EVALUATION OF WHEAT (*Triticum aestivum*) VARIETIES FOR GROWTH AND NITROGEN USE EFFICIENCY AT AMBO, ETHIOPIA

M.Sc THESIS

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EVALUATION OF WHEAT (*Triticum aestivum*) VARIETIES FOR GROWTH AND NITROGEN USE EFFICIENCY AT AMBO, ETHIOPIA

MSc Thesis

By

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Decision/suggestion of Department Graduate Council (DGC)

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DEDICATION

In the name of GOD, I dedicate this thesis manuscript to my beloved wife Hanna Melkamu Bayessa for her incomparable support during my study period.

STATEMENT OF AUTHOR

First, I declare that this thesis is my reliable work and that all sources of materials used for this thesis have been correctly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree in Agronomy at Jimma University and deposited at the university library to be made available to borrow under the rule 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 others.

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BIOGRAPHICAL SKETCH

The author Zewdie Ejerssa was born on October 29, 1983 at Gedo, West Showa Zone in Oromia Regional National State, Ethiopia. When his ages reach for School he attended elementary education at Gedo Elementary school and Secondary school at Ambo compressive senior secondary School. He then joined Ambo University in 2005 and graduated with a B.Sc degree in crop production in April, 2009. After graduation, he was employed by the Ministry of Federal Affairs (now, Ministry of Peace) in May, 2009 and was assigned to work as Equitable Development Advisor where he served on special support Regions for more than 8 years. He joined Jimma University in October 2017 to study the Degree of Master of Science in Agronomy.

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LIST OF ABBREVETION AND ACRONYMS

AARC	Ambo Agriculture Research Center
CIMMYT	International center for Wheat and Maize improvement
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
KARC	Kulumsa Agricultural Research Center
NARE	N Apparent recovery efficiency
NH_4^+	Ammonium
$N0_3^-$	Nitrate
NUE	Nitrogen Use Efficiency
NUpE	Nitrogen Uptake efficiency
NUtE	Nitrogen utilization Efficiency
PNB	Partial N Balance
SAS	Statistical Analysis System
SDW	Shoot Dry Weight
UK	United Kingdom

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ABSTRACT

Wheat is one of the most important cereal crops in Ethiopia. However, the yield of the crop is low due to minimum use of improved varieties, low and poor soil fertility, Nitrogen rate and application of management practices. Therefore, wheat varieties for nitrogen use efficiency were evaluated during the 2018/2019 cropping season under greenhouse condition at Ambo, Central Ethiopia. A greenhouse experimental was laid out in randomized complete block design (RCBD) with three replications. The treatment consist of six wheat varieties (Hidasse, Libben, Lemu, Hulluka, Shorima and Wane) and three rates of Nitrogen (0, 34.5 and 69kg N ha^{-1}). The results of this study showed that the main effects of N rate, varieties, and their interaction had significantly affect tiller number plant-1, fresh and dry shoot biomass, and root to shoot ratio, total N uptake, apparent N recovery efficiency, and partial N balance. Plant height, fresh and dry root weights were significantly affected only by the main effect of variety and nitrogen rate whereas they did not significantly influenced by interaction of the two factors. On the other hand, root volume was affected only by main effect of variety. The highest value of tiller number plant^{-1} (3.78), total N uptake (107.99kgha^{-1}), apparent N recovery efficiency (112.56%) and partial N balance (1.44kg/kg) were obtained when Hulluka variety was applied with 34.5 kg N ha^{-1}. The lowest tiller number per plant were recorded from Hidase, Lemu, and Shorima varieties applied with nill Nitrogen while the lowest values of apparent nitrogen recovery efficiency and partial nitrogen balance were obtained when Lemu and Shorima varieties applied with the highest nitrogen rate of 69 kg N ha^{-1}.The lowest total N uptake were resulted from all varieties planted with no N fertilizer. On the other hand, the highest root to shoot ration (0.37) was obtained from Hulluka with nill N application while the lowest root to shoot ratio (0.15) was recorded when Hidase variety applied with 69 kg N ha^{-1}. The highest fresh and dry shoot biomass were recorded from Wane variety planted with 69 kg N ha^{-1}.Huluka variety resulted significantly high fresh and dry root biomass. The correlation analysis indicated that there was a significantly strong positive correlation between N uptakes of wheat cultivars with tiller number per plant, apparent N recovery efficiency and partial nitrogen balance. In conclusion, the results obtained revealed that Huluka variety applied with 34.5 kg N ha^{-1} significantly improved the N uptake of wheat crop which could result in higher grain yield with low fertilization condition.

Keyword: bread wheat, nitrogen fertilizer, nitrogen use efficiency,

1 INTRODUCTION

Wheat is a grass species which belongs to the genus *Triticum*, family poaceae and one of the oldest crops with thousands known varieties and the most important are common wheat (*Triticum aestivum*) (Shewry, 2009). It is the most important cereal crops which is widely grown in the world, together with Maize and Rice being the most important globally occupying 28.1% of current total cereal production (FAO, 2017). One third of the world's population use wheat as stable food (Hussain *et al*., 2002) and also as important source of both carbohydrates and protein inhuman and livestock nutrition (Shewry, 2009).

Global wheat production was approximately 754.1million tons on an area of 222.40 million ha (FAOSTAT 2018). In Ethiopia about 3.90 million tons of wheat was produced from 1.60 million hectares per year, making it the second largest wheat producer country in the sub-Sahara Africa (SSA) next to South Africa (USAID, 2017). However, the amount of wheat produced is insufficient to meet the domestic needs, which is compelling the country to import about 25 to 35% of the annual wheat grain required for consumption (CSA, 2016).

In Ethiopia wheat crop is mainly cultivated in the highlands, which lies between 6 and 16° N and 35 and 42° E, at altitude ranging from 1500 to 2800 meters above sea level and with mean minimum temperatures of 6 ^{0}C to 11 ^{0}C (Hailu, 1991;MOA, 2012). The major wheat producing areas in Ethiopia are Arsi, Bale, Shewa, Iluababor, Western Hararghe, Sidamo, Tigray, North Gonder and Gojem zones (Bekele *et al*., 2000), in percentage: Oromia Regional State (54%), Amhara (32%); Southern Nations, Nationalities and Peoples (9 %); and Tigray (7 %) (CSA, 2013). Of wheat type's bread (*Triticum aestrivum*) and durum (*Triticum turgidum Var. durum*) are cultivated in the country, where bread wheat is the major crop varieties grown in the Ethiopia through farmers' field (Grai and Feed Annual Report, 2013). Wheat production in the country ranks fourth after teff (*Eragrostis*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in terms of area converge and third in total production (CSA, 2016).

To increase production and productivity, many improved wheat varieties have been developed. However, improved varieties often developed without considering their ability to grow and yield under low soil nutrient status (Wissum *et al*., 2009). One of the worldwide limiting nutrients is nitrogen having great impacts on food production (Guller *et al*., 2004). The doubling of agricultural food production over the past four decades has been reached in part with a 7-fold increase in the use of N-fertilizers, where approximately 90-100 million metric tons used for agriculture production (London et al., 2005). Nitrogen being a primary nutrient of an integral part of the plant tissues it has direct and indirect effect on the crop performance that both excess and deficiency have adverse effects on the crop growth and development (Fan and Christie, 2005).

Nitrogen fertilizer application has become an important tool used to increase crop yields and grain quality in intensive agricultural systems (Andrews *et al*., 2004). However, large proportion of the applied N fertilizer is lost due to surface runoff, leaching, soil denitrification, volatilization and low nitrogen use efficiency by crops (Raun and Johnson, 1999). This has resulted in environmental pollution and low crop productivity (Raun and Johnson, 1999; Pan *et al*., 2006; Asplund *et al.*, 2014). Carranca (2012), reported that crops are often fertilized with large amounts of N fertilizer, but only a small fraction of this fertilizer (roughly 5% to 50%) is taken up by the crop during the growing period. Of the total input in the form of nitrogen, only 15-20% is actually embedded in the food that reaches the consumers' plates, implying very large nutrient losses to the environment (Sutton *et al.*, 2013), while in Sub-Saharan Africa soil nutrient depletion is common (FAO, 2015).

Plants require Nitrogen in the higher amount (Taiz and Zeiger, 2006), while the amount of N available to the plant is generally limited (Elser *et al*., 2007) and nitrogen fertilizer is expensive to be used in present day (Ehdaie *et al.,* 2001). Given the low buying capacity of our resource poor farmers, there is a need to reduce the use of inorganic N fertilizer and search for plant genotypes with greater N use efficiencies, either in a strict physiological sense (increased carbon) gain per unit N), or in an agronomic sense (increased dry matter or protein yield per unit plant N or per unit N applied and available to the crop) (Andrews *et al*., 2004).

The variability among modern wheat cultivars in NUE has been attributed to nitrogen uptake efficiency (NUpE) and nitrogen utilization efficiency (NUtE) (Barraclough *et al*., 2010). LeGouis *et al*. (2010) reported various contributions of NUpE and NUtE to wheat genetic variation in NUE. Gaju *et al.* (2011) also reported genetic variability in NUE under low N application rate due largely to differences in NUtE rather than NUpE. Different studies indicated that the development and use of wheat varieties with higher NUE can contribute to a reducing the amount of nitrogen to be applied without decreasing grain yield (Barraclough *et al*., 2014; Gaju *et al*., 2014).

Globally, the estimates of nitrogen use efficiency are about 50% N is recovered in wheat crops (Dobermann, 2005). In the UK, about 65% can be recovered by crops (Sylvester-Bradley and Kindred, 2009) and similar recovery levels have been recorded in Australia (Fischer *et al*., 1993). Lassaletta (2014) stated, that nutrient use efficiency acts as the indictor to check the ability of a crop to convert available nutrients to economic yield. Due to environmental and economic concerns with N fertilizers, improvement in nitrogen fertilizer application to wheat varieties has become a desirable option for sustainable wheat production. Modern cultivars use N more efficiently and are more tolerant to low N availability compared to pioneer cultivars and there was evidence that improving of NUE of wheat is very important practices in terms of input reduction, minimizing greenhouse gas emission and environmental pollution (Zhang *et al.*, 2015).

However, the information on the nitrogen use efficacy of bread wheat varieties in Ethiopia is sparse. Besides, knowing the N use efficiency of wheat varieties is crucial for resource poor farmers to use efficient varieties to increase yields in the region. Therefore, there is a need to examine the N use efficiency of different wheat varieties as one of the potential area of the country in wheat production. Therefore, investigating the bread wheat varieties for nitrogen use efficiency is important for sustainable improvement of wheat production.

1.1 **Objectives**

- To determine the response of wheat varieties for growth and biomass yield under greenhouse condition.
- To evaluate nitrogen use efficiency of different wheat varieties for better production at Ambo

2 LITERATURE RERIW

2.1 Concept and Definition of Nitrogen Use Efficiency (NUE)

The concept of nitrogen use efficiency (NUE) has been widely used to characterize plant behavior regarding different level of nitrogen (N) availability. It is important to separate the concept of NUE and as phenotypic trait. More several definition and evaluation methods have been suggested of which some of them actually named “nitrogen use efficiency” (Good *et al.* 2004; Fageria *et al*. 2008). Moll *et al*. (1982) defined the most widespread NUE trail definition, at least among breeders, computed as the grain weight divided by the total N available to plant, and separated in to two components. NUE_{Moll} = NUpE × NUtE (Conmier,2015), with NUpE the N uptake efficiency calculated as the nitrogen in Plant at harvest divided by the available N in soil, and NUtE the utilization of efficiency calculated as the grain dry mass divided by the total amount of N in plant harvest. Then to compute these values when comparing different genotypes there are two main issues: (i) the complex estimation of N available to crop, and (ii) the estimation of the total amount of N in the plant. Ortiz-Monasterio *et al. (*1997) reported utilization efficiency can also be subdivided in to two components, Utilization efficiency = Harvest index x Nutrient biomass production efficiency.

The current strategy of selecting and evaluating under medium to high N levels has resulted in germplasm that produces higher yield when grown under low or high levels of N fertility (Ortiz-Monasterio, 2001). CIMMYT bread wheat from 1950 to 1985 gradually became not only more responsive to N inputs, but also more efficient in their use, Gerloff's, (1977). As a result, CIMMYT bread wheat do not require more N than the old tall cultivars; in fact, they often need less N to produce the same yield. In addition, since CIMMYT bread wheat are more responsive to N application, the optimum economic rate is higher than that for the old tall cultivars (Ortiz-Monasterio *et aI.,* 1997a). The level of N in the soil plays a very important role in the expression of uptake and utilization efficiency (Dhugga and Waines, 1989; Ortiz Monasterio *et al*.1997). The level of soil N may be manipulated together with genetic variability to develop cultivars with improved performance under both low and high input conditions (Ortiz Monasterio *et aI*., 1997a; van Ginkel *et al*., 2001).

According to Raun (2002), the improvement of NUE in the wheat is a major challenge necessarily to ensure sustainable yields and food security worldwide. Various alternative production practices have increase NUE related to more standard high-input crops rotation with legume is significantly improved than wheat-follow or wheat-wheat cycles (Baruddin and Merey, 1994). NUE is higher in tall wheat varieties for dry matter production and in dwarf-wheat varieties for grain production (Singh and Arora 2001). NUE with a high harvesting index (dry biomass) and low forage yield were observed in winter wheat varieties (Kunampiu *et al*., 1997). Recently, an increase in NUE of 14 to 18% in modern UK varieties in response to N supply (Sylvester-Bradley *et al*., 2009) while 24 to 29% increase in NUE in Spanish modern wheat (Acreche *et al*., 2009). Thus, improvements were more dependent on agronomic measurement than breeding for enhanced NUE.

Most wheat production involves N fertilizer application before or at sowing or 6 to 8 weeks after sowing (McDonald *et al.*, 1992) N is available in most soils in the inorganic forms as NH_4+, NO_3- and N_2 and in the organic form as amino acids and urea (Crawford and Glass, 1998). N uptake depends on root architecture and available soil moisture (rainfall) to be present soon after N application. At different stage of plant growth and different N-fertilizer application important strategy that improve N use (NUE) by plant and reduces N loss as a result of volatilization, denitrification or leaching (Kichey *et al*., 2007; Ehdaie *et al*., 2010). In the evidence of genotype or environment variation in nitrogen use in different studies have compared crop performance (yield, quality and under various fertilizer and management regimes across different environment and growing location. Management practice, and calculation of NUE unfortunately significant genotype x environment (G x E) interaction exist across (Huggin and Pan., 2003).

According to Presterel *et al.,* (2003) some genotypes grew well under low nitrogen apply while others didn`t. Wheat varieties evaluated, both NupE and NutE were reduced at higher N supply, causing on overall reduction in NUE (Qritz-Monastrio *et al*., 1997). Le Gouis *et al*. (2000) found that the genetic variability in grain yield of wheat growing varieties at low nitrogen was significant. Strong QTLs for yield under low N fertilization condition exist in hexaploid wheat, and suggests the possibility to improved yield stability by combining QTLs related to yield that are expressed in low N environment (Quarrie *et al*., 2007). Evidence of directed genetic improvement of NUE is limited (Kamprath *et al.,* 1982). However, several co-localizations between physiological trails, agronomic trails, and candidate's gene were identifying in wheat related directly or indirectly to the capacity of the plant to take-up or utilized N at particularly stage of its development cycle. In wheat, QTLs for GS activity were co-localized with those for grain N content (Habash *et al*, 2007).

2.1.1 **Role of nitrogen in Agronomy**

A nutrient-efficient plant is defined as one "that produces higher economic yield with a determined quantity of applied or absorbed nutrient compared to other or a standard plant under similar growing conditions" (Fageria *et al.,* 2008). In somewhat bridging Agronomy and ecological aspects, Siddiqi and Glass (1981) suggest calculating the "efficiency of utilization" as the inverse of the internal nutrient concentration times the biomass (or yield). They also suggest a ratio of utilization efficiencies to be used as a "utilization index" for comparisons of deferent plant (e.g. varieties). Similar approaches for comparing varieties have been used by others.

2.1.2 **Importance of Nitrogen Use Efficiency in Agro ecology**

In plant ecology nutrient use efficiency was initially defined as the plant biomass produced per gram of nutrient in the biomass, *i.e.* the inverse of plant tissue concentration (Chapin, 1980). The time aspect was introduced with nitrogen productivity (Ingestad, 1979; Ågren, 1985), as the rate of dry matter production per unit of N in the plant in a given time (dry weight g-1 N day^{-1}). Vitousek, (1982) developed a definition for perennial systems, suggesting that nutrient use efficiency should be the "grams of organic matter lost from plants or permanently stored within plants per unit of nutrient lost or permanently stored". Berendse and Aerts, (1987) proposed defining in NUE as the nitrogen productivity multiplied by the mean N residence time. Under steady-state, NUE would be the "dry weight which can be produced per unit of nitrogen taken up".

2.2 Role of Nitrogen on Growth

2.2.1 The growth of wheat root

Plant roots take up N mainly in the form of nitrate (NO_3-) and ammonium (NH_4 +), but also organic N in the form of amino acids (Nasholm *et al.*, 2001; Maathuis, 2009). Since the roots are responsible for N-uptake, root morphology could affect the N status of the plant. N uptake by wheat has shown preference between N forms, where net uptake was increased 35% when supplying at least 25% of the N as NH_4+ compared to all of the N as NO_3- (Wang and Below1992). The majority of N ion in soil water is delivered to the roots through mass flow is a process where dissolved to the root based to on hydraulic pull of water to the plant as a result of shoot evapotranspiration (Russel *et al*.,1984). Maximum root surface area enables greater capacity for ion absorption from the soil solution or soil particles (barber *et al*, 1984). According Garntt (2009), at low levels of N in soil solution, many plants will commit extra carbon resource to farther develop to root systems to enable greater penetration of the soil. However, increase carbon delivery to the root will have consequence on shoot biomass and potentially yield penalties. Therefore, from a NUE, context, trait that enhance N acquisition (efficiency and activity) without increase demand on plant carbon to roots will be a favorable direction in any NUE breeding or trait selection program (Fageria and Baligar 2005; Hirel *et al*., 2007, Gamtt *et al*., 2009).

Generally, plant contains 3-5% N in the shoot tissue biomass, which is by far the most abundance soil derived nutrient outside of oxygen, hydrogen and carbon. Plant absorb N from the soil in the form of NO_3- and NH_4+ ions. Most N uptake is in the form of NO_3-, which moves from the soil solution in to the plant root cell with absorbed water. N is also essential component of nucleic acids (DNA and RNA), amino acids, vitamins (*e.g.*: biotin thiamine, niacin and riboflavin) and all protein and a vast array of N containing organic molecules (Abdullah, 2013).

In plants, N is particularly important for photosynthesis, where it is needed for both binding CO_2 (RubisCO) and harvesting the light (chlorophyll and associated proteins) (Evans, 1989). Nitrogen is later transported to the grains. From a human perspective, grain N is important for the gluten content, which is responsible for the viscoelasticity of wheat dough that allows bread. In previous studies, seedling and shoot weight are often related. In a study on twenty varieties of Argentinian wheat, seedling root weight was found to be correlated to leaf area (Maydup *et al*., 2012). Furthermore, varieties with higher seedling root weight (in hydroponics) have higher N uptake at low level of N fertilization in the field (Bertholdsson & Kolodinska Brantestam, 2009). Earlier studies found that in varieties of wheat with early vigorous growth also had more vigorous root and took up more N in pot experiments than less vigorous lines (Liao *et al*., 2004, 2006). The same line also produced greater shoot and root biomass in unploughed soil than a conventional cultivar (Watt *et a*l., 2005). This suggests that early vigorous might be beneficial for N uptake and, ultimately, grain biomass and grain N to rise (Shewry, 2009).

2.2.2 **Effect of nitrogen on growth and development**

Nitrogen is an integral component of many essential plant compounds such as amino acids, which are the building blocks of all proteins including enzymes, nucleic acid and chlorophyll (Brady and well, 2002). Nitrogen is present in many essential compounds, it is not surprising that growth without added nitrogen is slow (Salisbeury and Ross, 1992), Nitrogen One of the most important functions of N in wheat is the promotion of rapid growth through increase in height, tiller number, size of leaves and length of roots (Chatterjee and Maiti, 1985). Makes up 1-7% of the dry matter of plants. The N deficiency cause plant growth and development thin and spindle, high sugar content (thickening of cells) and formation of chlorosis as a deficiency symptom on older leaves, under severe condition. On the other hand, Excess nitrogen supply causes higher photosynthetic activities, vigorous growth, weak stem, dark green color, reduced product quality; delayed in maturity, increase in susceptibility to insect pests and diseases and building up of nitrate in foliage which is harmful to animals (Mengel and Kirkby, 1996; Brady and Weil, 2002).Wheat is important to be able to distinguish between growth and development when describing plant changes, especially when the plant growth stages overlap each other, for example when some part is developing and growing and another part is reduced or dying (White *et al*., 2008).

Wheat Tillering

Winter wheat needs 100 degree-days to develop one leaf, but there can be some differences between varieties and growing conditions (Robertson *et al*., 2004). The first tiller appears when the main stem has three leaves. The number of tillers that develops depends on the growing conditions, the duration of the tillering period and the plant density. Commonly the main stem can develop three primary tillers; these tillers may in turn develop secondary tillers, and the secondary may develop tertiary and so on (Fagaria *et al*., 2006).Tiller formation and growth is sensitive to environmental and nutritional stress. It both delays tiller emergence and slows growth (Perry & Belford, 2000). In general, however, tillering is most dependent on environmental conditions and temperature, radiation, water and nutrients, and especially the duration of growing conditions (Spink *et al*., 2000).The internal light competition between plants regulates the stand density and the production of tillers ceases when the fraction of Photosynthetic Active Radiation (PAR) exceeds a specific threshold (Evers *et al.,* 2006). The response to grain yield from spring-developed tillers is therefore more important in late-seeded wheat and sparse stands (Thiry *et al*., 2002). Abdullatif *et al*., (2010) who reported that increasing in the number of effective tillers with nitrogen fertilization. Bereket *et al*., (2014) and Abdollahi *et al*., (2012) also reported that nitrogen fertilization have significant effect on effective number of tillers of wheat.

2.2.2.1 Plant height

Plant height was affected by N-rate and variety. Wheat Variety of *Lemu* had higher plant height than *wane (*Dereje, 2018), though inconsistent, their heights increased with increasing N rate. Tayebeh *et al*., (2011) and Sofonyas (2016) reported significant increments in plant height due to application of high nitrogen rate. According to Shahzad *et al.,* (2007) reported that height of the crop is mainly controlled by the genetic makeup of genotype and it can also be affected by the environmental factors.

2.2.3 **Effect of nitrogen on biomass production and allocation**

Plant used nitrogen to growth for photosynthesis and many other processes. The time of active growth N is needed for biomass production, and therefore the NUE equation used considers the mean N during the major growth period and not only the N present in the plant at harvest (Fageria, 2005). According to Evans (1989), the amount of chlorophyll in the leaf per unit leaf area is correlated with the total leaf N per leaf area when leaf age and n fertilization are varied. The biomass production, is affected by the internal N concentration (Agren, 1985) along with environmental factors. The close relationship between N and biomass production, it has been shown that the amount of N accumulated by the crop is closely related to the number of grains and the yield (Sinclair and Jamieson, 2006).The partitioning of assimilates to increase the duration of stem elongation, and reduced partitioning to the peduncle and other structural biomass has been suggested as a promising route for increasing wheat yields (Reynolds*et al.*, 2009).

2.2.4 Effects of nitrogen on dry matter and straw yield

The increase N fertilizer application was reported to dry matter increase the accumulation in crops (Barnes, 1985) by enhancing nitrogen uptake (Dalal and Dixit, 1987). Increasing dry matter is to increase in length of leaves, elongation of stem and panicles, or in general to increase in vegetative growth of the plant (Kumbhar and Sonar, 1980). Ghoshal and Singh (1995) also reported similar results showing greater responses of wheat biomass to nitrogen fertilizer application. Similar of documented, Jedel and Helm (1992) an increased in straw yield with nitrogen application on cereals, particularly wheat and barley. The application of N to the plant stimulates root growth and development as well as uptake of other nutrients (FAO, 2000; Brady and Weil, 2002).

2.3 Strategies to Improvement NUE

Cereals require N fertilization to produce maximum yields and high protein content (Barraclough *et al*., 2010). However, NUE in cereals is generally poor, where it is estimated 30-40% of the total N fertilizers applied is actually harvested in the grain. Of the total applied N the rest percent is lost, where often-excessive application can affect natural ecosystems through N pollution. Loss of N also contributes to significant direct economic losses to the growth particular when N fertilizer costly high (Glass *et al*., 2003; Guber and Gilloway, 2008). Therefore, initiatives to improve NUE will be important in order to minimize both N-fertilizer losses and the direct production costs of the crop. On the basis of field experiments, (Cassman *et al*., 2002) reported N recover in wheat varied from the low as percent under unfavorable weather to 49 percent under favourable weather condition.

One of the main causes of low NUE in actual N management practices is the limited synchrony between N soil availability and crop demand (Cassmann *et al*., 2002; Fageria and Baliger, 2005). Consequently, many different agronomic avenues are pursued to improve NUE in cereal crops which including: 1) Application of the correct dose of N-fertilizer and/or application during growth stages when nitrogen required; 2) Directed delivery of N to minimize losses or maximum utilization, for example, banding or pointe placement closes to the root; 3) Use of cover crops, to retain organic matter and soil N in the soil; 4) Increase utilization of crop rotation , such as wheat following legumes, and avoiding wheat- follow or wheat to wheat scenarios; 5) Use of modern farming technology such as conservation tillage to control weed soil moisture, erosion operation costs and environment; 6) Identifying the best sowing rate, spacing and depth for best use of soil water and fertilizers and 7) the selection of wheat germplasm that produced larger seed to ensure quick plant establishment and access to available N at young seedling stage. A long side any improvement in NUE related agronomic comparable improvement to plant germplasm must also occur. NUE traditionally hasn't been a central driver in genetic improvement program. By traditional breeding program or marker-based approaches including the use of quantitative trait loci (QTL) analysis (Quarrie *et al*., 2005). Furthermore there is a need to better understand N use in wheat, particularly the plant's capacity for mining N from the soil and its efficient use once within plant.

2.4 **Plant and Soil Factors Influencing NUE**

Cereal crops have poor NUE due to a range of biotic and agronomic-based factors, which includes the primary growing conditions that influence overall photosynthesis and plant respiration such as day/night temperature (Yoshida *et al*., 1982) and the amount and timing of prescription (Abdullah Faraj, 2013). High-yielding varieties will often demand large amounts of N fertilized to meet expected yield or to improve grain quality (higher protein content). While pest and disease pressure will often affect to demand for N, this can consequently reduce yield and NUE. Furthermore, the type of plant also has a dramatic impact on NUE, in general, cereal crops have higher N recovery efficiency (RE_N) than root crops, which in turn have a higher RE_N than leafy vegetative (Balasubramanian *et al*., 2004). The impact of N fertilization on the crop plants is very much influenced by the cycling of N between inorganic and organic forms and the relationship between the N present in air, water and soil fractions. This transition of N activity is referred to the N cycle, which describes the different forms and stages that N exists in the air, soil, water and the biological continuum. N is never lost completely in the cycle, but merely changes its form and availability (Mosier *et al*., 2004).

Application of organic material or crop residues with high C: N ratios to the soil can stimulate microbial N immobilization, a process where available $NH_4^+$and NO_3^- is competitively used microbes. This process can reduced crop yield unless N is supplemented with applied fertilizers (Van Lauwe *et al*., 2002). Soil based constraints can also promote or decrease microbial based N cycling activities including denitrification, ammonia volatilization (Shoji*et al*., 2001a). Excesses water in poorly drained soils results in anaerobic conditions, which directly affected the rate of denitrification by nitrifying bacteria. This promotes an accumulation of NH_4^+ in the soil solution (Van Kessel *et al*., 1993). The rate of volatilization of fertilizer N is then largely controlled by the pH and NH_4^+content of the soil (Vlek and Craswell, 1981).

2.5 **Nutrient Management for Wheat Production**

Soil nutrients and conservation need proper management for sustainable crop production. Nutrient management strategies should vary according to type of soil, climatic conditions, crop species, cultivar within species, and socioeconomic considerations (Fageria, 2009). The use of organic matter and mineral fertilizers has been proved to be a sound as amendment for soil fertility management strategy (Singhl*et al*., 2011). Farmers often apply excess of N as insurance against low yields. This is one of the challenges for plant breeders to increase NUE in a way that will reduce production costs and minimized environmental pollution while at the same time meeting both yield and quality measures (Daberkow*et al*.,2000).

Wheat can be obtained from highly productive varieties with appropriate nutrient and crop management on fertile soils with adequate water supply (Holmburg, 2000). Globally, wheat yields have increased considerably as a result of breeding programmers that have incorporated the short-straw trait from Mexican varieties and such varieties are more responsive to applied nutrients and are also more resistant to lodging as compared to the local wheat varieties (Amsal *et al.*, 1999). Wheat can grow on almost any soil, but for good growth it needs a fertile soil with good structure and porous subsoil for deep roots.

Nitrogen having the great role in agricultural soils, it is a highly mobile element and dynamic causing environmental problem through increased N pollution both at local and global level (Glass *et al.*, 2003; Gruber and Galloway 2008). The strategies of Improve N efficient use are to use genetic modification and/ or to breed for new varieties that take up more organic or inorganic from the soil N and utilized the observed metabolized more efficiently without compromising yield (Hirel and Lemaire 2006).

2.6 **Factor Affecting of N Use Efficiency**

Factors which influence NUE includes, variety, N source, N application method, time of N application, tillage, quantity of N applied (generally decreases use efficiency with increasing N applied), product (Forage and Grain), and soil type (organic matter) (Birhanu, 2010). According to Tilahun *et al*. (1996), nitrogen use efficiency can be improved with fertilizer timing and adjusting, no yield reduction was observed as result of split nitrogen application; rather its enhanced grain yield, total nitrogen uptake, and agronomic efficiency. The time application of 50% of the total N at sowing and the rest at full tillering stage significantly increased grain yield as well as the protein content of wheat (Asnakew *et al*., 1991). Crop response to N application varies with rate and timing of N application in relation to plant development (Mugendi *et al*., 2000). The most agronomic problems with the 13 use of N is the substantial loss of N in the form of NH_3 due to hydrolysis after application of urea (Miller and Donahue, 1995).

2.6.1 Effects of varieties on nitrogen efficiency of wheat

The different genotypes and cultivars have different N use efficiency capacity (Lin *et al*., 2007). Thus, to achieve higher nitrogen use efficiency and yield components greater emphasis should include the full package of agronomic management strategies, such as, improved varieties, moisture conservation structures, crop cover, crop rotation, control of weed, pest and disease and different soil amendment mechanisms.

According to Arega *et al*. (2013), comparative study on varietal difference and N fertilization on wheat grain yield and quality showed significant variations among the varieties for all the agronomic traits, except for grain yield. Modern barley genotypes have recently showed improve NUE with increased yields without the need for elevated N application rates (Sylvester-Bradley *et al.*, 2008). Wheat was also reported that the hybrids are more stable than pure lines (Mühleisen *et al*. 2014) indicating a higher tolerance to abiotic stresses. Some study also showed that best parent heterosis was higher at low N level than at high N level (Le Gouis and Pluchard 1996, Le Gouis *et al*., 2002).

The old and recent varieties are compared in the same N conditions, a significant genetic improvement of NUE was measured in various studies at different N levels. In the same way, Cormier *et al*. (2013) estimated genetic progress at +0.30-0.37 % year-1 between 1985 and 2010 using 195 European elite winter varieties at optimal and sub-optimal N levels.

2.6.1 **Effects of nitrogen application methods and time on nitrogen efficiency of wheat**

Fertilization application should combine rate, timing, splitting, and source of application, with a view to optimize wheat yield and its quality (Abedi, 2010). This necessitates consideration of the overall NUE in food grain production expressed as partial factor productivity of N. Partial factor productivity of N is an aggregate efficiency index that includes contributions to crop yield derived from uptake of indigenous soil N, fertilizer N uptake efficiency, and the efficiency with which N acquired by the plant is converted to grain yield.

As nitrogen fertilizers rates and timing of application are a decisive factor in the obtaining of high yields, increase protein content and improved grain quality, numerous studies have been done in order to determine the optimum rate and time of N application (Cui *et al.*, 2010). It is shown by some researches that applications of N later in the season (spring) and near an thesis is more effective in enhancing grain protein content in wheat than earlier applications (Ottman *et al*., 2000; Bly and Woodard, 2003). The use of nitrogen split application method that correspond to plant demand at different growth stages is an important strategy that improved N use efficiency by plant and reduce N loss as a result volatilization, denitrification or leaching (Kichey *et al.*, 2007; Ehdaie *et al.*, 2010).

2.6.2 **Effects of nitrogen rates on nitrogen efficiency of wheat**

Use of adequate N rates is essential for efficient use of N fertilizer and to maintain economic sustainability of cropping systems. Excessive use of N fertilizers is economically unfavorable, because incremental increases in yield diminish with increasing amounts of N applied, and it could lead to detrimental effects on the quality of soil and water resources (Fageria and Baligar, 2005a). The same authors also stated that, nitrogen is a mobile nutrient in soil and plant systems. Hence, creation of crop response curves showing yield versus N rates is the most efficient and effective method for defining the N requirement of a crop. Development of appropriate crop response curves to applied N fertilizer requires optimal environmental conditions during crop growth, and experiments should be conducted across years to obtain meaningful results. Nitrogen rate significantly influence N uptake efficiency, N biomass production efficiency, N use efficiency for grain and N use efficiency for protein yield of wheat (Haile *et al*., 2012; Bereket *et al*., 2014; Majid *et al*., 2010). Increasing levels of nitrogen increases grain and dry matter yields, number of kernels per head and plant height of wheat (Hussain and Shah, 2002; Damene, 2003).

2.7 **Evidence of NUE Productivity**

Identifying productivity and quality trails ultimately requires genetic variability to be present amongst parental line and selection. Evidence of directed genetic improvement of NUE is limited (Abdullah Faraj, B., 2013). However, several co-localizations between physiological trails, agronomic trails, and candidate genes were identified in maize, rice and wheat all related directly or indirectly to the capacity of the plants to take-up or utilize N at particular stage of its developmental cycles (Bahaddin, 2011). Evidence of genetic inter-specific variability for NUE in many annual species, including rice (Broadbent *et al*., 1987), wheat (Le Gouis *et al.,* 2000) and maize (Bertin and Gallas 2001). NUE improvements have also been observed in dry land system including spring barley (*Hordeum vulgare L*.) corn (Zea mays L.) and winter wheat (*tiriticum aestivum L*.) when grown in rotation with adequate N fertilization instead of continuous winter wheat-fallow (Halvorson and Reule 1994). Modern barley genotypes have recently showed improved NUE with increased yields without the need for elevated N application rates (Sylvester-Bradley *et al*., 2008). In this study it was confirmed that NupE and NutE play a role in improving NUE in the barley. This result is similar to that in maize, where at low N, the genetic variation in NUE for maize related to NutE while at high N, genetic variation in NUE was related to a mix of N uptake and N utilization efficiency (Moll *et al.*, 1982).

3 MATERIAL AND METHODS

3.1 Description of the Study Area

A Pot experiment was conducted at Ambo Agricultural Research Centre in West Showa Zone Oromia Regional National State, Ethiopia during the year 2018/2019 cropping season under greenhouse condition. Ambo Agricultural Research Centre is geographically located at 114 km west of Addis Ababa in Oromia Regional National State at latitude of 8^0 57'N and $38^0$07'E longitude, altitude of 2175 meter above sea level. It receives an average annual rainfall of 1018 mm with maximum and minimum temperatures of 26.89 and 10.02^0C, respectively and the average maximum and minimum relative humidity of the area are 91and 40%, respectively.

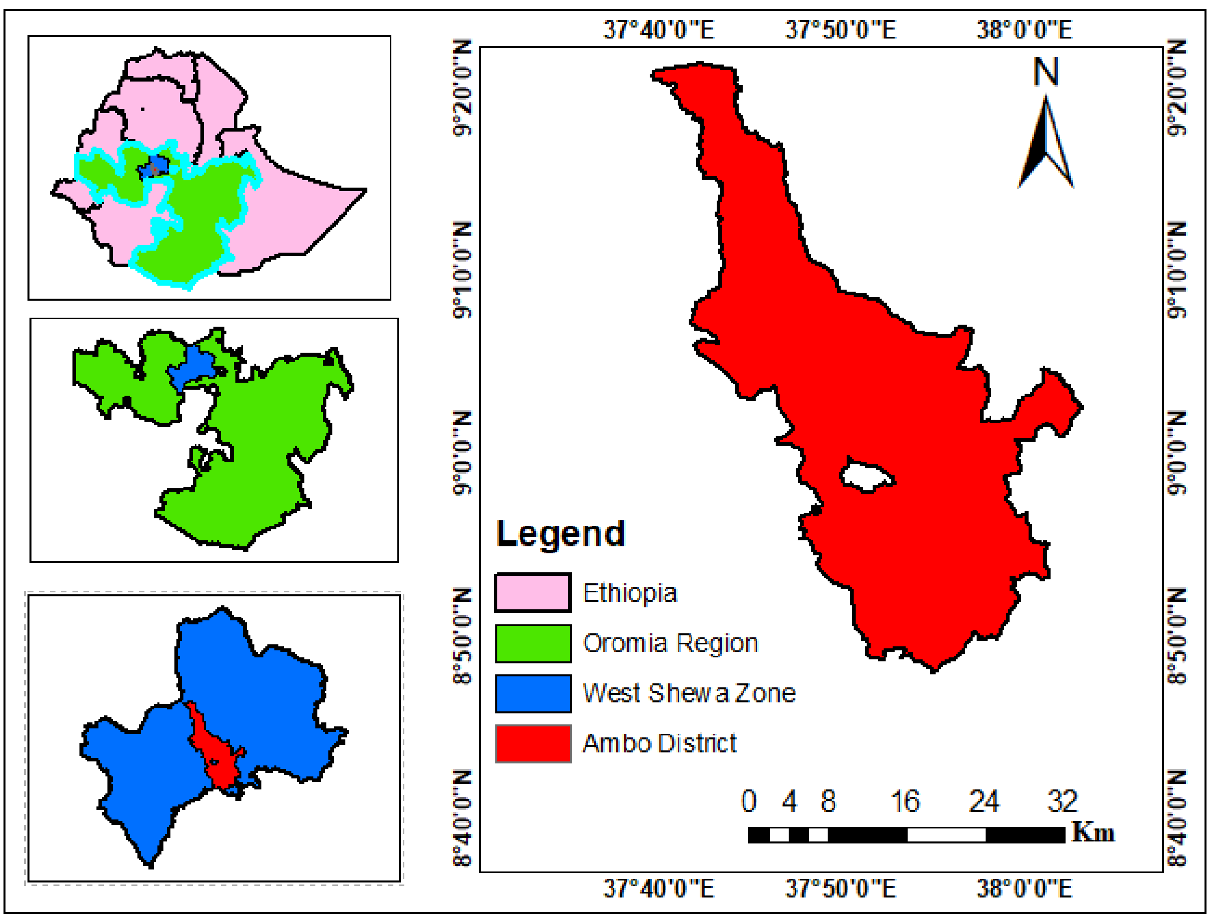

Figure 1. Map of study area in greenhouse experiment; Geographical positioning system coordinate

3.2 **Experimental Materials**

Six recently released improved Wheat varieties seeds were used in the experiment. Urea was used as source of Nitrogen. The seeds of all the varieties were obtained from Kulumsa Agricultural Research Center (KARC). Varieties are presented in Table 1.

Table 1. Description of the six Bread Wheat Varieties used for the Experimental

Varieties	Origin	Select at	Pedigree	Year of release	Grain yield t/ha		Adaptation zone	
					On station	on farm	Altitude	RF
Shorima	ICARDA	KATC	UTQUE96/3/PYN/BAU//MILAN	2011	2.9-7	2.3-4.4	2100-2700	700-1100
Hulukka	ICARDA	KARC	UTQUE96/3/PYN/BAU//MILAN	2012	4.4-7	3.8-6	2200-2600	500-800
Hidase	CIMMYT	KARC	*YANAC/3/PRL/SARA/TSI/VEE#5/4/CROC-/AE…*	2012	4.4-7	3.5-6	2200-2600	>500
Libben		BAKO	UCULA/KAUZ/6/PCN/BOW/4/MAYA/NAC/3/RPB/4,68//PYN/PHO/5/MUNI	2015	5.5-6.5	4.5-5	2300-2500	>900
Lemu		KARC	*WAXWING*2/HEILO*	2016	5.5-6	4.-5.5	>2200	800-1100
Wane		KARC	*SOKOLL/EXCALIBUR*	2016	5.-6	4-5	2100-2700	700-100

(MoA, Crop Variety Register 1995-2013; Indashaw, 2018)

3.3 Experimental Design and Treatments

The treatment consist of six bread wheat (*Tritium aestivum)* varieties (Hidasse, libben, lemu, Hulluka, Shorima, Wane) were evaluated for nutrient use efficiency (NUE) in plastic pots under three level of N fertilizer namely 0, 34.5 and 69 kg ha^{-1} N. The experiment was laid out as randomized complete block design (RCBD) and replicated three replications. The six wheat varieties were arranged in factorial combination with the three level of nitrogen rate. Thus, there were 6x3 treatment combinations, which were replicated three times, resulting in 54 experimental units.

Table 2. Treatment combination of wheat varieties and nitrogen levels

Treatment number	wheat varieties	Nitrogen (kg ha^{-1})
1	Hidase	0
2	Hidase	34.5
3	Hidase	69
4	Libben	0
5	Libben	34.5
6	Libben	69
7	Lemu	0
8	Lemu	34.5
9	Lemu	69
10	Hulluka	0
11	Hulluka	34.5
12	Hulluka	69
13	Shorima	0
14	Shorima	34.5
15	Shorima	69
16	Wane	0
17	Wane	34.5
18	Wane	69

3.4 **Experimental Procedure**

The experiment was conducted in green house with 54 total trapezium plastic pots and each pot was put side by side with the same treatment. Pot arrangement was arranged based on randomization and tagged for identification. The trapezium plastic pots of 8 kg capacity with upper (21cm), lower (15cm) and height 14cm, were filled with 6kg of dry soil and nitrogen level application at planting and tillering stage. By calculating the rate of nitrogen based on area of pots in relation with an area of a hectare was applied to the pots per the rate for each treatment and mixed with the soil evenly before planting seed. Urea was used as a source of nitrogen and was applied as per the rate of each treatment during planting and tillering. Ten wheat seed were sown per pot and two poorly established seedling per pots were thinned and other agronomic management practices like weeding, watering, control disease were held as recommended (MoANR, 2016).

3.5 **Soil Sampling and Analysis**

Soil samples for pot experiment were collected from Tokke Kutaye district, 12 km from Ambo Agricultural Research center through Guder town. One composite soil sample before treatment application was collected in diagonal pattern from a depth of 0-30 cm. The collected soil sample was aired dried, ground using a pestle and mortar and allowed to pass through a 2 mm sieve. Soil Analysis was done following standard procedures for soil nutrient analysis. The soil pH was measured with digital pH meter using supernatant suspension of 1:2.5 soils to water ratio. The particle size distribution (texture), of the soil sample was determined using the Boycouos hydrometric method (Van Reeuwijk, 1992). Soil organic matter was determined by using Walkley and Black method (Walkley and Black, 1934). Total nitrogen was determined following Kjeldahl procedure as described by Bremner and Mulvaney (1982) the available phosphors and nitrogen was determined by the Bray II method (Bray and Kurtz, 1945). Cation exchange capacity was determined at soil pH 7 after displacement by using 1N ammonium acetate method, then, estimated titrimetric ally by distillation of ammonium that was displaced by sodium (Gaskin *et al*., 2008).

3.6 Data collection

3.6.1 Phenological and growth parameters

The data were collected from each wheat varieties for N use efficiency parameter throughout the experiment period from plant growth, at vegetative stage before flowering and Processing of tissue for total N analysis. The details of data collection technique are described below;

Plant height: -data was measured as the height from the ground level to the top most point using ruler from each pot at 55 days after planting from three randomly selected plants per pot and the average values of three plants was used for statistical analysis.

Number of leafs plant^{-1}: were determined by counting the leaves of three randomly selected plants of each pot and the average values was used for statistical analysis.

Number of tillers per plant: - The number of tiller was determined by counting the tiller of three randomly selected plants of each pot and the average values was used for statistical analysis.

Shoot Fresh Biomass: The above ground parts of all plants in the pots were harvested and weighed using a sensitive balance and the average value was used as shoot biomass per plant.

Root Fresh Biomass: The underground parts of all plants in the pots was separated from soil by washing with water and weighed using a sensitive balance after the excess water was drained.

Shoot and Root dry weight: After taking the fresh weight of shoot and root parts, the sample were dried in an oven 70^0C to constant weight and then the dry weight will be measured using sensitive balance and average of the plant.

3.7 Plant Sampling and Analysis

Plant was collected from each pot before flowering stage and the collected plant sample was washed by distilled water. The oven dry plant tissues were then grounded into 1 mm size subjected to wet digestion and analyzed shoot dry biomass from total N content. The N content of the plant tissue was determined by Kjeldahl procedure (Black, 1965).The Kjeldahl procedure is based on the principle that by treating plant material with concentrated sulfuric acid it is oxidized and nitrogen in the plant material is being converted in to ammonium sulfate during the oxidation. The ammonia was liberated in the distillation process with NaOH is trapped by the standard H_2SO_4. The total nutrient uptake was calculated as by multiplying the N concentration plant tissue by dry biomass per hectare of wheat.

3.7.1 **Nitrogen use efficiency**

N uptake: N uptake was calculated by multiplying dry matter production with corresponding their concentrations (N %) and expressed in kg/ha.

Plant part N uptake (Kg/ha) = $\frac{\text{Dry Wt.}\left(\frac{kg}{ha}\right) * N\%}{100}$

Apparent N fertilizer use (recovery) efficiency (ANRE) is the amount of fertilizer N taken up by the plant per kg of N applied as fertilizer, which was calculated as described by Azizian, and Sepaskhah (2014), Cleemput *et al*. (2008), Craswell and Godwin (1984):

% fertilizer nutrient recovery (ANRE) = $\frac{(TNF)-(TNU)}{R} X100$

Partial Nitrogen balance is how much nitrogen is being taken up out of the system in relation to how much is applied (Dobermann, 2007):

Partial Nitrogen balance = $\frac{UN}{F}$, where, UN = nitrogen content of harvested portion of the crop; F = amount of nutrient applied.

3.8 **Data Analysis**

All the measured parameters were subjected to analysis of variance appropriate to factorial experiment in RCBD according to the General Linear Model. Data were analyzed using SAS 9.3 (SAS, 2013) and correlation and the interpretations were made following the procedure described by Gomez and Gomez (1984). Mean separation was carried out using LSD (Least Significant difference) test at 5% level of significance (Steel and Torrie, 1980.

4 RESULTS AND DISCUSSIONS

4.1 Soil Physico-Chemical Properties

Chemical properties of the soil used for pot experiment is summarized in Table 3. The soil pH was 5.83, which is moderately acid (Doll, 1964). The Cation exchange capacity was 22.92 mg/100g very high (Hazelton and Murphy, 2007). Total Nitrogen in soil was 0.12% found in low range (Bashour, 2007). The total Nitrogen is a limiting factor for optimum crop growth. The available P of the soil is 15.31mg kg^{-1} and found in medium range for the soil at the site (Bashour, 2007). Organic carbon content of the soil was 1.6% and soil organic matter was 2.77%which is in the medium range. The soil textural class at site is silty clay (SC) with particle size distribution of 67.5% clay, 15 % silt and 17.5% sand (Table 3).

Table 3. Selected soil physical and chemical properties of the surface soil (0-30 cm depth) of the experimental site

Parameters	Soil		
	Values	Rating for soil	Reference
Soil Chemical			
pH (1:2.5 H_2O)	5.83	Moderately acid	Doll (1964)
Organic carbon (%)	1.6	High	Hazelton and Murphy (2007)
CEC(maq/100gsoil)	22.92	Very high	Hazelton and Murphy (2007)
Total Nitrogen (%)	0.12	Low	Bashour (2007)
Available P(mg/kg)	15.31	Medium	Bashour (2007)
Organic Matter (%)	2.77	Medium	
Soil Texture	%		
Clay	67.5%		
Sand	17.5%		
Silt	15%		
Class	silty clay		

4.2 Effects of Nitrogen Rate and Varieties on Crop Phenology

4.2.1 Plant height

The mean values for plant height are presented in Table 4. The analysis of variance revealed statistically significant differences in plant height due to the main effect of variety ($P<0.001$) and nitrogen rate ($P<0.05$) (Appendix Table 1).

The tallest plant height (52.67cm) was recorded for Wane variety while the shortest plant height (35.77cm) was resulted from Hulluka variety (Table 4). Regarding nitrogen rate, the tallest plant heights were obtained from the pot applied with 34.5 kg N ha^{-1} (46.10cm) and 69kg N ha^{-1}(46.72 cm) whereas the shortest plant height (42.62cm) was obtained from the pot applied with no Nitrogen fertilizer (Table 4). The result of this study is in conformity with the Tayebeh *et al*, (2011) and Sofonyas (2016) who were reported significant differences in plant height due to the application of nitrogen rate. Similarly, Amanulia and Maimoona (2007) reported that the increased rates of N increased plant height and the shortest plants were recorded from the control treatment. This idea is in conformity with reports of (Abdo *et al.*, 2012; Haile *et al*., 2012; Girma *et al*., 2012; Gerba *et al.*, 2013) who observed increased plant height. The mean values of plant height vary from 35.77cm to 52.67cm. This variation could be related to the inherent character of the variety. Plant height differences among various cultivars are generally due to their genetic constitution (Sial *et al*., 2009). Though it is inconsistent, the heights of plants increase with the increase of N rate.

Table 4. Main effect of varieties and nitrogen rate plant height

Varieties	Plant height (cm)
Hidase	46.51bc
LIben	42.49c
Lemu	45.33bc
Hulluka	35.77d
Shorima	48.16b
Wane	52.67a
LSD (%)	4.47
Nitrogen	
0	42.62b
34.5	46.10a
69	46.72a
LSD (%)	3.16
CV (%)	10.34

NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance

4.2.2 Number of tillers plant

The mean values of number of tillers plant-1 are presented in Table 5. The analysis of variance for number of tiller plant $^{-1}$ showed highly significant ($P < 0.001$) differences due to the main effects of N-rate, varieties and their interactions (Appendix Table 1). The maximum number of tillers per plant (3.78) was obtained from Hulluka variety applied with 34.5 kg Nha^{-1}. However, this result is statistically similar with the Hidase variety applied with 34.5kg N ha^{-1} and Huluka variety applied with 69 kg N ha^{-1}. The response of the crop in terms of number of effective tillers numbers was higher at 34.5kg N ha^{-1}. The lowest numbers of tiller plant-1 were obtained from the pots planted with Lemu (1.11), Hulluka (1.22) and Hidase (1.33) varieties with no Nitrogen fertilizer (Table 5). The variation could be related to the inherit character of the varieties. This might be attributed to different capacity of varieties in number of tiller plant$^{-1.}$ The result of this study is similar with that of Suleiman *et al*., (2014) who reported that significant difference among varieties for tillering. Similarly, Abdullatif *et al*, (2010) also reported that increase in number of effective tillers with nitrogen fertilizer application. Bereket *et al.*, (2014), Abdollahi *et al.*, (2012) also reported that nitrogen fertilization have significant effect on effective number of tillers of wheat.

Table 5. Interaction effect of varieties and Nitrogen rate on number of effective tillers per plant and number of leafs per plant.

Treatments		Number of tillers plant^{r-1}	Leaf number per plant
Wheat varieties	Nitrogen rate(kg ha^{-1})		
	0	1.33h	6.67
Hidase	34.5	3.44ab	6.67
	69	3.22bc	6.67
	0	1.89fg	7.00
Liben	34.5	2.89cd	6.67
	69	2.44de	6.67
	0	1.11h	7.00
Lemu	34.5	2.11ef	7.00
	69	2.56de	6.67
	0	1.89fg	7.00
Huluka	34.5	3.78a	6.33
	69	3.33abc	6.00
	0	1.22h	7.00
Shorima	34.5	2.33ef	7.33
	69	2.89cd	7.00
	0	1.44gh	6.33
Wane	34.5	2.33ef	7.00
	69	2.55de	7.33
LSD (5%)		0.32	NS
CV (%)		13.83	8.72

NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance.

4.2.3 **Number of leaves per plant**

The analysis of variance for leaves plant^{-1} showed that there is non-significant (P>0.05) difference due to varieties, nitrogen rate and their interaction (Appendix Table 1). This result is in agreement with the observation of Mohammed A *et al.*, (2000) who reported non-significant effect of wheat varieties on number of leaves per plant.

4.2.4 **Fresh and dry shoot biomass**

The data on mean fresh and dry shoot biomass of wheat is presented in Table 6. The analysis variance for fresh and dry shoot biomass were significantly (p<0.001) different due to main effect of varieties, nitrogen rate and their interaction, but on dry shoot biomass varieties were non-significant (P>0.05) (Appendix Table 2). The highest shoot fresh weight of 19973 kg ha^{-1} was obtained from a variety Wane applied with 69 kg N ha^{-1} whereas the lowest fresh shoot weight of was obtained for all varieties applied with 0 kg N ha^{-1} (Table 6).

The maximum dry shoot value was recorded for a varieties Wane (4853 Kg ha^{-1}) applied with 69 kg N ha^{-1}, but statistically Hulluka and Hiddase had similar result applied with 69 kg N ha^{-1}. Whereas, the lowest value of dry weight was obtained for a variety Libben (2080 Kg ha^{-1}) and Hulluka (2093 Kg ha^{-1}) with no fertilization. However, Lemu, Shorima and Wane varieties had statistically similar results with no fertilization (Table 6). The increased rate of N fertilizer application was reported to have increased dry matter accumulation in crops (Barnes, 1985) by enhancing nitrogen uptake (Dalal and Dixit, 1987). An increase in dry matter is attend as a result of increase in length of leaves, elongation of stem and panicles, or in general due to increase in vegetative growth of the plant (Kumbhar and Sonar, 1980). Ghoshal and Singh (1995) also reported similar results showing greater responses of wheat biomass to nitrogen fertilizer application. Similarly, Jedel and Helm (1992) reported an increased in straw yield with nitrogen fertilizer application rate in cereals, particularly wheat and barley. Therefore, the maximum production of fresh and dry shoot weight ha^{-1} might be due to the role of nitrogen in accelerating vegetative growth of plants.

Table 6. Interaction effect of varieties and N-rate the interaction of plant fresh shoot, dry shoot biomass

Treatments		Shoot Fresh Biomass (Kg ha^{-1})	Shoot Dry Biomass (Kg ha^{-1})
Wheat Variety	Nitrogen rate (Kg ha^{-1})		
Hidase	0	8200f	2440de
	34.5	14920cde	3507bcd
	69	16667bcd	4147abc
Liben	0	7373f	2080f
	34.5	16853bc	3867bcd
	69	14173e	3200de
Lemu	0	8507f	2587ef
	34.5	15440cde	3693bcd
	69	15560cde	3813bcd
Huluka	0	7413f	2093f
	34.5	17680b	3787bcd
	69	16827bc	4200ab
Shorima	0	8640f	2560ef
	34.5	15800bcde	3587bcd
	69	15347cde	3400cd
Wane	0	8907f	2573ef
	34.5	14720de	3520bcd
	69	19973a	4853a
LSD (5%)		1997.6	756.03
CV (%)		8.92	13.69

Significant. Means in column followed by the same letters are not significantly different at 5% level of significance

4.2.5 Root fresh and dry root biomass

The data on mean root fresh and root dry of wheat varieties are presented in Table 7. The analysis of variance revealed highly significant ($P<0.001$) differences in fresh and dry root biomass due to the main effect of varieties, nitrogen rate, but the interaction of varieties and N rate were not significant (Appendix Table 3).

The highest root fresh weight of 7809 kg ha-1 was obtained for “Hulluka variety” whereas the lowest root weight of 4853 Kg ha-1 was obtained for a variety “Lemu” (Table 7). With regards to root dry weight the highest value was recorded 1084 Kg ha-1 for “Hulluka variety” whereas the lowest root dry weight of 507 Kg ha-1was obtained for “Hiddase variety” (Table 7). The maximum root fresh and dry weights ha-1, however, was produced with the application of 34.5 kg N ha-1. The lowest weight was recorded from the control pots. The variation could be related to the inherit character of the varieties. This might be attributed to different capacity of varieties in root biomass plant^{-1}. Liao *et al*., (2004 and 2006) found that in varieties of wheat with early vigorous growth also had more vigorous root and took up more N in pot experiments than less vigorous lines. Shewry (2009) also, was suggested that early vigorous might be beneficial for N uptake and, ultimately, grain biomass and grain N to rise.

Table 7. Main effect of varieties and nitrogen rate plant fresh root and dry root biomass

Varieties	Fresh Root biomass (Kg ha^{-1})	Dry Root biomass (Kg ha^{-1})
Hidase	4951c	658c
Liben	5902b	942b
Lemu	4853c	747c
Hulluka	7609a	1084a
Shorima	5013c	729c
Wane	5009c	720c
LSD (%)	732.15	108.5
Nitrogen rates (Kg ha^{-1})		
0	3629b	602b
34.5	6600a	927a
69	6440a	911a
LSD (5%)	517.71	76.72
CV (%)	13.75	13.92

NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance

4.2.6 **Root to shoot ratio**

The data on mean root to soot ratio wheat varieties are presented in Table 8. The analysis of variance revealed highly significant ($P<0.001$) differences in root to shoot ratio due to the main effect of varieties and significant ($P<0.05$) their interaction, but N rate had no significant effect (Appendix Table 4).

Hulluka and Liben varieties had the highest root: shoot ratio when compared with other varieties. The highest root: shoot ratio 0.37 and 0.33 was obtained from Hulluka and Libben varieties applied with no nitrogen fertilizer at control. Whereas the lowest root: shoot of 0.15 obtained from Hidasse varieties (Table 8). The lowest root: shoot ratio was produced with the application of 69 kg ha$^{-1.}$ This might be because N stress significantly increased the root-to-shoot as observed in maize under different N levels (Qiang *et al.*, 2017).

Table 8. Interaction effect of varieties and N-rate plant R: S ratio

Treatments		Root: shoot
Wheat Variety	Nitrogen rate(kg/ha)	
Hidase	0	0.23def
	34.5	0.22ef
	69	0.15g
Liben	0	0.33ab
	34.5	0.28bcd
	69	0.33ab
Lemu	0	0.20efg
	34.5	0.25cde
	69	0.22ef
Huluka	0	0.37a
	34.5	0.33ab
	69	0.29bc
Shorima	0	0.21efg
	34.5	0.23ef
	69	0.25cde
Wane	0	0.22ef
	34.5	0.20efg
	69	0.18fg
LSD (%)		0.06
CV (%)		13.44

NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance

4.2.7 **Root volume**

The data on mean root volume of wheat varieties are presented in Table 9. The analysis of variance revealed significant ($P<0.05$) differences in root volume due to the main effect of varieties, but f nitrogen rate and their interaction had no significant effect ($P>0.05$) (Appendix Table 4).

"Hulluka" and "Hidasse" had the highest root volume when compared with other wheat varieties. The highest root volume of 6.00ml and 6.11ml were obtained from "Hulukka" and "Hidasse" varieties respectively, whereas the lowest root volume of 4.89ml obtained from "Shorima" (Table 9). The greater root biomass of vigorous wheats results mainly from more and longer branch roots rather than from heavier or thicker roots (Palta *et al.*, 2004, 2007; Watt et al., 2005; Liao *et al.*, 2006). Vigorous root systems in wheat have double the number of roots because of their more profuse root branching Liu *et al*., (2009) was subjected the adequate amount of N, plants increase root size (root length, root volume and root dry weight) or increase root N uptake ability.

Table 9. Main effect of varieties and N-rate plant root volume.

Varieties	Root Volume(ml)
Hidase	6.11a
LIben	5.67abc
Lemu	5.00bc
Hulluka	6.00a
Shorima	4.89c
Wane	5.78ab
LSD (%)	0.86
Nitrogen	
0	5.78
34.5	5.28
69	5.67
LSD (%)	NS
CV (%)	

NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance

4.2.8 **Total Nitrogen Uptake**

The data on mean total nitrogen uptake of wheat is presented in Table 10. The analysis of variance revealed highly significant (P<0.001) differences in total N uptake due to the interaction of varieties and nitrogen rate (Appendix Table 5).

The highest total nitrogen uptake (107.99 N kg ha-$^{1)}$ was observed from Hulluka variety applied with 34.5 kg N ha^{-1}.However, this treatment is statistically similar with the total nitrogen uptake recorded from Huluka variety applied with 69 kg N ha^{-1}.

The lowest total nitrogen uptake was obtained when Hidase, Liben, Lemu, Huluka, Shorima, and Wane varieties were applied with nill nitrogen fertilizer (Table 10). Split applications of N might have decreased the losses of N and better synchronization with plant demand resulting in increased in wheat biomass. Most of variation in total N uptake might be due to differences in growth (total dry matter production) rather than differences in N concentration (total N %). The difference recorded among six wheat varieties in relation to total N uptake was in agreement with the results of (Asnakew*et al.*, 1991) who reported that bread wheat is the most responsive to applied N. The increasing resource uptake through increased root surface area might have helped the plant to produce more tillers.

Table 10.Interaction effect of varieties and Nitrogen rate on plant N uptake kg-1 N applied, apparent nitrogen recovering efficiency and partial nitrogen balance

Treatments		Nitrogen Uptake (N kg ha^{-1})	Apparent recovery efficiency (ANRE) (%)	Partial Nutrient Balance (kg/kg)
Wheat Variety	N kg/ha			
Hidase	0	24.21f	_	_
	34.5	65.11e	54.52bc	0.87cb
	69	82.72cd	39.01bc	0.55d
Liben	0	23.11f	_	_
	34.5	95.26bc	95.31a	1.26a
	69	83.09cd	39.99bc	0.55d
Lemu	0	29.28f	_	_
	34.5	74.33de	60.20b	0.99b
	69	78.73cde	32.31c	0.52d
Huluka	0	23.57f	_	_
	34.5	107.99a	112.56a	1.44a
	69	99.18ab	50.40bc	0.66cd
Shorima	0	27.35f	_	_
	34.5	75.63de	61.76b	0.98b
	69	72.18de	29.88c	0.48d
Wane	0	27.63f	_	_
	34.5	70.48de	55.78bc	0.93b
	69	95.12bc	44.99bc	0.63cd
LSD (%)		16.86	15.23	0.14
CV (%)		15.57	22.30	26.85

NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance

4.2.9 **Apparent nitrogen recovery efficiency**

The data on mean apparent nitrogen recovery efficiency of wheat varieties is presented in Table 9. Mean Nitrogen apparent recovering efficiency (NARE) depends on the congruence between plant N demand and the quality of N released from applied N (Dobbermann, 2005). The analysis of variance revealed highly significant (P<0.001) differences in Apparent nitrogen recovery efficiency due to the main effect of varieties, nitrogen rate and interaction of the two (Appendix Table 5).

The highest apparent nitrogen recovery efficiency were recorded for both Hulluka(112.5%) and Liben (95.31%) varieties respectively applied with 34.5 kg nitrogen per hectare as compared to other treatments. Whereas, the lowest apparent recover efficiency were recorded from Shorima (29.88%) and Lemu(32.31%) varieties respectively with the application of 69 kg N ha^{-1} (Table 10). The result of current study showed that nitrogen recovery efficiencies were decreased with increasing of N rate. This result is was in agreement with the study of Sinbo *et at*, (2004) who reported that NAR efficiency was higher at low rates of nitrogen application but drastically decreased with farther increase in nitrogen rate. Similarly, Sofonyas (2016) also reported that there was decreasing trend of apparent nitrogen recover efficiency with increased N rate. In general, the apparent recovery efficiency obtained from this study ranged between 29.88% and 112.56 for the different wheat varieties and different N rates under greenhouse condition. Other researchers who worked on different N source (organic and inorganic inputs) had reported the same result, as percentage N recovery ranging from 25% to 111% (Wasteman *et al.,* 1872; Kuruijs *et al*., 1988; Christianson *et al.,* 1990; Gachengo *et al*., 1999; Rees and Castle 2002).

4.2.10 **Partial nitrogen balance**

The data on mean partial nitrogen balance of wheat is presented in Table 9. The analysis of variance revealed highly significant (P<0.001) differences in partial Nitrogen Balance due to the main effect of varieties, nitrogen rate and their interaction (Appendix Table 5).

The highest partial nitrogen balance (1.44kg/kg) and (1.26kg/kg) were recorded for Hulluka and Libben varieties respectively when they are applied with 34.5 kg N ha^{-1}. Whereas, the lowest partial N balance (0.48kg/kg) was recorded from Shorima variety with application of 69 kg **N** ha^{-1}. However, this result is statistically similar with Hiddase, Liben and Lemu varieties applied with 69 kg N ha^{-1}. The difference in PNB could be because of variation of genotypes capacity in nitrogen uptake thus influencing NUE. This observation is consistent with the results of Tong *et al*. (1999) who attributed the relative importance of uptake N to explain NUE variation to an increase N rate. Ortiz-Monateio *et al.* (1997) also reported that PNB was high when N level is low and it decreases as N level increase. Consistent with in this finding, Van Sanford and MacKowen (1986) also observed significant differences in NUE in a pool of 25 wheat genotypes.

4.3 Pearson Correlation of Growth Parameters with Nitrogen Uptake of Wheat

The result of the correlation analysis of some measured traits (selected pairs of growth parameters) are presented in Table 11. Result of the correlation analysis indicated that there was a significantly strong positive correlation between total N uptakes with shoot fresh biomass (0.92), Dry shoot biomass (0.84), Apparent N recovery efficiency (0.87) and Partial Nitrogen balance (0.85) (Table 11) whereas plant height, tiller number per plant, root fresh, and root dry weight were positively correlated and negative correlation was observed with root to shoot ratio and Root volume. However, the wheat dry matter yield was non-significant and positively correlated to number of leaves per plant, whereas the dry shoot yield was negatively associated with root to shoot significant (Table 11).

Dry shoot showed significantly positive association with plant height (0.61), Shoot fresh (0.95), fresh root weight (0.58), dry root weight (0.57), apparent recovery efficiency (0.66) and Partial nitrogen balance (0.67), but negatively correlated with root volume, root: shoot ratio. Whereas, Leaves number was non-significantly had a positive correlation to fresh root, dry root. (Table 11). There were very strong positive correlations Apparent N recovery efficiency with total uptake (0.85), partial N balance (0.97), and tiller number $plant^{-1}$ (0.70) and dry root weight (0-64). The value of correlation between apparent N recover with partial N balance indicate that these parameters can be viewed as the most reliable to screen cultivars N responsiveness for NUE (Table 11).

Partial nitrogen balance had significant positive correlations with number of tillers planr^{-1} (0.71), dry shoot biomass (0.67), dry root weight (0.64) and total N uptake (0.85), However, NRE had non-significant negative correlations with leaf number plant^{-1} and root volume, while non-significant positive correlation was observed with plant height and root: shoot ratio (Table11)

Table 11. Correlation coefficients between mean N use efficiency and various growth parameters of bread wheat varieties and N application

	NL	NTP	PH	FBW	DBW	FRW	DRW	R:S	RV	NUT	NRE	PNB
NL		**-0.251ns**	**0.297***	**0.038ns**	**0.115ns**	**-0.029ns**	**0.033ns**	**0.008ns**	**-0.099ns**	**-0.084ns**	**-0.094ns**	**-0.059ns**
NTP			**-0.014ns**	**0.651****	**0.509****	**0.707****	**0.555****	**0.143ns**	**0.175ns**	**0.752****	**0.701*****	**0.706*****
PH				**0.467****	**0.613****	**0.023ns**	**0.010ns**	**-0.580****	**-0.196ns**	**0.270***	**0.115ns**	**0.172ns**
FBW					**0.954*****	**0.696****	**0.673****	**-0.191ns**	**-0.034ns**	**0.920****	**0.785*****	**0.798*****
DBW						**0.584****	**0.574****	**-0.332***	**-0.019ns**	**0.840****	**0.664*****	**0.667*****
FRW							**0.912*****	**0.454****	**-0.020ns**	**0.749****	**0.693*****	**0.701*****
DRW								**0.533****	**-0.038ns**	**0.724****	**0.665****	**0.640*****
R:S									**0.071ns**	**-0.037ns**	**0.053ns**	**0.020ns**
RV										**-0.051ns**	**-0.007ns**	**-0.078ns**
NUT											**0.867*****	**0.853*****
NRE												**0.978*****
PNB												

***= Significant at P<0.0001; **= Significant at P<001; *= Significant at P<0.05; ns=Not significant; VC= variety; NR=Nitrogen Rete; NL= Number of leaf; NTP= Number of tiller per plant; PH= Plant height; FBW= Fresh biomass weight; DBW= Dry biomass weight; FRW= Fresh root weight; DRW= Dry root weight; R: S= Root: shoot ratio; RV= Root volume; NUT= Nitrogen use uptake; ANRE= Apparent nitrogen recovery efficiency; PNB= Partial nitrogen balance.

5 SUMMARY AND CONCLUSION

Wheat is an important crop in Ethiopia. However, poor soil fertility, especially low levels of nitrogen due to the poor agronomic and soil management practices, has been demonstrated to be a major constraint to the production of the crop in the country. Under such situation, it is important to have practical and improvement options. One of the options is selecting crop genotypes that superiors to highly N response and hence screening wheat varieties for such purpose become necessary as an immediate solution.

Main effects of N rate, varieties, and their interaction had significantly affect tiller number plant-1, fresh and dry shoot biomass, root to shoot ratio, total N uptake, apparent N recovery efficiency, and partial N balance. Plant height, fresh and dry root weights were significantly affected only by the main effect of variety and nitrogen rata whereas they did not significantly influenced by interaction of the two factors. On the other hand, root volume was affected only by main effect of variety.

Hulluka variety shown improved performance having highest value of tiller number per plant, total N uptake, apparent N recovery efficiency and partial N balance applied with 34.5 kg N ha^{-1}, and had highest root to shoot ratio with no N application. Varieties of wheat with higher NUE values tended to have higher nitrogen response, and that breeding for NUE could be a potential method to improved yield and nitrogen response to nitrogen fertilizers. Improved NUE would have many benefits. The most important would to be the economic gains for producers by requiring less nitrogen fertilizers to reach maximum yield and more efficient use of fertilizers by reducing the risk of N loss to the environment through leaching or volatilization.

In this study, strong positive correlation and significant differences were observed among most growth parameters of evaluated wheat varieties. This indicate the existence of potential variability among the wheat varieties for efficient use of nitrogen. Hulluka was superior cultivars to improved higher total N uptake than the other wheat varieties, which could result in higher producing grain yield under low fertilization situation.

Therefore, those selected wheat varieties can be recommended to be directly grown by farmers who have under low fertilization situation varieties well for improvement of production in area and save the farmers from cost of mineral N fertilizer. Since this experiment was conducted only for a single season in greenhouse, it is suggested that repeat of the study for more seasons should be tested at field. It is also recommended that similar cultivars be further evaluated for NUE under field condition

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7 APPENDICES

Appendix Table 1 Analysis of wheat varieties for plant height, number of leafs plant-1 and number of tiller plant-1

Sources of variation	Degree Freedom	Mean square of		
		Plant height(cm)	Number of leafs plant^{-1}	Number of tillers plant^{-1}
Variety (VT)	5	293.71***	0.36^{Ns}	1.44**
Nitrogen rate (NR)	2	87.87*	0.07^{Ns}	10.81**
Replication	2	37.35ns	0.35^{Ns}	0.01^{NS}
VT*NR	10	11.61ns	0.36^{Ns}	0.35**
Error	34	21.79	0.35	0.11
CV%		3.3	8.73	13.85

VT*NR= interaction between variety and Nitrogen rate; ***= Significant at P<0.0001; **= Significant at P<001; *= Significant at P<0.05; ns=Not significant;

Appendix Table 2 Analysis of wheat varieties for fresh shoot and dry shoot weight t

Sources of variation	Degree Freedom	Mean square of	
		Fresh Shoot Biomass (Kg ha^{-1})	Dry Shoot Biomass (kg ha^{-1})
Variety (VT)	5	3608160.0*	370447.41ns
Nitrogen rate (NR)	2	384267822.2**	12251496.3**
Replication	2	1424266.7ns	135940.74ns
VT*NR	10	6754328.9**	473505.19*
Error	34	1449239.2	207595.64
CV%		8.92	13.69

VT*NR= interaction between variety and Nitrogen rate; CV= coefficient variation; ***= Significant at P<0.0001; **= Significant at P<001; *= Significant at P<0.05; ns=Not significant;

Appendix Table 3 Analysis of wheat varieties for fresh root and dry root weight

Sources of variation	Degree Freedom	Mean square of	
		Fresh Root weight (kg ha $^{-1}$)	Dry Root weight (kg ha $^{-1}$)
Variety(VT)	5	10417807***	242275.6***
Nitrogen rate (NR)	2	50266341***	602755.6***
Replication	2	2884651.9*	65688.9*
VT*NR	10	953060.7ns	23164.4ns
Error	34	584071.5	12826.1
CV%		13.75	13.92

VT*NR= interaction between variety and Nitrogen rate; CV= coefficient variation; ***= Significant at P<0.0001; **= Significant at P<001; *=Significant at P<0.05; ns=Not significant;

Appendix Table 4Analysis of what varieties for root: shoot ratio and root volume t

Sources of variation	Degree Freedom	Mean square of	
		Root: shoot Ratio	Root Volume (ml)
Variety (VT)	5	0.031**	2.37*
Nitrogen rate (NR)	2	0.002ns	1.24ns
Replication	2	0.008*	2.82**
VT*NR	10	0.003*	1.69ns
Error	34	0.001	0.8
CV%		13.44	16.07

VT*NR= interaction between variety and Nitrogen rate; CV= coefficient variation; ***= Significant at P<0.0001; **= Significant at P<001; *=Significant at P<0.05; ns=Not significant;

Appendix Table 5Analysis of wheat varieties for total N uptake, apparent N recovery efficiency and partial N balance

Sources of variation	Degree Freedom	Mean square of		
		Total N uptake	Apparent N Recovery Efficiency (%)	Partial Nitrogen Balance kg/kg
Variety (VT)	5	848.64***	879.48*	0.07*
Nitrogen rate (NR)	2	21204.89***	24259.38**	5.24**
Replication	2	20.87^{NS}	193.73*	0.03ns
VT*NR	10	420.90**	545.28*	0.05*
Error	34	103.28	252.88	0.02
CV%		15.57	22.30	26.85

VT*NR= interaction between variety and Nitrogen rate; CV= coefficient variation; ***= Significant at P<0.0001; **= Significant at P<001; *= Significant at P<0.05; ns=Not significant;