer effects on major cereal crops was made through Freedom from Hunger Campaign program which showed the positive benefits of fertilizer addition. Fertilizer is a single factor for increasing yield and it can contribute to the yield increase, provided that the use-efficiency can be raised and that other necessary agronomic factors are supplied. Fertilizer use should only be encouraged in line with the use of improved cultural practices, erosion control, and pest and weed control, use of potential crops and varieties and reduction of post-harvest crop loss. It is only through such an approach that wastage of the costly agro-inputs can be reduced, which ultimately leads to the maximization of benefits.

Despite the recognition for the need to increase fertilizer use in Ethiopia, fertilizer consumption was still below 20 kg/ha (Yirga and Hassan, 2013). The average intensity of fertilizer use in the country (which is roughly less than 40 kilograms per hectare) remains much lower than elsewhere (e.g., 54 kg/ha in Latin America, 80 kg/ha in South Asia, and

87 kg/ha in Southeast Asia) (IFDC, 2015). In Ethiopia more fertilizer is used in the wheat/teff cropping systems of the Mid Highlands when compared to the Upper Highlands (Yirga and Hassan, 2013). Only 30 to 40% of Ethiopian smallholder farmers use fertilizer, and those that do only apply 37 to 40 kg on average per hectare, which is significantly below the recommended rates (MoA, 2012). N and P fertilizers were the only focused fertilizer types at the inception of fertilizer use in Ethiopia. There has been no change in composition of the use of fertilizers in Ethiopian agriculture until 2014/15 cropping season (IFDC, 2015). As a result until 2013, urea and DAP (di-ammonium phosphate) (supplying nitrogen and phosphorus) fertilizers had been the only fertilizer sources that have been in use in the Ethiopian agriculture for more than four decades, creating nutrient imbalances in soils (Nandwa and Bekunda, 1998).

Adoption and use of new fertilizers introduced jointly by MoANR and the Agricultural Transformation Agency(ATA) through conducting demonstrations on farmers' fields with the aim of testing their performance as well as creating awareness to farmers. New fertilizer sources that has other nutrients in addition to N and P were demonstrated on more than 40, 000 farmers plots in four major crops(maize, tef, wheat and barley ) and in four major regions (Amhara, Oromiya, Tigray and SNNPR) where the majority of the fertilizer is consumed in Ethiopia(IFDC, 2015). As a result, the DAP was made gradually to be replaced by NPS (sulfur containing DAP) and other forms of blended fertilizers containing k, Zn and B.

## 2.4. Nitrogen (N) Fertilizer forWheat Production

The present soil-nutrient balance in Ethiopia is dramatically negative, in particular the presence of nitrogen. Particularly those fertilizers, containing N and P are the major inputs affecting wheat growth, grain yield and quality (Tilahun, 1994). Nitrogen is the most limiting nutrient for wheat production that affects the rapid plant growth and improves yield and yield component of wheat. Many research findings showed that N application increased grain yield, through its effect on number of fertile tiller per unit area, number of grain per spike and harvest index(Asif*et al.*, 2012). Nitrogen is the key nutrient in increasing productivity and as a result the increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers (Rahimizadeh, 2010). In similar fashion, in Ethiopia, increasing usage of N fertilizer is considered as one of the primary means of increasing wheat grain yield (Asnake (1991), even though there is still significant gap between the recommended dose and actual amount of fertilizer given to land in case of urea(IFDC, 2015).

Simply increasing the use of mineral fertilizers is not enough to stop nutrient depletion and steadily achieve the right balance. Ideal nitrogen management optimizes yield, farm profit and nitrogen use efficiency while minimizing the potential for leaching of nitrogen beyond the crop rooting zone (Rahmati. 2009). Under most field conditions, since the amounts of soluble and readily mineralized soil N are insufficient to meet the crop requirement to obtain better growth and then high yield, addition of N as chemical fertilizer, manure, crop residue, or other source, is required. Reduction of applied N fertilizer rate to an optimized level can reduce soil nitrate leaching (Power *et al.*, 2000).

## 2.5. PhosphorusAvailability and Functions

Phosphorus (P) is a vital resource for sustaining world agriculture. It is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. Phosphorus is affected by or affects the availability or utilization of many other nutrients. The effects of P on other nutrients or practices or the effects of other nutrients or practices on P are interactions significant to profitable crop production. The influence of phosphorus on crop maturity is often an added bonus to its effect on increasing yields. Phosphorus in a balanced soil fertility program, increases water use efficiency and helps crops achieve optimal performance under limited moisture conditions (PPI, 1999)

The availability of soil P is influenced by soil reaction, soil type, amount and forms of P as well as many other factors. There are significant differences in P sorption among

Ethiopian soils, and most soils are non-responsive to P supply at lower application rates. There are four categories of P-sorption isotherms in Ethiopia with significant differences in sorption capacity (Mamo and Haque, 1987) from which the volcanic ash-based soils (e.g. Andosols) need about 100 times more P compared to fluvisols or regosols.

The free phosphoric acid ($H_3PO_4$) predominates in strongly acid solutions and $PO_4^{3-}$ in strongly alkaline solutions. However, the proportions of these two forms are negligible within the pH range of 5 to 9. At intermediates pH level (pH 7.2), $H_2PO_4^-$ and $HPO_4^{2-}$ may be present simultaneously in equal amounts whereas below and above this pH, $H_2PO_4^-$ and $HPO_4^{2-}$are the predominant forms of available P, respectively. As the pH of the solution goes up, phosphate ions tend to dissociate proton ($H^+$) and get converted to the $HPO_4^{2-}$ ions. Primary orthophosphate ($H_2PO_4$) is somewhat more available to plants than $HPO_4^{2-}$ (Tisdale *et al*., 2002).

Oxisols high in iron oxides and aluminum oxides, and many sandy soils low in humus content, for instance, have low available P (Miller and Danahaue, 1995). Addition of organic matter indirectly reduces P adsorption by inhibiting aluminum oxide and to certain extent Fe-oxide crystallization while addition of manure and fertilizer P reduces P fixation by increasing saturation of adsorption sites (Boeggaad*et al*,1990).

In acid soils with high Al and Fe contents, phosphoric acid and soluble P fertilizer transformed into insoluble forms of P so quickly that plants can derive very little from P fertilized treatments (Sinha,1999). Brady and Weil (2002) indicated that at pH lower than 5.5, the retention results largely from the reactions with Fe, Al and their hydrous oxides resulting into low forms of available P. At pH higher than 7.0, high concentration of Ca, Mg and their carbonates cause precipitation of the added phosphorus and reduce the availability of P (Mengel and Kirkby, 1996). Optimum P availability in mineral soils as generalized by these authors is believed to be near pH 6.5. Large addition of P is required to reach a given level of solution P in fine textured compared to coarse-textured soils. Consequently, high clay calcareous soils often require more fertilizer P to optimize yields compared to loam soils. Soils containing large quantities of clay fix more P than soils with low clay content. In other words, the more surface area exposed with a given type of clay, the greater is the tendency to absorb P (Tisdale *et al*., 2002).

## 2.6. The Importance of Potassium asa Crop Nutrient

Potassium (K) is the second most abundant mineral nutrient in plants after N. It is 4–6 times more abundant than the macronutrients P, Ca, Mg and S. K is absorbed as the monovalent cation $K^+$ and it is mobile in the phloem tissue of the plants. K is involved in the working of more than 60 enzymes, in photosynthesis and the movement of its products (photosynthates) to storage organs (seeds, tubers, roots and fruits), water economy and providing resistance against a number of pests, diseases and stresses (frost and drought). It plays a role in regulating stomatal opening and, therefore, in the internal water relations of plants (FAO, 2006).

Potash fertilizers are those that contain potassium in water-soluble form. Potassium activates those enzymes in the cytoplasmic pool including those which control carbohydrate and protein metabolism; the fixation of carbon dioxide ($CO_2$) in photosynthesis; and the assimilation of nitrate by plants. Aids plants in the production of starches, controls root growth, ATP production, translocation of sugars, nitrogen fixation in legumes, and is important for efficient water use.

Deficiency gives rise to problems in numerous physiological functions resulting in poor growth, reduced yield and decreased resistance to various stresses. Potassium in the vacuole plays a key role in water relations in the maintenance of turgor and control of stomatal movement. It is also essential in the regulation of cell growth. In the process of photosynthesis, K functions directly or indirectly at various stages including light interception, $CO_2$ availability and chlorophyll synthesis. Potassium is the predominant cation in plants and, in this form, functions in the transport of nitrate from root to shoot, as well as the loading of assimilates (sucrose and amino acids) into the phloem and their transport to fruits and storage organs. Crops well supplied with K are more resistant to stresses both biotic (e.g. pest attack) and abiotic (e.g. drought stress, cold stress and salt stress) (Cakmak 2005; Oosterhuis*et al.* 2014; Mengel and Kirkby 2001; Marschner 2012).

Potassium and N interact in the processes described above and both nutrients are required in relatively similar amounts. Crop nutrient requirements may differ, but numerous observations of many different agricultural crops indicate that they often remove very similar amounts of N and K from the soil. It is only in fruit and vegetable crops that K uptake exceeds N. As a result in crop fertilization these two nutrients must therefore be provided in a balanced supply in order to obtain high yields, as well as ensuring the most economic fertilizer use and restricting wastage of N fertilizer to reduce environmental pollution.

Potassium is required in highest amounts by the plant as an osmoticum to maintain cell turgor and, in this respect, it interacts with N because, by applying N, both cell number and cell size increase and thus also the water content of a crop.

## 2.7. The Move to K Fertilizers Use

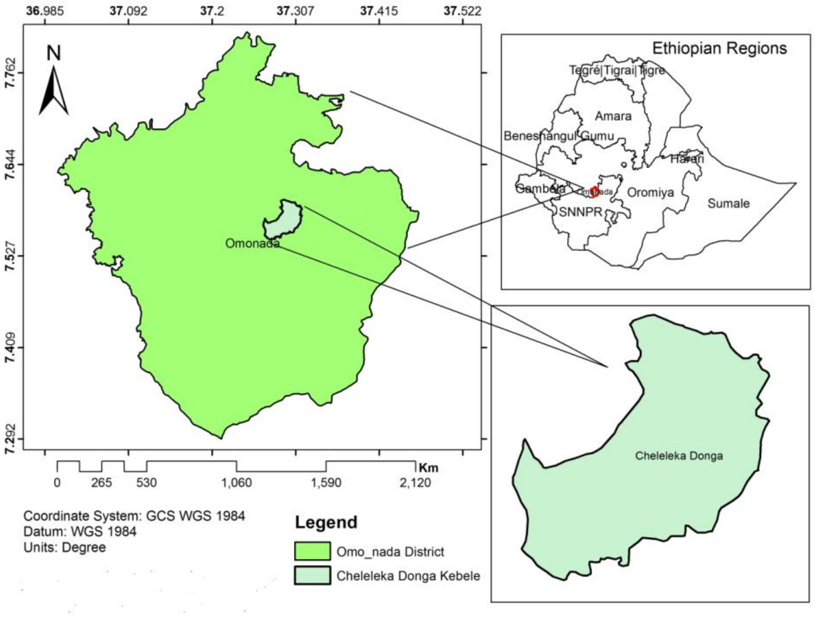
Earlier findings from FAO-assisted fertilizer demonstration trials carried out in Ethiopia in the 1970s, through the Freedom from Hunger Campaign, showed inconsistent and/or non-significant responses to potash fertilizer. Thus, until recently, many researchers believed that K fertilizers were not necessary. However, there is a report as widespread K deficiency in soils and crops has been observed in recent years (Abayneh and Berhanu, 2006; Haile and Boke, 2011). There are also reports that indicate rapid increases in wheat, barley, tef, and potato crop yields as a result of potash fertilizer application on soils. For example, the works of Astatke*et al*. (2004) and Wassie (2009) proved a sharp increase in wheat and potato yields grown on Vertisols and Nitisols with an application of 50 kg/ha $K_2SO_4$ and KCl, respectively. In Gimbichuworeda, KCl fertilizer application to bread wheat increased the yield by 25% (SubbaRao and Srivastava, 2012). Although there is high exchangeable K level in the highland Vertisols soils, crops responded to K fertilizers, proving that the soil exchangeable K was fixed by the clay and unavailable to plants. The total absence or low application level of K fertilization combined with intensive continuous cropping leads to the depletion of soil K reserves. Even soils which are initially well supplied with K will become deficient under such management systems. Total consumption of K from soil by wheat producing yields of 10 t/ ha varies from 160 to 242 kg K/ ha (Kemmler, 1983).

According to Loide (2004), higher levels of exchangeable Mg suppress K availability to plants by occupying the exchange complex. In Ethiopia, the latest recommendation to apply potash as straight fertilizer in the needy woredas and kebeles take these facts into account.K fertilizer demonstration work conducted in Dugdaworeda, Oromia region, showed wheat supplemented with KCl fertilizer performed very well (plots were dense, greenish and with a better stand) when compared to the non-K treated plot. Based on that a sort of recommendation developed farmers to apply 100 kg/ha of the fertilizer on clay soils for cereals.

# 3. MATERIALS AND METHODS

## 3.1.Study Area Description

The study was conducted during 2019 cropping season under rain fed conditions on farmer's field at Cheleleka Donga kebele, Omo-Nadda district, Jimma zone of Oromia Regional State. The specific experiment site is situated at $37^0$ 17' 540 E longitudesand $07^0$ 35' 699 N latitude, and at an altitude of 2393m asl. Cheleleka Donga is one of the potential wheat producing kebeles in the district. The area is characterized by gentle, flat and undulated topography within altitudinal range of 2400m – 3340masl. The dominant soil type is Andosol with patches of sparsely distributed Nitisol. Tef, wheat and faba bean are among the common crops of Cheleleka Donga. The area has a bimodal rainfall pattern with unpredictable small rains from March to April and the main rainy season extending from June to September. The area receives an average total annual rainfall ranging from 1066mm – 1200mm with mean annual ranging from $18^0$C – $25^0$C (Eyasu, 2016).



Map of the study area (Cheleleka Donga kebele)

### 3.2. Experimental Materials

Urea (46% N), triple super phosphate (TSP) (46% $P_2O_5$), and KCl (60% $K_2O$) were used as source of N, P and K, respectively. A wheat variety called Senate which is farmers favorite in the area was used as a test crop with a seeding rate of 150kg/ha. This variety was selected and released nationally in 2014 from ICARDA collection for the purpose of overcoming wheat rust disease. In addition to its resistance to rust disease, it has a high yielding potential with average productivity ranging from 3.4 to 6.7 t/ha. It was recommended for the area in 2016 after a participatory variety selection was made by Ju-cascape project to replace the previously recommended variety called Digelu which was found to be highly susceptible to leaf and stem rust diseases.

### 3.3.Treatmentsand Experimental Designs

The experiment comprised of three levels of $K_2O$ fertilizer (0, 18, and 36kg/ha), three levels of $P_2O_5$ (37.7, 46 and 69 kg/ha) and two levels of N (64 and 73 kg/ha) arranged in a 3*3*2 factorial combination of 18 treatments.It was laid out in Randomized Complete Block Design (RCBD) with four replications.

The N and P treatments rates were derived from the previous fertilizer recommendations as follows:

- 100kg DAP + 100kg Urea = $\underline{\text{64kg N}}$ + $\underline{\text{46 kg } P_2O_5}$
- 150kg DAP + 100kg Urea $\underline{\text{= 73 kg N}}$ + $\underline{\text{69kg } P_2O_5}$
- 100 kg NPSB + 100kg Urea = 65kg N + $\underline{\text{37.7kg } P_2O_5}$
- K was included to evaluate the argument on the need for K

Table 1 Treatmentarrangement of the experiment

| **Trt No.** | **UREA (kg/ha)** | **TSP (kg/ha)** | **KCl (kg/ha)** | **N (kg/ha)** | **$P_2O_5$ (kg/ha)** | **$K_2O$ (kg/ha)** |
|---|---|---|---|---|---|---|
| **T1** | 139 | 82 | 0 | 64 | 37.7 | 0 |
| **T2** | 139 | 100 | 0 | 64 | 46 | 0 |
| **T3** | 139 | 150 | 0 | 64 | 69 | 0 |
| **T4** | 159 | 82 | 0 | 73 | 37.7 | 0 |
| **T5** | 159 | 100 | 0 | 73 | 46 | 0 |
| **T6** | 159 | 150 | 0 | 73 | 69 | 0 |
| **T7** | 139 | 82 | 30 | 64 | 37.7 | 18 |
| **T8** | 139 | 100 | 30 | 64 | 46 | 18 |
| **T9** | 139 | 150 | 30 | 64 | 69 | 18 |
| **T10** | 159 | 82 | 30 | 73 | 37.7 | 18 |
| **T11** | 159 | 100 | 30 | 73 | 46 | 18 |
| **T12** | 159 | 150 | 30 | 73 | 69 | 18 |
| **T13** | 139 | 82 | 60 | 64 | 37.7 | 36 |
| **T14** | 139 | 100 | 60 | 64 | 46 | 36 |
| **T15** | 139 | 150 | 60 | 64 | 69 | 36 |
| **T16** | 159 | 82 | 60 | 73 | 37.7 | 36 |
| **T17** | 159 | 100 | 60 | 73 | 46 | 36 |
| **T18** | 159 | 150 | 60 | 73 | 69 | 36 |

Key: TSP = Triple Supper Phosphate, KCl = Muriate of potash, N =Nitrogen, $P_2O_5$= Phosphorus pent oxide, $K_2O$ = Potassium oxide

## 3.4. Experimental Procedures

The experimental plot was prepared according to the local farmer’s conventional practice using local ox-drawn implement (*Maresha*). The field was plowed to the optimum level before sowing. A path of 0.5m and 1m was left between plots within a block and between blocks, respectively. A plot sizeof 2 m*3m (6 $m^2$) was used. Seed was sown by drilling in rows separated by 30cm (ten rows per plot) from each other. Full doses of K and P were applied at the time of planting along with 1/3rd of the N rate. The rest 2/3rdof N was applied at tillering. Pallas® 45 OD herbicide was applied at a rate of 0.5l/ha 25days after sowing for the control of both grass and broad leaved weeds. It wassupplemented with hand weeding when necessary. One time hoeing was also carried out for the control of weeds and at the same time for application of the remaining amount of urea.

## 3.5.Data Collection

### 3.5.1.Soil chemical analysis

Soil samplewas collected from the top 0-20cm depth of the trial field by augur using zigzag sampling technique before sowing. One composite sample was prepared from a total of five samples. Materials other than soil particles (roots, stones, debris etc ) were removed from the sample before it was sent for laboratory analysis.

The composite soil sample was taken to Ziway Soil Testing Laboratory Center. The sample was dried, crushed and sieved using 2mm sieve following FAO guidelines (FAO, 1990). The pH of the soil was determined in water suspension with soil to water ratio of 1:2.5 (van Reeuwijk, 1992). Percent organic carbon (%OC) was determined by Walkley-Black Method (Olsen, *et al*., 1954). Total nitrogen content (%tN) was determined by Kjeldhal Method (van Reeuwijk, 1992). Available phosphorus (Av. P) was determined by extraction with sodium bicarbonate (Olsen, *et al*., 1954) method. Exchangeable bases (Na, K, Mg, and Ca) were determined by Ammonium Acetate Sand Percolation Method and Cation Exchange Capacity (CEC) was determined by Ammonium Distillation Method (van Reeuwijk, 1992).

### 3.5.2.Growth parameters

**Number of leaves per plant**: Total number of leaves per plant was determined ~~by~~ using ten randomly selected plants from the middle rows of each plot.

**Leaf area:** The average leaf area of individual plant (LA) was determined by measuring length (L) and width (W)of flag leaves. Leaf length was measured from the insertion point on the stem to the tip of the leaf, while leaf width was measured at the maximum width of the leaf. Leaf area of individual plant was computed by multiplying leaf number (LNo.), length and width with 0.75, which is a constant or correction factor for the crop (LA per plant = LNo.*L*W*0.75) (Yasin and Sami, 2014).

**Leaf area index** was computed by multiplying Leaf area per plant by plant Number per meter square (PNo./$m^2$) (LAI = LA *PNo./$m^2$)

**Number of effective tillersper plant:** After heading, the number of tillers that produced heads were counted for ten bunches and subsequently converted into number of tillers per plant.

**Plant height (cm)**: At maturity, ten plants were randomly taken from central rows of each plot and their heights were measured from the base of the plant to tip of the spike using meter tape. Finally, average height was determined by summing up the height of the ten plants and then dividing by ten.

**Spike length (cm)**: At maturity, ten plants were randomly selected from central rows and their spike lengths were measured from the base of the spike to its tip using meter tape. Finally, values were averaged and taken as spike length of a plant.

**Above ground biomassyield**: the stand in harvest area (2m*1.2m) of each plot was clipped at ground level and sundried to a constant weight. Then, measured using Micro digital hanging scale balance of 50kg weighing capacity. The value obtained converted to biomass yield t/ha as follows:

$$BMY\ (t/ha) = \frac{10(SBMY)}{HA}$$

Where: BMY = above ground biomass yield

SBMY = Sample biomass yield kg/ha

HA = harvest area which is 2.4$m^2$ in this case

### 3.5.3.Yield and yield components

**Number of spikelet per spike:** Five plants were randomly selected from the central rows of a plot at maturity. Spikelet of each spike was counted and average value taken as number of spikelet per spikes.

**Number of seeds(kernel) per spike:** Five plants were randomly selected fromthe central rows of a plot at maturity. The heads were threshed together and the number of seeds was counted and divided by five. The average valuewastaken as number of kernels per spike.

**1000 seed weight**: thousand kernels were counted by using PfeufferContador seed counter machine and weighed using digital sensitive balance

**Grain yield**: Grain sampled from each plot was checked for its moisture content using DRAMINSKI GMM mini grain moisture meter and standardized to 12.5%.Then adjusted yield(AdjY) was computed as follows:

- $\text{AdjY} = AcY - (AcY(\frac{MSM\%-12.5\%}{100})$
- Where:
    - AdjY = Adjusted yield
    - AcY = Actual yield obtained
    - MSM% = measured seed moisture percent
    - 12.5% = standard wheat seed moisture percent

### 3.5.4.Economic analysis

Partial budget analysis is computed if and only if there is statistically significant difference among the treatments for grain yield**(**CIMMYT, 1988**).**Therefore, in the present study, only phosphorus rate was considered for economic analysis. The cost of $P_2O_5$was derived from NPSBand the benefits were compared for those obtained by the main effect of phosphorus. Cost of inputs (fertilizer), was the only cost that varies. Grain yield was used as means ofincome source and analyzed as described in CIMMYT(1988).

Straw yield was omitted from the analysis due to no cash value for crop residue in the area except using for thatching roof and feeding livestock. The absence of variation in biomass among treatments also limited the use of biomass yield as a source of variation. The cost of different rates of fertilizer for each P treatment was calculated at a rate of 1550 birr /100 kg of NPSB, and converted to hectare. The other costs which include seed cost, herbicide cost, and agronomic management costs that donot vary among the treatment were not included in the analysis. Grain yield was adjusted to 90% of yield obtained from trial plots to match with expected yield at farmers' level due to poor crop husbandry, highpost harvesting losses and in appropriateharvesting technology and larger area.

$$Adjusted\ yield\ = Actual\ yield * 0.9$$

The analysis was done based on the current priceof wheat grain and chemical fertilizers at the time of sowing. Thebenefits obtained from grain yield of eachtreatment was calculated according to the local market price and thenconverted in to birr per hectare (price of grain yield was estimated at 1500 birr /100kg),

$$Field\ Net\ Benefit\ (\mathrm{ETB}) = Adjusted\ yield\left(\frac{kg}{ha}\right) * price\ (\frac{ETB}{kg})$$

After calculating net benefit by subtractingvariable costs from the gross benefits, treatmentswere ranked from the lowest to the highestvariable costs.

$$Costs\ tha\ vary\ \ (ETB) = \sum_{n=1}^{n}\left(cost\ that\ vary\ (\frac{ETB}{ha})\right)$$

Where: n = the number of variables their cost vary along treatments

Marginal rate of return (MRR) was calculated by dividing marginal benefit to marginal costs of successive two treatments (CIMMYT, 1988).

$$MRR\ (\%) = \frac{Change\ in\ net\ benefit(ETB)}{The\ change\ in\ costs\ that\ vary(ETB)} * 100$$

In this study the comparison was made with the treatment with lowest net benefit.

### 3.5.5.Data analysis

The data collected in the course of the experiment were subjected to Analysis of Variance (ANOVA) using SAS statistical softwareversion 9.0 (SAS Institute Inc., 2002)**.**Linear regression and correlation models were applied to determine the magnitude and extent of relationships between treatments. Least significant difference (LSD) procedure was employed for separation of mean values of significantly influenced parameters.

# 4. RESULTS AND DISCUSSION

## 4.1.Soil Chemical Properties Before Planting

According to soil fertility classification of Landon (1991), the soil pH (5.43) of the experimental site fell in the strongly acidic (pH of 5.1-5.5) range, which is below the optimum pH range for wheat production (5.5-7.5). The existence of high available $Fe^{3+}$ which is the common characteristics of acidic soils (Karltun*et al*, 2013) was recognized in soils of the study area. The pH of a soil is one of the most important properties influencing plant growth and production as it affects ion exchange capacity, nutrient availability, performance of pesticides (which include herbicides), and organic matter decomposition(MSU, 2017)

Nitrogen, potassium, calcium, magnesium and sulfur are more available within soil pHof 6.5 to 8 (Karltun*et al*, 2013; FAO, 2006). Accordingly, except theconcentrationof $K^+$,the rest nutrients in this study were found within low to mediumrange (Table2). The result obtained for exchangeable K, which was rated as very high in the current study, agrees with the common idea that has been provoked as Ethiopian soils are rich in potassium(FAO, 1982).

In line with the present results, it has also been reported that Ethiopian soils in general show moderate to strong acidity and are relatively high in organic matter and have a high cation exchange capacity, high mean N and K contents, and somewhat low P content with Ca and Mg contents at the international average (FAO, 1982).In contrary, it has been reported that K deficiency is associated with soil acidity in areas where there is high rainfall and crop production has been practiced for many years (Agegnehu, 2009).

The amount of plant available phosphorus is strongly correlated to soil pH.It is available in optimum with in pH range of 6.5 – 7.5. The available P and S values in this study were found to be below the lower critical range (Karltun*et al*, 2013). This could be due to the presence of amorphous hydrated oxides in Andosols which induce a very high phosphate, borate and molybdate fixing capacity(MSU, 2017).Furthermore, it has been reported that inorganic forms of P are bound strongly to clays and oxide surfaces in acid soils, as the maximum solubility of phosphorus is within pH 5.5-8.0 andat lower pH levels phosphorus forms low solubility compounds with iron and aluminum (Brunno and Kevin, 2016).

Cation and anion exchange capacities are influenced by soil pH.The base cations ($Na^+$, $K^+$, $Ca^{2+}$, & $Mg^{2+}$) are bound more weakly to the soil at low pH, as they are displaced by $H^+$ on the negative charges on clays and organic matter along the soil surface and may not be available to plants and lost from the soil through leaching or uptake**(**Brady and Weil, 2008)**,**In the present study, it was observed that exchangeable Ca and Mg were in the range of medium fertility class, while K was in the very high range.Minimum absolute level of K is between 0.07 and 0.20 meq/100g (Afari-Sefa, *et al*., 2004which is by far less than the one recorded in this study. The CEC of the soil was found in the range of high fertility class (Table 2). High K availability can decrease the availability of magnesium to the plant, and may result in Mg deficiency of crops grown on soils that are already low in Mg**(**Brady and Weil, 2008).

Soil organic matter (SOM) serves multiple functions in the soil, including nutrient retention, improving water holding capacity, and soil aggregation and is a key indicator of soil quality. The organic carbon (OC) content of the soil in the present study was high and, as a result, the tN% was also sufficient to support crop growth (Karltun*et al*, 2013), reflecting the peculiar nature of Andosols**(**Nanzyo, 2002). Soil OC is apromising indicator for guiding N fertilizermanagementwhere soil heterogeneity is a challenge among smallholder farmingsystems (AssefaMenna, *et al*, 2015).

Table 2 Soil chemical property of the study area

| Parameters | Value | Fertility class | Reference |
|---|---|---|---|
| Soil pH | 5.43 | Strongly acidic | Landon, 1991 |
| Ca (cmol(+)/kg Soil) | 9.32 | Medium | FAO, 2006 |
| Mg(cmol(+)/kg Soil) | 2.16 | Medium | FAO, 2006 |
| K(cmol(+)/kg Soil) | 1.51 | Very high | FAO, 2006 |
| Na(cmol(+)/kg Soil) | 0.07 | Very low | FAO, 2006 |
| CEC(cmol(+)/kg Soil) | 26.43 | High | FAO, 2006 |
| Avail. P(mg/kg) | 6.44 | Very low/acutely low | Karltun*et al*, 2013 |
| S(mg/kg) | 12.96 | Low | Karltun*et al*, 2013 |
| Fe(mg/kg) | 116.53 | High | Karltun*et al*, 2013 |
| TN(%) | 0.26 | Medium/Sufficient | Karltun*et al*, 2013 |
| OC(%) | 4.03 | High | Karltun*et al*, 2013 |

### 4.2. Leaf Area Index (LAI)

Treatment effects were not statistically significant (P > 0.05) for leaf area index (LAI) of the crop (Appendix Table 1**).**However, LAI increased with increasing rate of N, probably because of increased number of tillers and size of individual leaves.In agreement with the present result, it has been reported that application of120 kgN/ha and 150kgN/hadidn't show significant difference for LAI (Rahman*et al*. 2014).

### 4.3. Number of Effective TillerPer Plant

Fertilizer treatments didn't show significant effect (P > 0.05) on number of effective tillers per plant (Appendix Table 2**)**. A similar experiment conducted at Kulumsa on two wheat varieties has also demonstrated the absence of significant difference between 64.1 kgN/ha + 36.1kg $P_2O_5$/ha and 73kgN/ha + 54.15kg $P_2O_5$/ha for number of effective tillers per plant (Diriba, *et al*. 2019). This could be due to smaller difference between the fertilizer rates to bring about significant variation.

## 4.4. Plant Height

Plant height was not significantly affected by N, P and K treatments as well as by their interaction (Appendix Table 3). In line with this result, it has been reported that there was no significant difference among plots which received 60, 90 and 120 kg N/ha or 20 to 100 kg/ha of $K_2O$ for wheat plant height at ChefeDonsa incentral Ethiopia (EIAR, 2018). Similarly, a study conducted at Assosa in western Ethiopia has shown lack of significant difference in plant height of teffbetween plots that received 69 kg/ha and 93kg/ha of N and 20kg/ha and 30 kg/ha of P (EIAR, 2018), indicating that the difference between N, P and K rates used in this experiment was not huge enough to significantly influence plant height.

## 4.5. Spike Length

Spike length was significantly affected by Nitrogen rate, but the effect of $P_2O_5$and $K_2O$ rates and their interaction was not significant (Appendix Table 4). The highest spike length was recorded for those plots which received 73Kg N/ha (Table 3). In agreement with this result, a study conducted at Kulumsahas shown that the maximum spike length was recorded for plots that received the highest rate of N (100.3 kg/ha) (Diriba, *et al*. 2019).

Table 3Effect of N rate on wheat spike length

| **Parameter** | **Nitrogen (Kg/ha)** | | | **CV (%)** | **LSD** | **P** |
|---|---|---|---|---|---|---|
| | 64 | 73 | Mean | | | |
| **Spike length (cm)** | $9.44^b$ | $9.71^a$ | 9.58 | 5.48 | 0.249 | 0.0307 |

*Figures followed by same letters in a row are not significantly different at 5% P level*

## 4.6. Number of Spikelet per Spike

Spikelet number per spike was significantly affected ($P < 0.05$) by the main effect $K_2O$ and its interaction with $P_2O_5$(Appendix Table 5**)**. The highest spikelet number per spike was obtained from plots which received 69 kg $P_2O_5$ +18kg $K_2O$/ha,while the lowest value was recorded for 69 kg $P_2O_5$ +0 kg $K_2O$/ha (Table 4), indicating that increasing the rate of $P_2O_5$ alone may not increase number of spikelet per spike. Similar finding has been reported from Pakstan, indicating that number of spikelet per spike decreases when NPK rate exceeds 150-125-100 kg/ha (Malghani*et al*, 2010).On the other hand, Rahman*et al*. (2014) have reported lack of significant difference between plots which received 50 and 80kgN/ha for number of spikelets per spike.

Table 4Interaction of potassium and phosphorus fertilizer rates for number of spikelet per spike

| **$P_2O_5$(kg/ha)** | **$K_2O$(kg/ha)** | | |
|---|---|---|---|
| | 0 | 18 | 36 |
| **37.7** | $17.88^{ab}$ | $17.87^{ab}$ | $16.96^{bcd}$ |
| **46** | $17.54a^{bc}$ | $17.25^{abcd}$ | $17.25^{abcd}$ |
| **69** | $16.54^{d}$ | $18.00^{a}$ | $16.67^{cd}$ |
| | CV = 5.43 | LSD = 0.94 | P = 0.0164 |

*Figures followed by same letter(s) within rows and columns are not significantly different at 5% P level*

### 4.7. Number of Seed per Spike

Seed number per spike was significantly influenced ($P < 0.05$) by the main effect N and $K_2O$ as well as by their interaction (Appendix Table 6**)**. The highest seed (kernel) number per spike was recorded for 64kgN/ha + 18kg $K_2O$/ha (Table 5). In agreement with this result, Malghani.*et al*. (2010) have reported that maximum number of grains per spike was recorded for NPK rate of 175-150-125 kg/ha.

Table 5The effect of N and $K_2O$ on number of seeds per spike

| **N (kg/ha)** | **$K_2O$ (kg/ha)** | | |
|---|---|---|---|
| | 0 | 18 | 36 |
| **64** | $53.79^b$ | $60.12^a$ | $53.28^b$ |
| **73** | $51.95^b$ | $53.53^b$ | $54.75^b$ |
| | CV= 7.6 | LSD= 3.38 | P = 0.0002 |

*Figures followed by same letter(s) within rows and columns are not significantly different at 5% P level*

## 4.8. Thousand Seed Weight

The analysis of variance showed that thousand kernel weightwas significantly affected by $K_2O$ rate and $K_2O$ by $P_2O_5$interaction (Table 6).However, the effect of $P_2O_5$ alonewas not significant for 1000 seed weight(Appendix Table 7), probably indicating that the effect of $K_2O$ favored $P_2O_5$ to influence thousand seed weight of the crop. In agreement with this, Abebaw and Hirpa(2018) reported that there was no significant difference in thousand seed weight with increasing rate of $P_2O_5$.Similarly, it has been reported that thousand grain weight showed no variation with increasing NPK rates from 75-50-25 to 175-150-125 kg/ha (Malghani.*et al*, 2010). Nevertheless, it has been documented that Phosphorus deficiency directly affects 1000 grain weight due to its function in stimulation, flourishing and seed formation (Iqbal, and Chauhan, 2003).

Table 6Interaction of $P_2O_5$ and$K_2O$ for 1000 seed weight of Wheat

| **$P_2O_5$(kg/ha)** | **$K_2O$ (kg/ha)** | | |
|---|---|---|---|
| | 0 | 18 | 36 |
| **37.7** | $40.43^{bc}$ | $39.81^c$ | $40.54^{abc}$ |
| **46** | $39.79^c$ | $40.75^{abc}$ | $41.84^a$ |
| **69** | $39.85^c$ | $41.50^{ab}$ | $40.81^{abc}$ |
| | CV = 3.39 | LSD= 1.375 | P = 0.0344 |

*Figures followed by same letter(s) within rows and columns are not significantly different at 5% P level.*

## 4.9. Above Ground Biomass

Analysis of variance showed that biomass yield was not significantly affected by the main effect of fertilizers and by their interaction (Appendix Table 8**)**. However, it has been documented that, among the mineral nutrients, nitrogen accumulation is closely linked to biomass accumulation, as crop radiation use efficiency is determined by the amount of leaf N per unit leaf area (Sinclair and Horie, 1989). Although it is generally believed that addition of nitrogen enhancesvegetative growth of wheat and results in increased plant biomass,Rahman*et al* (2014) have reported absence of significant differenceamong N rates of 60, 80, 110 and 140kg/ha for biomass yield.

## 4.10. Grain yield

Analysis of variance showed that $P_2O_5$rate significantly influenced ($P < 0.05$)grain yieldper ha (Appendix Table 9**)**. The highest grain yield (4574 kg/ha) was recorded for 69 kg $P_2O_5$/ha, followed by 46 kg $P_2O_5$/ha which gave an average grain yield of 4323 kg/ha (Table 7). Previous research findings indicated presence of huge variability in nutrient requirement among locations. Accordingly rates of 46-123N kg/ha and 46-80 $P_2O_5$kg/ha were recommended for south eastern partsof the country for wheat production (Yesuf andDuga, 2000; Haile *et al.*,2012, Dawit*et al.*, 2015; Abdo*et al.*, 2012).Similarly, a demand of 92-138 N kg/ha and 46-69 $P_2O_5$kg/ha for north western partsthe country were identified (Minale*et al.*, 2006, Asmare*et al.*, 1995). For central parts of the country a range of 60-130.5 kg/ha for N and 23-80 kg/ha for $P_2O_5$ were identified (Workneh and Mwangi, 1994; Teklu*et al.*, 2000; Getachew and Taye, 2005; Genene, 2003; Gebreyes, 2008; Amsal*et al.*, 1996; Adamu 2013).Similar findings were reported from southern parts (69-110 N kg/ha and 46 $P_2O_5$ kg/ha)(Woldeyesus*et al.*, 2012; Damene, 2003; Bekalu and Mamo, 2016). Similar work was done in northern parts of the country (46-138 N kg/ha and 46-115 $P_2O_5$ kg/ha)(Bereket*et al.*, 2014; Assefa*et al.*, 2015; Abreha*et al.*, 2013)for wheat growing areas indicating the great variability in nutrient demand, even within similar wheat belts. In general a range of 46-138 for N and 0 (at Afar) - 115 kg/ha for $P_2O_5$ was determined countrywide for wheat production, despite the accustomed use of 100kg/ha DAP or NPS or NPSB plus 100kg urea which when seen nutrient wise has been about 64 kg N/ha and 37.7-46kg $P_2O_5$/ha.

Application of potassium fertilizer did not significantly influencewheat grain yield, probably because of high K content of the soil. This result was in agreement with the findings of Dawit*et al*. (2015) whoreported that grain yield response of bread wheat to Kfertilizer application was not significant at Asassa, Bekoji, Kulumsa and Arsi Robe research stationsand concluded that theavailable soil K at all locations was sufficient to support plant growth and yieldperformance.However, in some cases like in highland Vertisols,even though there is high exchangeable K level in the soils, crops may respond to K fertilizer~~s~~ applications, indicating that the soil exchangeable K is fixed by clay particles and became unavailable to plants (IPI, 2016).

Table 7Wheat average grain yield as affected by the main effect $P_2O_5$

| Parameter | $P_2O_5$ (kg/ha) | | | | CV | LSD | P |
|---|---|---|---|---|---|---|---|
| | 37.7 | 46 | 69 | Mean | | | |
| Grain yield (kg/ha) | $4057^b$ | $4323^{ab}$ | $4574^a$ | 4318 | 15.46 | 388 | 0.035 |

*Figures followed by same letter(s) within a roware not significantly different at 5% P level.*

## 4.11. Correlation of Growth and Yield Parameters

Results of Pearson correlation analysis showed that number of seeds per spike was positively and significantly related with grain yield. Plant length showed a positive and significantcorrelation with spike length, above ground biomass yield and grain yield. Number of effective tillers per plant showed significant and positive correlation with leaf area index (LAI) (Table8).

Table 8Pearson correlation analysis result among treatment and growth factors

| Variables vs Variables | | Corr. Coefficient | P-value |
|---|---|---|---|
| Plant height | Spike Length | 0.38029 | 0.001 |
| Plant height | Above ground Biomass yield | 0.45624 | <.0001 |
| Plant height | Grain yield | 0.29615 | 0.0115 |
| Leaf area index | Tiller per plant | 0.53219 | <.0001 |
| Leaf area index | Above ground Biomass yield | 0.25623 | 0.0298 |
| Tiller per plant | Above ground Biomass yield | 0.24393 | 0.0389 |
| Spikelet per spike | Seed per spike | 0.342 | 0.0033 |
| Seed per spike | Grain yield | 0.24953 | 0.0345 |
| 1000 seed weight | Above ground Biomass yield | 0.55639 | <.0001 |
| 1000 seed weight | Grain yield | 0.67883 | <.0001 |
| Biomass | Grain yield | 0.81729 | <.0001 |

## 4.12. Regression Analysis for Grain Yield

Results of multiple regression analysis ($Y = 2094.90 + 20.15\,N + 15.34P + 4.16K$) showed that for every unit of yield increment above 2094.90kg/hathe contribution of N, $P_2O_5$ and $K_2O$ fertilizers was 51%, 39% and 10%, respectively.It also indicated that the applied N, P and K contributed to only about 40% grain yield. In line with this, results of an on farm trial conducted in northern Ethiopia using optimum inputs, row planting, reduced seeding rate and proper implementation of agronomic practices have shown that wheat yield increased on average by about threefolds (4800kg/ha) compared to the control (1800kg/ha) (Gashaw, *et al*, 2014). Similarly, a study made on rice in China has confirmed that a yield improvement of 16% - 52% and 0-16% through varietal renewal and agronomic management, respectively (Zhang, .*et al*. 2016). Furthermore, Hobbs *et al*. (1998) haveexplained that for sustainable improvement of crop yield, maintaining factors affecting yield (nutrients, planting date, crop establishment, and water management, lodging and weed control) at optimumlevelis required.

Results of simple regression analysis for grain yield versus each nutrient Y$= 2937.90 + 20.15N,\ Y = 3537.5 + 15.34P$ and $Y = 4255.60 + 0.0416K$ with decreasing order of their contribution, although the effect of N and K were not statistically significantly different ($P > 0.05$) for grain yield.This finding was in agreement with the results of Malghani.*et al*, (2010) who concluded that for optimum wheat grain yield the proportion of nitrogen and phosphorus need to be 1:1ratio. This shows that if the N rate is 73kg/ha the corresponding P rate should be 55kg/ha and when 64kg/ha N is used the corresponding P rate should be 48kg/ha. The above N rates were derived from the previous fertilizer recommendations used in the country (73 kgN/ha = 150 DAP +100kg Urea and 64kgN/ha = 100 kg DAP or NPS or NPSB plus 100kg/ha urea). Hence, it is possible to conclude that the rate of P recommended previously was fair in relation to the recent recommendations.

### 4.13. Partial Budget rate analysis

Partialbudget analysis was done for those treatments which showed significantly different effects (CIMMYT, 1988). Accordingly, grain yield was significantly influenced only by phosphorus fertilizer and, thus, the analysis was done for phosphorus using the least net benefit (37.7kg$P_2O_5$/ha) as a control. A treatment is said to be inferior when it has net benefits less or equal to those treatments with a lower cost and a treatment is said to be superior when no other option exists offering a greater net benefit at equal or lesser cost.This tells the amount of additional net benefit for each unit cost incurred. In order to make farmer recommendations from the marginal rate of return, the minimum acceptable rate of return was considered 100%. Hence, the treatment with highest net benefit and with greater than 100% MRR was selected as the best recommendation for farmers. Based on the above assumptions, a maximum net benefit of 58912.13 ETB was computed for the grain yield obtained from application of 69 $P_2O_5$ kg/ha, while the highest marginal rate of return, 953%, was obtained from 46 $P_2O_5$ kg/ha.Since the MRR of 258% is greater than the minimum acceptable MRR (100%) for the treatment with maximum net benefit (69 $P_2O_5$ kg/ha), it is economically acceptable to use this rate (Table 9).

Table 9Partial budget and Marginal rate analysisfor grain yield of wheat

| Variables | $P_2O_5$ rates (kg/ha) | | |
|---|---|---|---|
| | 37.7 | 46 | 69 |
| Average yield(kg) | 4057 | 4323 | 4574 |
| Adjusted yield (kg) | 3651.3 | 3890.7 | 4116.6 |
| Gross field benefit (ETB) | 54769.5 | 58360.5 | 61749 |
| Cost that vary | | | |
| fertilizer cost(ETB) | 1550 | 1891 | 2836.87 |
| Net benefit (ETB) | 53219.5 | 56469.5 | 58912.13 |
| MRR (%) | | 953 | 258 |

# 5. CONCLUSIONS AND RECOMMENDATIONS

The soil of the study area (Andosols) is naturally rich in potassium, total nitrogen and organic carbon. Although the geographical distribution of the soil is limited worldwide (~ 1%) it is categorized under agriculturally high potential soils. The strong acidic property of the soil can render the availability of some nutrients like phosphorus. This calls for soil pH reclamation work to be carried out in the area.

The first fertilizer recommendation seemed more perfect and well recognized than the recent approach.The current crop and soil type based fertilizer recommendation approach is good in considering some critical micro and macro nutrient to be incorporated in fertilizer type, but the problem is the supplementation has been made atexpense of the other primary nutrients like phosphorus.

The various blanket fertilizer rates recommended so far didn't bring about significant changes in grain yield, except for phosphorus. Although the available potassium in the study soil was found to be high, response was observed for some agronomic parameters, indicating that the applied potassium was more accessed than which is available in the soil, probably because of its interaction with either nitrogen or phosphorus. This, in turn, shows the increase in nutrient use efficiency of nitrogen and phosphorus due to the applied potassium.

In the study area phosphorus availability in the soil was found very limited which couldn't be compensated by the fertilizer rate recommended for western parts of the country (100kg NPSB/ha). The maximum rate of phosphorus applied (69kg $P_2O_5$/ha) computed from 150 kg DAPwhichis equivalent to 183kgNPSB/ha)showed about 13% yield advantage and also found to be economicalwhen compared with the current recommendation.

Finally this study result indicated that the blanket fertilizer rate recommended is not enough to satisfy optimum wheat production under the study area and it needs further quantification of the rate particularly for phosphorus along with the other nutrients identified as limited (S, Zn and B).

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# 7. APPENDICES

Appendix Table 1.ANOVA table for effects of treatments on Leaf Area Index (LAI)

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|
| Rep | 3 | 7.396111 | 2.46537 | 3.57 | 0.0239 |
| Trt | 17 | 11.28 | 0.663529 | 0.96 | 0.5185 |
| N | 1 | 0.160556 | 0.160556 | 0.23 | 0.6327 |
| $P_2O_5$ | 2 | 1.700833 | 0.850417 | 1.23 | 0.3045 |
| $K_2O$ | 2 | 0.823333 | 0.411667 | 0.6 | 0.5565 |
| N* $P_2O_5$ | 2 | 2.663611 | 1.331806 | 1.93 | 0.1609 |
| N* $K_2O$ | 2 | 2.164444 | 1.082222 | 1.57 | 0.2233 |
| $P_2O_5$* $K_2O$ | 4 | 0.643333 | 0.160833 | 0.23 | 0.9179 |
| N* $P_2O_5$* $K_2O$ | 4 | 1.168889 | 0.292222 | 0.42 | 0.7907 |
| Error | 34 | 23.47389 | 0.690409 | | |
| Total | 71 | 51.475 | | | |

Appendix Table 2ANOVA table for effects of treatments on tillering capacity

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|
| Rep | 3 | 0.082404 | 0.027468 | 4.46 | 0.0096 |
| Trt | 17 | 0.08479 | 0.004988 | 0.81 | 0.6717 |
| N | 1 | 0.000401 | 0.000401 | 0.07 | 0.8001 |
| $P_2O_5$ | 2 | 0.019203 | 0.009601 | 1.56 | 0.2251 |
| $K_2O$ | 2 | 0.006219 | 0.00311 | 0.5 | 0.6081 |
| N* $P_2O_5$ | 2 | 0.002636 | 0.001318 | 0.21 | 0.8085 |
| N* $K_2O$ | 2 | 0.002969 | 0.001485 | 0.24 | 0.7872 |
| $P_2O_5$* $K_2O$ | 4 | 0.021081 | 0.00527 | 0.86 | 0.5004 |
| N* $P_2O_5$* $K_2O$ | 4 | 0.034281 | 0.00857 | 1.39 | 0.2578 |
| Error | 34 | 0.209481 | 0.006161 | | |
| Total | 71 | 0.463465 | | | |

Appendix Table 3ANOVA table for effects of treatment on plant height (PH)

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Rep | 3 | 50.05483 | 16.68494 | 1.88 | 0.1509 |
| Trt | 17 | 104.6723 | 6.157192 | 0.7 | 0.7855 |
| N | 1 | 8.439201 | 8.439201 | 0.95 | 0.3359 |
| $P_2O_5$ | 2 | 1.199236 | 0.599618 | 0.07 | 0.9347 |
| $K_2O$ | 2 | 0.465486 | 0.232743 | 0.03 | 0.9741 |
| N* $P_2O_5$ | 2 | 16.93757 | 8.468785 | 0.96 | 0.3945 |
| N* $K_2O$ | 2 | 27.22549 | 13.61274 | 1.54 | 0.2296 |
| $P_2O_5$* $K_2O$ | 4 | 33.44222 | 8.360556 | 0.94 | 0.4506 |
| N* $P_2O_5$* $K_2O$ | 4 | 12.33306 | 3.083264 | 0.35 | 0.8435 |
| Error | 34 | 301.1623 | 8.857715 | | |
| Total | 71 | 555.9316 | | | |

Appendix Table 4ANOVA table for effects of treatments on spike length

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|
| Rep | 3 | 1.436549 | 0.47885 | 1.62 | 0.2038 |
| Trt | 17 | 5.231963 | 0.307763 | 1.04 | 0.4457 |
| N | 1 | 1.369513 | 1.369513 | 4.62 | 0.0388 |
| $P_2O_5$ | 2 | 0.008633 | 0.004317 | 0.01 | 0.9855 |
| $K_2O$ | 2 | 1.441675 | 0.720838 | 2.43 | 0.1029 |
| N* $P_2O_5$ | 2 | 0.1137 | 0.05685 | 0.19 | 0.8263 |
| N* $K_2O$ | 2 | 1.666758 | 0.833379 | 2.81 | 0.0741 |
| $P_2O_5$* $K_2O$ | 4 | 0.491092 | 0.122773 | 0.41 | 0.7971 |
| N* $P_2O_5$* $K_2O$ | 4 | 0.330592 | 0.082648 | 0.28 | 0.8896 |
| Error | 34 | 10.07421 | 0.2963 | | |
| Total | 71 | 22.16469 | | | |

Appendix Table 5ANOVA table for effects of treatments on spikelet per spike

| Source of | DF | Anova | Mean | F | Pr> F |
|---|---|---|---|---|---|

| Variance | | SS | Square | Value | |
|---|---|---|---|---|---|
| Rep | 3 | 1.08625 | 0.362083 | 0.62 | 0.6087 |
| Trt | 17 | 26.15405 | 1.538474 | 2.62 | 0.0082 |
| N | 1 | 1.130006 | 1.130006 | 1.93 | 0.1742 |
| $P_2O_5$ | 2 | 3.004408 | 1.502204 | 2.56 | 0.0921 |
| $K_2O$ | 2 | 6.730825 | 3.365413 | 5.74 | 0.0071 |
| N* $P_2O_5$ | 2 | 1.828036 | 0.914018 | 1.56 | 0.2252 |
| N* $K_2O$ | 2 | 2.484103 | 1.242051 | 2.12 | 0.136 |
| $P_2O_5$* $K_2O$ | 4 | 8.653117 | 2.163279 | 3.69 | 0.0134 |
| N* $P_2O_5$* $K_2O$ | 4 | 1.488556 | 0.372139 | 0.63 | 0.6415 |
| Error | 34 | 19.9474 | 0.586688 | | |
| Total | 71 | 72.50675 | | | |

Appendix Table 6ANOVA table for effect of treatments on seed per spike

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|
| Rep | 3 | 86.87039 | 28.9568 | 2.8 | 0.0547 |
| Trt | 17 | 603.7078 | 35.51222 | 3.43 | 0.0011 |
| N | 1 | 111.2038 | 111.2038 | 10.75 | 0.0024 |
| $P_2O_5$ | 2 | 11.56585 | 5.782926 | 0.56 | 0.5769 |
| $K_2O$ | 2 | 206.036 | 103.018 | 9.96 | 0.0004 |
| N* $P_2O_5$ | 2 | 21.79237 | 10.89618 | 1.05 | 0.3599 |
| N* $K_2O$ | 2 | 175.0306 | 87.51531 | 8.46 | 0.001 |
| $P_2O_5$* $K_2O$ | 4 | 48.535 | 12.13375 | 1.17 | 0.34 |
| N* $P_2O_5$* $K_2O$ | 4 | 44.21413 | 11.05353 | 1.07 | 0.3872 |
| Error | 34 | 351.699 | 10.34409 | | |
| Total | 71 | 1660.655 | | | |

Appendix Table 7ANOVA Table for effect of treatments on 1000 seed weight

| Source of | DF | Anova | Mean | F | Pr> F |
|---|---|---|---|---|---|

| Variance | | SS | Square | Value | |
|---|---|---|---|---|---|
| Rep | 3 | 6.617083 | 2.205694 | 1.42 | 0.2545 |
| Trt | 17 | 47.48569 | 2.793276 | 1.8 | 0.0718 |
| N | 1 | 2.840139 | 2.840139 | 1.83 | 0.1856 |
| $P_2O_5$ | 2 | 4.026944 | 2.013472 | 1.29 | 0.2872 |
| $K_2O$ | 2 | 13.36111 | 6.680556 | 4.29 | 0.0217 |
| N* $P_2O_5$ | 2 | 5.035278 | 2.517639 | 1.62 | 0.2131 |
| N* $K_2O$ | 2 | 0.191111 | 0.095556 | 0.06 | 0.9405 |
| $P_2O_5$* $K_2O$ | 4 | 16.89639 | 4.224097 | 2.72 | 0.0459 |
| N* $P_2O_5$* $K_2O$ | 4 | 4.959722 | 1.239931 | 0.8 | 0.5354 |
| Error | 34 | 52.88972 | 1.55558 | | |
| Total | 71 | 154.3032 | | | |

Appendix Table 8ANOVA table for effect of treatments on biomass yield

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|
| Rep | 3 | 8.747915 | 2.915972 | 1.34 | 0.278 |
| Trt | 17 | 18.20634 | 1.070961 | 0.49 | 0.9393 |
| N | 1 | 2.948401 | 2.948401 | 1.35 | 0.2527 |
| $P_2O_5$ | 2 | 2.917669 | 1.458835 | 0.67 | 0.5184 |
| $K_2O$ | 2 | 2.538453 | 1.269226 | 0.58 | 0.5638 |
| N* $P_2O_5$ | 2 | 1.052869 | 0.526435 | 0.24 | 0.7866 |
| N* $K_2O$ | 2 | 1.962703 | 0.981351 | 0.45 | 0.641 |
| $P_2O_5$* $K_2O$ | 4 | 6.724881 | 1.68122 | 0.77 | 0.551 |
| N* $P_2O_5$* $K_2O$ | 4 | 0.804014 | 0.201003 | 0.09 | 0.9843 |
| Error | 34 | 74.04692 | 2.177851 | | |
| Total | 71 | 119.9502 | | | |

Appendix Table 9ANOVA table for effect of treatments on grain yield

| Source of Variance | DF | Anova SS | Mean Square | F Value | Pr> F |
|---|---|---|---|---|---|
| Rep | 3 | 73.94998 | 24.64999 | 0.56 | 0.6433 |
| Trt | 17 | 948.8864 | 55.81685 | 1.27 | 0.266 |
| N | 1 | 59.1872 | 59.1872 | 1.35 | 0.2532 |
| $P_2O_5$ | 2 | 321.7219 | 160.8609 | 3.67 | 0.036 |
| $K_2O$ | 2 | 31.09705 | 15.54853 | 0.35 | 0.7038 |
| N* $P_2O_5$ | 2 | 85.41558 | 42.70779 | 0.97 | 0.3875 |
| N* $K_2O$ | 2 | 49.81791 | 24.90895 | 0.57 | 0.5716 |
| $P_2O_5$* $K_2O$ | 4 | 385.6673 | 96.41683 | 2.2 | 0.0897 |
| N* $P_2O_5$* $K_2O$ | 4 | 39.50937 | 9.877342 | 0.23 | 0.9223 |
| Error | 34 | 1489.361 | 43.80473 | | |
| Total | 71 | 3484.614 | | | |