Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Split Nitrogen Applications in Dedessa District, Southwest Ethiopia

M.Sc. Thesis

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Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Split Nitrogen Applications in Dedessa District, Southwest Ethiopia

By

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MSc. Thesis

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DEDICATION

I dedicate this thesis to my beloved mother **Yofete Abamagal**whose strength and endless love inspires my soul. This thesis is also to my wife Lensa Kedir and my daughter Afrah Remedan for their support in the success of my thesis.

STATEMENT OF AUTHOR

First, I declare that this thesis is my authenticated work and that all sources of materialsused for the thesis have been duly acknowledged. The thesis has been submitted in partial fulfillment of the requirements for an MSc degree at Jimma University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this Thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author was born on June, 03, 1986, from his father Abdela Ibrahim and his motherYofete Abamagalin Dembi, Buno Bedele zone of Oromia regional state. He attended his Elementary, junior and Senior Secondary Education at Dembi primary, Secondary and Preparatory School respectively. Afterpassing the Ethiopian Schools Leaving Certificate Examination (ESLCE), he joined Kombolcha TVET College of Agriculture in September, 2003 andgraduated in July, 2005 with a Diploma in Plant Sciences. Then after graduation he was employed in Dedessa Woreda Agriculture Office in 2006 and served for four years (2006-2010) as Crop protection and agronomy expert. Then he joinedthe in-service program of Jimma University College of Agriculture and Veterinary Medicine graduate withBSc degree in Plant science in June 2014. After completion of his BSc study, he hasalso served as Head, Department of Agriculturalextension atDedessa woreda Agriculture office, until hejoined the School of Graduate studies of Jimma University College of Agriculture and Veterinary Medicine to study his Master of Science degree in agronomy in 2017.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CSA	Central statistical agency
FAO	Food and agricultural organization
GNC	Grain Nitrogen Concentration
GNU	Grain Nitrogen Uptake
GY	Grain Yield.
IFA	International Fertilizer Association’s
KARC	Kulumsa Agricultural Research Center
LSD	Least Significant Difference
LSPP	Length of Spike per Plant
MC	Moisture Content
MoA	Ministry of Agriculture
NET	Number of Effective Tiller
NSPS	Number of seeds per spike
NUE	Nitrogen use efficiency
OMC	Organic Matter Contents
PFP	Partial Factor Productivity
SAS	Statistical Analysis System
SNC	Straw Nitrogen Concentration
SNU	Straw Nitrogen uptake
SRL	Specific root length
TN	Total Nitrogen
TNU	Total Nitrogen uptake
TSW	Thousand Seed Weight

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ABSTRACT

Bread wheat is an important staple and cash crop grown by smallholder farmers in the highlands of Ethiopia. However, the productivity of the crop is constrained by low soil fertility and poor nitrogen (N) fertilizer management. Application of N fertilizer at the right rate and split timings is essential for the improvement of soil fertility, crop productivity and enhanced total N uptake by crops. Therefore,this experiment was conducted to assess the response of bread wheat varieties to split N application on grain yield, N concentration and uptake.A field experiment was conductedin Dedessa district, southwest Ethiopia in 2018. Factorial combinations of three bread wheat varieties (Hidase, Ogolcho and Danda'a) and three split N applications (¼ at sowing + $^1/_2$at mid-tillering + $^1/_4$at anthesis, $^1/_3$ at sowing + $^1/_3$mid-tillering + $^1/_3$ at anthesis and ½ at sowing + ½ mid-tillering,0 at anthesis) were combined. The experiment was laid out in a split plot design with three replications. Varieties were assigned on the main plots and splits N application to the subplots.Variety Ogolcho had higher value for number of effective tiller m^2(65),length of spike(9.75),number of kernel (53),harvest index(53.7%), thousand seed weight(43.55g),grain yield(3965 kgha^{-1}),partial factor productivity (2641 kg grains kg^{-1} N)and grain N uptake(67.1kgha^1). On the other hand, Danda'a variety exhibited greater values for straw yield(*5060 kg*ha^1), *total biomass yield(7715 kgha^{-1}).SplitNapplication had significant effect on the yield and yield component ofbread wheat. Split Napplication $^1/_4$ at sowing + $^1/_2$at mid-tillering + $^1/_4$ at anthesis gave the highestlength of spike (10.83cm),number of effective tiller m^2*(*65.5*), *number of kernel per plant (52.77),thousand seed weight (45.2g) and harvest index(57%), partial factor productivity (26.8 kg grains kg^{-1} N),compared to the rest ofsplit Napplication. Split N application ¼ at sowing + $^1/_2$ at mid-tillering + $^1/_4$at anthesis gave the highest grain yield, partial factor productivity and total N uptake than the rest application methods. This application method gave a yield advantage of 18.24 % over commonly practiced $^1/_2$ at sowing and $^1/_2$ at mid-tillering and 0 at anthesis,respectively. It also gave the highest grain N uptake(69.2 kgha^{-1}) and total N uptake(109.4 kgha^{-1}). This study indicates that variety Ogolcho had the highest grain yield, partial factor productivity and total N uptake than the rest varieties with split N fertilizer applications of (*$^1/_4$ at sowing + *$^1/_2$* at mid-tillering $^1/_4$ at anthesis.*It is better to do further research on split N application with different sole N rate across different soil types, years and locations to draw sound recommendation.*

Keywords: N fertilizer, Grain Yield,Partial Factor Productivityand Total N uptake.

1. INTRODUCTION

Wheat(*Triticum aestivum* L.)was among the first domesticated and most widely cultivated food crop in the World (Raza *et al*., 2014). It is a self-pollinating annual plant in the true grass family Gramineae (Poaceae), is extensively grown as major staple food sources for 30% world population (Yadav and Dhanai. 2017). It is one of the most important cereals cultivated in Ethiopia**,** andexclusively produced under rain fed conditions both in the Meher (long) andbelg (short) rainyseasons. Ethiopia is the second largest wheat producer in Sub-Saharan Africa next to South Africa (White *et al.*, 2001). Despite the large area coverage of wheat, the national average yield in Ethiopia is about 2.2 t ha^{-1} which is belowthat of Kenya, Africa and the world's average of about 2.9, 2.4 and 3.2 t ha^{-1}, respectively (FAO,2014). It is mainly grown in the highlands of Ethiopia, 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).

In Ethiopia, the productivity of wheat within the category of cereals has shown an increment from 2.3 to 2.9t/ha^{-1} over the last five years (2012/13 -2017/18) post-harvest estimates (CSA 2018), wheat productivity of the country in terms of yield per unit area of land is very low due topoor agronomic and soil management practices. Furthermore, inadequate level of technology is also among the constraints to increased wheat production in the highlands and mid-highlands of Ethiopia (Demeke and Marcantonio, 2013). To increase and sustain wheat production and to narrow down the gap between supply and demand, adoption of proper soil fertility managements is of paramount importance. For the improvement of soil fertility, uses of both chemical and organic fertilizer become very vital. Although, there is potential for further crop yield improvement, the use of chemical fertilizers has made a significant contribution to crop yield increases so far (Asnakew *et al.***,** 1991).

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). Oromia Regional State accounts for over half of national wheat production (54 %), followed by Amhara (32 %); Southern Nations, Nationalities and Peoples (9 %; and Tigray (7%) (CSA, 2013). Of the current total wheat production area of about 75 percent is located in the Arsi, Bale and Shewa wheat belts (MOA, 2017).

Nutrient balances in the highlands of Ethiopia, typically the high potential areas for agricultural production are currently exposed to severe nutrient depletion. Yet, agricultural production in this area is increasing which benefits farmer's livelihoods and contributes to food security of the country as a whole, but at the expense of the natural resource base. To maintain the current increase in food production, the trade-offs towards soil nutrient depletion need to be counter-balanced by improved soil management (Van Beek*et al*,. 2016). It was, therefore, recommended that an effective strategy to increase the productive capacity of land in the studied areas include targeted soil and water conservation measures and improved integration of organic matter management with mineral fertilizer application, such as Nitrogen, which is the most essential plant nutrient (Van Beek et al,. 2016).

Nitrogen (N) is major and expensive macro nutrient constraint limiting wheat production in Ethiopian highlands (Legesseand Sakatu, 2017). Nitrogen availability influences the uptake, not only of itself, but also other nutrients (Onasanya*et al*., 2009). This is partly attributed to better plant growth by which N-fertilized plants have larger root systems for the capture of other nutrients (Masaka, 2006).It is key factor in achieving optimum and economic grain yield of wheat. Early season N application results in accumulation of dry matter by enhanced tiller number and larger photosynthetic surface (Legesseand Sakatu, 2017). Late application of N at or after the emergence of flag leaf do not increase the leaf area but increase N contents of vegetative parts and prolongation of leaf area duration is the major cause for the increase in yield (Pearman *et al*., 1979). Increasing N supply to a crop drives the production of greater canopy biomass with the potential for higher photosynthesis and productivity. Availability of N has positive impacts throughout the crop development affecting seedling establishment, tillering, number grains per spike, canopy development and grain filling (Hawkesford, 2014).

The response of wheat to N fertilizer is influenced by different factors: soil management, N fertilizer management and timing of application, soil properties, crop sequence, seasonaltrends and the supply of residual and mineralized N (Luigi *et al.*, 2018). Excess N application rate leads to acidity and susceptibility to other biotic and abiotic factors.

Therefore, application of N fertilizer at the right rate and splitting application time is essential for the improvement of soil fertility and crop productivity (Przulj and Momcilovic, 2001). The blanket recommendation rate for DAP fertilizers is 150 kgha^{-1}and Urea is 100-150 kg ha^{-1} for wheat. However, the rates are varied as per the agro-ecological areas of the country and farmers apply below the recommended rate(Hirel *et al.,*2007). However, in Southwest Ethiopia and around the study area mono cropping on cereal such as in wheat was the main cause for soil fertility depletion especially mobile nutrients like Nitrogen which requires immediate study or solution. The practice of N fertilizer being used in the study area is 46 kg N ha^{-1}which is very low to recover the removed nutrients, Dedesa Agriculture office (2018).

Farmers are usually challenged to decide regardingsplitapplicationof fertilizer. In N management, the splittiming of its application is more important than the optimum applicationrate. N requirements in wheat prior to tillering are low, usually not exceeding 10% of the total application (Alcoz *et al*., 1993). Decisions on the timing and splitting of N application must take into account the potential influence of run-off and leaching losses of N in high rainfall areas and the critical need for N between tillering and stem elongation growth stages. Therefore, splitting of N fertilizer application has been suggested as a strategy to improve N use efficiency in cereal such as wheat (Lopex-Belido *et al*., 2015) and rice (Merkeb and Amsalu. 2018).

Splitting of N application has an important role in optimizing fertilizer N use, achieving acceptable grain yield, and maintaining adequate grain protein (Kanampiu,. 1997) and economical and appropriatemethod of application needs to be determined to enhance productivity and profit of the growers under given situation (Manzoor *et al.,* 2006). However, with respect to the effect of a further splitting of this N rate (69kg Nha^{-1}) in several applications including a late N amendment, very different results have been described regarding grain yield and quality (Fuertes-Mendizábal *et al*., 2010). Haile *et al*. (2012) and Yohannes (2014) pointed out that there was a significantly higher grain yield, N utilization efficiency and N use efficiency for grain yield when N was applied ¼ at sowing, ½ at mid-tillering, and ¼ at anthesis. Furthermore, variability on grain yield and protein can also be attributed to differences to cultivar genetic potential and to crop management (Ladha *et al*. 2005) and plant interactions with environmental variables (Baligar *et al*. 2001). Optimum and efficient time of N application can increase the recovery of applied N up to 58-70% and hence increase yield and grain quality of a crop according to Hailu *et al*. (2012).

In southwest highlands of Ethiopia, wheat is grown during the highrain-fall season and losses of applied N through leaching may be decreased through proper splitting timing of Napplication. However little has been studied on split of N fertilizer application on wheat grown in high rainfall environments such as Dedessa district**.** Moreover, there was a need tostudy the role of N fertilizer in study area and more information was required onthe response of bread wheat variety to different split Nfertilizer applications.

Hence, this study was designed to with objectives of :

1.1 General Objectives

- To examine the response of bread wheat varieties to different split N application in Dedessa district.

1.1.2 Specific Objectives

- To determine the right splitting of N application on bread wheat varieties for better growth and grain yield in Dedessa district.
- To determine the total N uptake of bread wheat varieties under different splits of N application in Dedessa district.
- To evaluate the partial factor productivity of wheat varieties under different splits of N application in Dedessa district.

2. LITERATURE REVIEW

2.1.Importance of Bread Wheat

Wheat is the most important food crop for one third of world's population. Archeological evidences show that wheat at Neolithic sites in northern Mesopotamia (Iraq) and central and North Eastern Europe dated back 6750 BC to 7500 BC (Rao and Pandey., 2007). The origin of Modern Wheat is Karacadag mountain region which is currently south eastern Turkey (Hrist, 2012). Currently, wheat is a crop with 25,000 cultivars cultivated across world landscape. The two common species of wheat are bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum turgidum* L.), and 95% of consumed wheat is bread wheat (Hrist, 2012). Ethiopia is one of the centers of diversity of wheat. Both bread and durum wheat are produced in the country, but bread wheat is the major crop varieties grown in Ethiopia though farmers grow both varieties mixed together (Grain and Feed Annual Report, 2013).It has great nutritional value and contains starch (60-90%), protein (11-16.5%), fat (1.5-2%), inorganic ions (1.2-2%) and vitamins (Anonymous, 2012).

Wheat is one of the major cereal crops mainly used as human food. It supplies about 20% of food calories for world population. In Ethiopia, wheat is used for preparation of bread, biscuits, and pasta products such as macaroni, spaghetti, and noodles that are some of the industrial products. Traditionally, wheat is used for making of local food recipes such as '*dabo', 'dabo kolo', 'ganfo', 'kinche'*, and other types of local beverages like '*tella* '. The byproducts of wheat are useful for livestock and poultry feed. The straw may be used for newsprint, paperboard and other products (Gibson and Benson, 2002).

2.2. Nitrogen Application and Bread Wheat Production in Ethiopia

Nitrogen(N) is frequently the most deficient of all the plant nutrients in Ethiopia.Wheat is very sensitive to deficient nitrogen and very responsive to nitrogen fertilization.Varietybased fertilizerrecommendation is unusual in Ethiopia. DAP and Urea is the only fertilizers applied to all soil types in the country for soil fertility management. The blanket recommendation rate for DAP fertilizers is 150 kg ha^{-1}and Urea is 100-150 kg per ha^{-1} for wheat. However, the rates are varied as per agro ecological areas of the country and farmers apply below the recommended rate(Hirel *et al.*, 2007**)**. On the other hand, in southwest Ethiopia and around the study area mono cropping practice was the main cause for soil fertility depletion especially mobile nutrients like Nitrogen which requires immediate study or solution,. Dedessa woreda Agriculture (2018). The practice of N fertilizer being used in the study area is 46 kg N ha^{-1}which is very low to recover the removed nutrients (MOA2017).

Bread Wheat(*Triticum aestivum* L.)is the most cultivated cereal crop in the world and the quantity produced is more than that of any other crop, feeding about 40% of the world population. It was cultivated on an area of 7.0 million hectares during 2011/2012 with a production of 13.8 million tons (FAOSTAT, 2012). In 2017/18 Meher season, about 4.2 million farmers grew wheat, and more than1.697 million hectares of land were dedicated to wheat cultivation, constituting 13.38 % of the national grain area (CSA, 2018). Wheat production during 2017/18 Meher season was 4.64 million metric tons, accounting for 15.17 % of the total grain output in the country (CSA, 2018).

2.4. Response of Bread Wheat to N Fertilizer

2.4.1 Wheat growth response

Enhancing agricultural productivity is one of the central challenges to achieving food security and poverty reduction in Ethiopia (Birhan*et al.,* 2017). Considering the fact that soil fertility is one of the biggest challenges, an obvious strategy is to increase fertilizer application and promote good agronomic practices to enhance productivity (Birhan*et al.,* 2017). Nitrogen is important in crop production because it is an essential nutrient for plant growth. Wheat, like all living things, requires nitrogen and it is used at every growth stage because the plant is continually growing and producing new cells. Nitrogen is not used at a constant rate, though, as certain growth stages require more of it than others. The peak demand for nitrogen in wheat occurs just after anthesis when grain filling begins and stops around the soft dough stage (Daigger *et al.,* 1976).

Dry plant material contains about 1 to 4% N and N is an indispensable elementaryconstituent of numerous organic compounds of general importance such as amino acids,proteins, nucleic acids (Mengel and Kirkby,. 1996). It is involved in all major processes of plant development and yield formation. Besides, a good supply of nitrogen to the plantstimulates root growth and development as well as uptake of other nutrients (Brady and Weil, 2002). In green plant material, protein N is by far the largest N fraction andamounts about 80 to 85% of the total nitrogen. The nitrogen of nucleic acid and that ofsoluble amino N are about 10 and 5%, respectively, of the total N present in plant material.Nitrogen is also essential constituent of various coenzymes. The protein content of vegetativeplant organs as well as storage tissue may also be influenced by N supply (Mengel andKirkby, 1996). Nitrogen supply is related to carbohydrate utilization. When N supplies areinsufficient, carbohydrates will be deposited in vegetative cells, causing them to thicken,whereas under adequate N supplies and favorable growth conditions, proteins are formedfrom manufactured carbohydrates resulting in more protoplasm (Tisdale *et al*., 1993).

2.4.2 Yield and yield attribute

Availability of N has impacts throughout the crop development affecting seedling establishment, number of tillering, number grains per spike, canopy development and grain filling (Ali *et al*., 2000; Hawkesford, 2014). N availability influences the uptake, not only of itself, but also secondary nutrients (Abbas *et al*., 2011). Therefore, it is very crucial to apply N fertilizer to boost wheat grain yield and protein content in Ethiopia. Several investigators reported a beneficial effect of nitrogen application on wheatSobh, *et al* (2000). They reported that numbers of tillers and spikes/m^2, plant height, spike length, number of spikes lets and grains/spike, grain and straw yields of wheat increased with increasing N to optimum level. The interest in maximizing wheat yields has encouraged growers to adopt intensive management practices. It should be noted that both an optimized nitrogen management for a less responsive variety and a restrictive management for a more demanding variety may result in crops with little yield potential. High nutrient levels can also harm crops by making wheat plants more vulnerable to lodging, causing both damages to the environment through leaching and nitrate volatilization and economic losses to farmers (Rileyr, *et al* 2001), because only 33% of all nitrogen fertilizers applied to cereal crops are absorbed in harvested grains RaunandJohnson (1999). Therefore, N management is essential for economic yield, optimum nutrient utilization and to minimum pollution of the environment (Corbeels*et al*., 1999).

2.4.2.1Grain yield

Modern production agriculture requires efficient, sustainable, and environmentally sound management practicesBirhan*et al*, (2017). Under these situations, increasing crop yields per unit area through use of appropriate N management practices has become an essential component of modern crop production technology (Fageria and Barbosa Filho, 2001). Adoption of proper management strategies of N fertilizer may balance the supply of N required for optimum crop production while minimizing potential losses into the environment (Fageria *et al*., 2003a).

Nitrogen is major and expensive macro nutrient constraint limiting wheat production inEthiopian highlands (Tanner *et al.,* 1993). It is key factor in achieving optimum and economic grain yield ofwheat. Early season N application results in accumulation of dry matter by enhanced tiller number and largerphotosynthetic surface (Morgan 1988). Late application of N at or after the emergence of flag leaf do notincrease the leaf area but increase N contents of vegetative parts and prolongation of leaf area duration is themajor cause for the increase in yield (Pearman *et al.,* 1979).

Proper N application timing and rates are critical for meeting crop needs, and indicate considerable opportunities for improving N use efficiency (NUE) (Blankenau *et al.*, 2002). Growth stage of plants at the time of application determines NUE. Reports have shown that split N application in the later stages was effective in attaining higher N uptake efficiency (Kumari *et al.,* 2000). With regard to time of application, application ofnitrogen in three split doses of 1/4 at sowing, ½ at tillering,and the remaining 1/4 at anthesis increased the grain yieldby 9.2% in 2013 and by 9.5% in 2014 as compared to theapplication of nitrogen fertilizer in two equal doses of ½at sowing and the other ½ at tillering. The increases in thetotal aboveground biomass yield for the aforementionedapplication time were 8.9% in 2013 and 6% in 2014(Zemichael*et al.*, 2017).The increase in the magnitude of both yields might beattributed to enhanced synchronization of the demandof the plant for uptake of the nutrient during the active tillering growth period, resulting in higher photosynthesis and in turn, in higher assimilate production for grain filling. Similarly, Fageria and Prabhu (2004) reported that split application of nitrogen reduces the chance of N losses due to leaching, denitrification, and runoff.

2.4.2.2 Dry matter and straw yield

Aboveground biomass yield is an important factor because farmers are also interested in straw in addition to grain yield (Legese and Sakatu, 2017).Information on dry matter production and partitioning between various plant parts is important in the development of crop growth models (Sheng and Hunt, 1991). In addition, the value of the agricultural experiments could be enhanced significantly if information on dry matter production and its partitioning are available (Royo and Blanco, 1999). This information should permit better analysis and interpretation of the results and also allow one a better understanding of processes and resource exploitation for crop production (Williams *et al.,* 1996).

Increasing dry matter is attributed 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).Results of several studies have shown that application of N tends to increase the biomass ofdifferent crops. Zia *et al*. (1992) reported 40% increase in biomass of rice with the application of 80 to 150 kg N/ha. Ghoshal and Singh (1995) also reported similar results showing greaterresponse of rice biomass to N fertilizer.

2.4.2.3. Harvest index

Harvest index represents the ratio of the dry matter of harvested part of crop (grain yield) to the total dry matter production (Marschener, 1995). Tanaka (1994) indicated that harvest indexin wheat is closely related to the percentage of productive tillers and generally decreased withincrease of N application. An increase in N application favors huge vegetative growth andthereby results in lower percent of productive tillers, spike number and finally lower harvestindex (Tanaka, 1994).

Such a decreasing trend of harvest index with increased rate of N application has beenconfirmed by several studies (Hari*et al.,* 1997).However, with moderate doses of N application increment of harvest index can be achieved also reported an increasingtrend of harvest index to a certain level of N and a decreasing one with further increase in itsrate of application(Behera 1998).

2.4.2.1.4 Partial factor productivity

Adoption of inefficient N management practices is responsible for low partial factorproductivity. Partial factor productivity (PFP) is a useful measure of nutrient use efficiency as it provides an integrative index thatquantifies total economic output relative to the utilization of all nutrient resources in the system(Yadav, 2003). Decline in partial productivity for N has been reported in cereal based systemleading to higher investment in N to maintain higher yields. Decline in partial factor productivityfor N may be attributed to nutrient imbalance, decline in indigenous soil N supply, subsoilcompaction, reduced root volume and increased incidence of pests and diseases (Karim andRamasamy, 2000).

According to Cassman*et al*. (1996), PFP can be increased by increasing theamount, uptake and utilization of indigenous nutrients, and by increasing the efficiency withwhich applied nutrients are taken up by the crop and utilized to produce grain. Application of aunit fertilizer is economical, if the value of the increase in the crop yield due to the quantity offertilizer added is greater than the cost of fertilizer used. If a unit of fertilizer does not increasethe yield enough to pay for its cost, its application will not be economical and will not returnprofit even after a constant increase in the yield (Singh, 2004). The application of essential plantnutrients in optimum quantity and right proportion, through correct method and time ofapplication, is the key to increased and sustained crop production (Cisse and Amar, 2000).

2.5. Soil Conditions and N Availability

Nitrogen is one of the most widely distributed elements in nature and atmosphere is the main reservoir. The soil accounts for only a minute fraction of lithospheric N and of this soil N, only a very small proportion is directly available to plants, in the form of NO_3^- and NH_4^+ ions. Nitrogen is a very mobile element circulating between the atmosphere, the soil and living organisms (Mengel and Kirkby, 1996). Inorganic N exists in the form of NH_4+, NO_3^-, NO_2^-, N_20, NO and elemental nitrogen (N_2), while the organic form includes protein, amino acids, amino sugars and other NO_3^- and NO_2^- are produced from aerobic decomposition of OM or addition of fertilizers to the soil and are the most important in plant nutrition. Gaseous N_2, N_2O and NO are forms of N lost through denitrification, (Tisdale *et al.*, 1993).

Nitrogen is a unique plant nutrient, since plants absorb N as both NH_4^+ and NO_3^-. The age and type of plant, the environment and other factors determine preference of plants for either NH_4^+or NO_3^-. Arable crops mainly take up NO_3^- even when NH_4^+ fertilizers are in the soil. However, plant growth isimproved when the plants are nourished with both $NH_4^+$and NO_3 compared to either NH_4 +or NO_3^- alone. Wheat yields increased from7 to 47% with NH_4 + plus NO_3 compared to yields with NO_3^- alone, which was related to increased numbers of tillers and kernels per plant (Miller and Donahue, 1997).

The level of N applied to a crop depends largely on the particular crop species and prevalent soil conditions. The quantity of N taken up by a good crop over the growth period serves as a guideline in assessing the appropriate rate of N application. When the rate of inorganic N release from soil organic matter is high, lower N application rates are needed to be applied, whereas for soils low in N, the N application rate should be in excess of the total amount of N uptake (Mengel and Kirkby, 1996). Responses to N application are limited when water availability is restricted. Under arid conditions responses to N fertilizer depends largely on annual rainfall and its distributions unless irrigation is practiced. The response to N also depends on how well the crop is supplied with other nutrients. Without P and K applications, the yield response to increasing N levels was smaller than when adequate amounts of P and K were applied (Mengel and Kirkby, 1996). According to Ramsom (1983), possible negative effect of N maybe due to toxic levels of nitrite, which is converted from nitrate during denitrification under anaerobic conditions. This is caused by frequent rains early in the season that keep the surface of the soil wet for several weeks after, sealing it and reducing the movement of O_2 into the soil. However, nitrite does not accumulate longer in the soil since it is readily oxidized by Nitrobacter (Mengel and Kirkby, 1996).

Management practices such as large amount of soil disturbance accelerate losses of carbon and promote net N mineralization. In field situations, tillage influences soil moisture, soil temperature, pH, substrate distribution and quality in the soil physical properties. This tillage influenced soil physical properties may affect mineralization of nutrients from soil organic matter (Tracy *et al.,* 1990). Nitrate moves to the plant root more easily with the flow of soil water and exchange to the surface with $HCO3^-$ or OH- ions increasing the pH of the soil solution of rhisophere. In contrast, $NH4^+$ exchanges with H+ and thus lowering the pH of rhisophere soil solution; this change in pH influences the uptake of companion ions like phosphate (Brady and Weil, 2002).

2.6. Nitrogen Management for High Yield of Wheat

Management of nutrients is an important aspect for improving crop productivity. Nutrient management in crop production means, supplying essential plant nutrients to a crop inadequate amount and form toget maximum economic yield in a given agro-ecological regionDereje**,**(2018).Nutrientmanagement strategies should vary according to type of soil, climatic conditions, crop species, cultivar within species, and socioeconomic considerations (Fageria, 2009).Both the fertilizer form and the waythat N fertilizer is applied influence the possibility of nitrate leaching through the soil profile.Thethree most commonly used forms of N are urea, ammonium and nitrate. These differ in their mobility, transformation, and volatilization characteristics, and in the manner in which they are taken up by plants.

Ammonical forms are less prone to leaching. Aqua ammonia and Diammonium phosphate were the least mobile, with 93 and 73 %, respectively, being retained in the surface 4inches of soil. The ammonium ion is held on the soil’s cation exchange sites and thus is resistant to leaching (Green, 1981). Urea and nitrate, on the other hand, are readily leached immediately after application because they are not held on cation exchange sites. Nitrogen fertilizers can be applied by hand, tractor, or airplane, or in irrigation water. Because ammonium fertilizers are not readily mobile in soil, they should be placed near the plant roots. Urea and nitrate fertilizers, on the other hand, move readily in soil, and there is less restriction on where they are applied as long as they are in proximity to the plants. When N fertilizers are applied in solution via drip irrigation systems, the fertilizer is deposited near the drip orifices. However, with urea and nitrate fertilizers, continued irrigation after fertilizer application can result in leaching the nutrients beyond the root zone. Therefore, these fertilizers should be injected into a drip system toward the end of an irrigation to minimize the possibility of leaching beyond the roots. Sufficient time should be allowed before the next irrigation to allow the urea to be converted to ammonium, which will resist leaching. Slow-release N fertilizers such as sulfurcoated urea also can minimize the possibility of nitrate leaching beyond the root zone(Green, 1981).

Nitrogen applications should be made when crop demand is highest early in the crop cycle when the crop is growing rapidly. As the crop starts to mature, growth is reduced and the demand for N decreases. Little if any N should be applied after maximum growth of the crop has been attained. The quantity of N applied at any one time should match the crop's requirement at that stage of growth. It is generally better to apply several small quantities of N than a few large doses of N. Application of quantities of N in excess of plant needs will result in loss by volatilization and leaching and can harm the environment (Silva *et al.***,** 2000).

2.7 Optimizing Nitrogen Use Efficiency

A recent review of worldwide data on N use efficiency for cereal crops from researcher managed experimental plots reported that single-year fertilizer N recovery efficiencies averaged 65% for corn, 57% for wheat, and 46% for rice. However, experimental plots do not accurately reflect the efficiencies obtainable on-farm. Differences in the scale of farming operations and management practices (i.e. tillage, seeding, weed and pest control, irrigation, harvesting) usually result in lower nutrient use efficiency. Nitrogen recovery in crops grown by farmers rarely exceeds 50% and is often much lower. A review of best available information suggests average N recovery efficiency for fields managed by farmers' ranges from about 20% to 30% under rain fed conditions and 30% to 40% under irrigated conditions (Ladha *et al*., 2005).

Many regions of the world, particularly Africa, are in urgent need of greater nutrient inputs to support food production. The proper use of these increased nutrients would not only increase the regional food supplies but would also improve soil characteristics and, therefore, lead to less soil loss from erosion. Several nutrient replenishment strategies have been or are being developed in sub-Saharan Africa. The best strategy for nutrient replenishments will depend on the soil, climate, agro-ecosystem, socio economic conditions, and policy environment. Most of these nutrient replenishment strategies entail a combination of mineral and organic inputs, with the exact mix determined in part by socioeconomic conditions as well as the realization that organic materials cannot, in general, supply sufficient N to meet crop demand (Palm *et* *al.,* 1997). Though N is the primary limiting nutrient in most soils of sub-Saharan Africa, once the N is replenished, P quickly becomes limiting to crop production (Bationo *et al*., 1986). Numerous concepts and tools needed to increase NUE have been developed. These technologies can be divided into (1) those that enhance crop N demand and uptake (genetic improvements, management factors that remove restrictions on crop growth and N demand and management options that influence the availability of soil and fertilizer-N for plant uptake. It is important to understand; however, that many of the technology options have different effects on crop yield response to N and that it is often the combination of measures that leads to the greatest benefit (Giller *et al.*, 2004).

2.7.1 Nitrogen uptake

Plant roots take up N mainly in the form of nitrate (NO3 -) and ammonium (NH4 +), but also organic N in the form of amino acids. Since the roots are responsible for N-uptake, root morphology could affect the N status of the plant (Maathuis, 2009). The root system is important for access to nutrients such as N and to water (Wasson *et al.*, 2012). Specific root length (SRL) is a measure of the length of root produced from one unit of biomass. Specific root length has been found to be correlated with N uptake, *i.e.* comparing nine different species of trees (Reich *et al.*, 1998).

Early vigor is a term used to describe the growth of cereal seedlings, *e.g.* wheat, that have more vigorous early growth. It has been measured in different ways in previous studies, *e.g.* as seedling biomass (Liao *et al.*, 2004; Bertholdsson and Kolodinska Brantestam, 2009), leaf area development or both (Richards and Lukacs, (2002). In general, seedling root 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). Studies in barley using hydroponics have shown that decreasing seedling shoot weight due to breeding has been accompanied by decreasing root weight. Furthermore, varieties with higher seedling root weight (in hydroponics) have higher N uptake at low levels of N fertilization in the field (Bertholdsson and Kolodinska Brantestam, 2009). Wheat with early vigorous growth also had more vigorous roots and took up more N in pot experiments than less vigorous lines (Liao *et al.*, 2004). The same line also produced greater shoot and root biomass in unploughed soil than a conventional cultivar. This suggests that early vigor might be beneficial for N uptake and, ultimately, grain biomass and grain (Watt *et al.*, 2005).Nitrogen accumulates in the wheat plant with generally higher accumulation rates during the major growth period than during grain filling (Baresel *et al.*, 2008). Since uptake occurs in the root, it would be interesting to study the roots in later growth stages. That is difficult for practical reasons, but there are some data available.

2.7.2 Time of N application

Crop responses to nitrogen and plant use efficiency of nitrogen vary with rate and timing of N application in relation to plant development, cultivar and climatic conditions (Masaka 2006). Split-application of N resulted in superior quality attributes than when the entire N was applied at once (Ooro *et al*. 2011). According to Shanahan *et al*. (2008) the application of total N before or at sowing results in fewer kernels per ear, ears per area and reduced grain yield due to poor synchrony. However, the use of appropriate rates, efficient timing and placement of nitrogen could increase recovery of applied nitrogen up to 70 or to 80% (Legg and Meisinger 1982).

Asnakew *et al*. (1991) found that application of 50 % of the total N dose at sowing and the rest at full tillering stage significantly increased grain yield as well as protein content of wheat. Mugendi *et al*. (2000) stated that two thirds of nitrogen fertilizer applied as basal and rest and one-third applied as top dressing at crown root initiation stage gave better grain yield and N use efficiency. Tilahun *et al*. (2008) concluded that split application of N, one third rate at planting and the remaining two third at mid-tillering, provided optimum wheat yield. Haile *et al*. (2012) and Yohannes (2014) pointed out that there was a significantly higher grain yield, N utilization efficiency and N use efficiency for grain yield when N was applied ¼ at sowing, 1/2 at mid-tillering, and 1/4 at anthesis. Furthermore, variability on grain yield and protein can also be attributed to differences to cultivar genetic potential and to crop management (Ladha *et al*. 2005) and plant interactions with environmental variables (Baligar *et al*. 2001).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted inDedessa woreda during the 2018 cropping season.Administratively, Dedessa woreda located in Buno Bedele zone at a distance of about 60 km from Bedele town, 80 km North of Jimma town and 430 km away from Addis Ababa. It is bounded by Gatira woreda in the west, Gechi woreda in the North and Gumay woreda in the South and Goma woreda in the East. The dominant agricultural soils in the areas are Cambisols, Leptosols, Vertisols and Nitisols covering 32.9%, 24.5%, 20.6% and 17.1% respectively (Alemayehu, 2015).

The experiment was conducted at Yembero,kebeleFTC.The elevation of the experimental site was 2200 m.a.s.l.The kebele islocated at $08^0$10,0336’N and $036^0$27, 594’E and the soil of the site is classified as Nitisols.The rainy season starting in late March and ending in October and the dry season occurring during November to early March.

3.2. Experimental Materials

Three bread wheat varieties namely Ogolcho, Danda’a, andHidase were obtained fromKulumsa Agricultural Research Center (KARC). The varieties were selected for theiradaptability and high yield in the area(MOA 2012).

Table 1.Description of Bread Wheat Varieties

No	Name of Varieties	Year of release	Maturity days	R.fall (mm)	Altitude (m.a.s.l)	Agro-ecology	Yield per ton ha^{-1}on		Released by
							station	farm	
1	Denda’a (Danphe#1)	2010	110-145	>600	2000-2600	Mid altitude-highlands	3.5-5.5	2.5-5	KARC
2	Ogolcho (ETBW552	2012	102-133	400-500	1700-2300	Low land-Mid-altitude	2.8-4	2.2-4.5	KARC
3	Hidase (ETBW579	2012	121	500-800	2100-2600	Mid-altitude-highlands	4.4-7	3.5-6	KARC

KARC=Kulumsa Agricultural Center. Source: MoA, Crop Variety Registered (1995-2013)

3.3. Treatments and Experimental Design

The treatments werecomprising three bread wheat varieties (Danda’a, Ogolcho and Hidase) and three splitting of N applications (at sowing, tillering and anthesis stage).The experiment was arranged in factorial split plot design with 3 replications and consisting of nine treatment combinations (3×3). Each main plot had a gross plot size of 10.5 × 3 m and each sub-plot had a gross plot size of 3 m × 3 m (9 m^2) with spacing between block and within plot of 1 meter and 0.5 meter. The three bread wheat varieties were assigned to the main plots and the three splitting of N fertilizer to sub-plots. The recommended N fertilizer 69 kg ha^{-1} (150 kg ha $^{-1}$ urea) (MoA, 2016) issplited into three in varying stage of growth.

Table 2. Treatment combination and discription.

	Wheat Varieties	Sowing (kg N ha^{-1})	Tillaring (kg N ha^{-1})	Anthesis (kg N ha^{-1})	Total Kg (kg N ha^{-1})
1	OGOLCHO	1/4 (17.25)	1/2 (34.5)	1/4 (17.25)	69 kg N ha^{-1}
		1/3 (23)	1/3 (23)	1/3 (23)	69 kg N ha^{-1}
		1/2 (34.5)	1/2 (34.5)	0	69 kg N ha^{-1}
2	DANDA’A	1/4 (17.25)	1/2 (34.5)	1/4 (17.25)	69 kg N ha^{-1}
		1/3 (23)	1/3 (23)	1/3 (23)	69 kg N ha^{-1}
		1/2 (34.5)	1/2 (34.5)	0	69 kg N ha^{-1}
3	HIDASE	1/4 17.25)	1/2 (34.5)	1/4 (17.25)	69 kg N ha^{-1}
		1/3 (23)	1/3 (23)	1/3 (23)	69 kg N ha^{-1}
		1/2 (34.5)	1/2 (34.5)	0	69 kg N ha^{-1}

3.4. Experimental Procedures

The field of this experiment was ploughed by oxen to a depth of 10-15 cm to get a fine seed bed and leveled manually before the field layout was made. Fine seed bed was prepared according to the design and the field layout was made. Each treatmentswereassigned randomly to the experimental units within a main and sub plotThe seeds weresown 0.2 m space between rows and drilling techniques at the seed rate of 150 kg ha^{-1} (MOA, 2012). There wasa total of 15 rows per each sub plot (there were five plants and nine rows were used for sampling). Nitrogen fertilizer (urea) was added by splitting at different stage at sowing, tillering and anthesis. Sowing time was in August 2018. Uniform agronomic management practices (cultivation, weeding and other pest and disease management) activities was applied to all plots as per recommended.Phosphorus fertilizer at the recommended rate of 46P_2O_5 kg

ha^{-1} in the form of TSP was applied during sowing to allthe plots uniformly to minimize the crop phosphorusdeficiency every year.

3.5 Data Collection

3.5.1. Soil sampling and analysis

Soil sample werecollected prior to sowing and after harvest from the upper 0.30m of the experimental area in a zigzag manner to collect a representative soil sampleusing Auger. The sample was air-dried, ground using a pestle and a mortar and was allowed to pass through a 2mm sieve. The sample was analyzed at Jimma University (JUCAVM) soil laboratory for selected physico-chemical properties, namely soil pH,organic carbon, total nitrogen (TN %), available phosphorus (P), cations exchange capacity (CEC) and textural class analysis.

Soil organic carbon was determined using Walkley and Black method (Walkley and Black, 1934). The total N were analyzed by using a Kjeldahl method by oxidizing the OM in 0.1 N H_2SO_4 as described by Black (1965). The soil pH was measured using the in suspension of 1:2.5 soils to water ratio using pH meter. Cation exchange capacity was determined at soil pH 7 after displacement by using 1N ammonium acetate method, then, estimated titrimetrically by distillation of ammonium that was displaced by sodium (Gaskin *et al.*, 2008). The available phosphorus was determined by Bray 2 method (Bray and Qurtz, 1945). The particle size distribution (texture), of the soil sample, was determined by the Boycouos hydrometric method (Van Reeuwijk, 1992).

3.5.1.1.Physico-chemical properties of soils of the experimental site

The pre sowing result showed that the soil at the trial site was clay with bulk density of 1.36 gm/cm^{-3}. Moreover, it had a 5.18 pH value, 5.96% organic matter, CEC (24.9 (cmol), 0.24% total nitrogen and 8.09 mg $kg-^{1}$ available phosphorus (Table 1). According to Tekalign (1991) rating, organic matter content of soil is very low (<0.86%), low (0.86 to 2.59), medium (2.59 to 5.17), high (>5.17), and very high (not given). Total Nitrogen (TN %) is rated by Havlin *et al*. (1999) as very low (<0.1), low (0.1 to 0.15), medium (0.15 to 0.25), and high (> 0.25). According to Olsen *et al*. (1954) rating, P (mg kg-1) content is: (< 3) very low, (4 to 7) low, (8 to 11) medium, (>11) high. Then organic matter content, total nitrogen and available P at the site were within medium, medium and high range respectively. Azlan*et al.* (2012)

reported that soil texture influences the rate of soil organic matter (SOM) decomposition. Soils with high clay content may have higher SOM content, due to slower decomposition of organic matter. Though the values for some of the physico-chemical properties were in the optimum range for the crop growth, appropriate agronomic and soil management practices are mandatory for better yield and productivity.

Table 3: Initial physico- chemical properties of the surface soil

SN	Soil Parameters	Value	Rating	Reference
1	pH	5.18	Strong Acidic	Hazelton & Murphy (2007)
2	OC (%)	3.46	Medium	Hazelton & Murphy (2007)
3	OM (%)	5.96	Medium	FAO2006
4	TN (%)	0.24	Medium	Bruce & Rayment (1982)
5	CEC	24.9	Very High	FAO2006
6	Ava. P(ppm)	8.09	Medium	FAO2006
7	Textureclass	Clay	-	-
	Sand	20.8	-	
	Clay	50.4	-	
	Silt	28.4	-	

Where, pH = hydrogen power, % OC = percent of organic carbon, %TN = percent of totalnitrogen, CEC = Cation exchange capacity Ava.P.ppm = available phosphorus parts per million.

3.5.2. Crop Phenology

Days to 50% heading: numbers of days from date of sowing to the stage where 50% of the spikes have fully emerged were recorded.

Days to 75% physiological maturity: Days to physiological maturity was recorded as the number of days from emergence to the time when 75% of the plants showed yellow color and their spikelet into yellow in each net plot before senescence.

3.5.3. Growth parameters

Number Effective Tiller (NET): The number of effective (fertile) tillers bearing spikes was randomly selected from 0.5m x 0.5m ($0.25m^2$) was counted by using quadrant from each net plot at physiological maturity.

Plant height: It was measured by centimeters from the ground level to the tip of the main stem at physiological maturity from ten randomly selected plants from each plot excluding owns.

3.5.5. Yield and yield components

Spike length (cm): The main spikes from ten sample spikes were measured in (cm) and the average represents the spike length in cm for each plot across the treatment level.

Number of Seed per spike (NKPS):it was taken from ten randomly selected spikes per net plot at harvestthen threshed andaveraged per plant basis.

Thousandkernelweight (g): Thousand kernel weight was determined as the weight of 1000 seeds sampled from the harvested plot area using a sensitive balance.

Total Biomass (kg ha^{-1}): The aboveground biomass was sun dried for 10-15 days and their plot weight wasrecorded and then converted to kg ha^{-1} for statistical analysis.This was followed by threshing, winnowing andrecording of grain yield plot wise.

Grain yield (kg ha^{-1}): The grain yield was measured by taking the weight of the grains from the net plot area and converted to Kg ha^{-1} after adjusting the grain moisture content to 12.5%.

$$\textbf{Adjusted grain yield (kg ha}^{-1}\textbf{)} = \frac{\textbf{Actual yield (Kg ha}-\mathbf{1})(\mathbf{100}-\mathbf{MC})}{\mathbf{100}-\mathbf{12.5}}$$

Where, MC was the measured grain moisture content; and 12.5 was the standard moisture content for cereals.

Straw yield (kg ha-^{1}): Straw yield was determined by subtracting grain yield from total above ground biomass.

Harvest index (%): Harvest index per plot were recorded as the ratio of dry grain yield to the above ground biomass yield per plot. It was calculated by using the following equation:

$(\mathrm{HI} = \frac{(\mathrm{GY})}{(\mathrm{BY})} X\ 100)$, Where, GY=Grain Yield and BY=Biological Yield

Partial Factor Productivity (PFP):

$$\textbf{PFP}\ (\text{grainkg/N kg}) = \frac{\textbf{Yield of fertilized}}{\textbf{Nitrogen applied}}$$

3.5.4. Plant tissue sampling and analysis

Five plants wererandomly selected at physiological maturity and harvested from six central rows. Plants sampled for yield components at harvest was partitioned into vegetative and grains further determination of total N concentration in grains and straw using standard procedures. The grain sampleswereoven dried at 70 ºC to a constant weight, for 48 hours ground to pass 1 mm sieve and saved for tissue and grain analysis. The percent total N concentration of the plant materials was measured following the methods of Jackson (1967) and wet digestion, respectively.

Nitrogen uptake and accumulation

Nitrogen concentration and uptake in tissues of wheat crop**:** The nitrogen contents of the grain (GN %) and straw (SN %) was determined by the micro-Kjeldahl method using grain and straw sub-samples (Croswell and Godwin, 1984.). Grain nitrogen uptake(kg ha^{-1}) was computed as grain yield multiplied by percent N content of the grain foreach plot. Straw nitrogen uptake (kg ha^{-1}) was calculated as straw yield multiplied by percent N content of thestraw in each plot. Total nitrogen uptake (kg ha^{-1}) was obtained as the sum of grain nitrogen uptake and strawnitrogen uptake.

a) N uptake of grain or straw (kg ha^{-1}) = [Yield of grain or straw (kg ha^{-1}) × N concentrationof grain or straw (%)]

b) Total N uptake = N uptake of grain + N uptake of straw

3.6 Data Analysis

All measured parameters were checked for normality and subjected to analysis of variance (ANOVA) appropriate to factorial experiment in split-plot design according to the General Linear Model (GLM) using SAS 9.3. When ANOVA showed significant differences, mean separation were carried out using LSD (Least Significant Difference) test at 5% level of significance.

4. RESULTS AND DISCUSSION

4.1. Crop Phenology

4.1.1. Days to 50% heading

Results showed that main effects of varieties had highly significant($P<0.01$) and split N applicationswas significant($P<0.05$) influences ondays to 50% heading but their interaction effect were non-significant (Appendix 1).Hidase variety (58) was 10 days earlier than that of Danda'a (68) variety. This difference could be attributed to thegenetic makeup of varieties. This result in line with Dereje (2018) who stated that significant differences were observed between bread wheat varietieswith respect to days to 50% headingwhilethe interaction effect is non-significant.

Furthermore, resultsof ANOVA also revealed that there was a significant ($P<0.05$) effect on days to 50%headingin response to split N applications. Significantly,greater(64.8) days to 50%headingwere recorded when N was applied in two splits, i.e.½ at sowing + $^{1}/_{2}$at mid-tillering and 0 at anthesis while,the minimum days to 50%heading(63.78) was noticed in ¼ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$at anthesis stage (Table 4). This implies that splitNapplicationsshowed that, enough N applications at sowing and at mid-tillering results in rapid growth of the bread wheat and heading. This result agrees with the results of Bekalu and Arega (2016) who stated that sufficient nitrogen at the right time results in rapid growth and heading.

Table 4: Days to 50% heading, Days to 75% physiological maturity as influenced by main effect of varieties and split N application

VARIETY	DH	DM
HIDASE	58.0^{c}	92.9^{c}
OGOLCHO	66.2^{b}	104.3^{b}
DANDA'A	68.6^{a}	116.6^{a}
LSD (0.05)	0.64	0.21
CV(%)	2.34	1.2
N-Splitting		
N$_1$ ($^{1}/_{4}$, $^{1}/_{2,}$$^{1}/_{4}$)	63.78^{b}	99.56^{b}
N$_2$ ($^{1}/_{3}$, $^{1}/_{3}$,$^{1}/_{3}$)	64.2^{ab}	107.1^{a}
N$_3$ ($^{1}/_{2}$, $^{1}/_{2}$, 0)	64.8^{a}	107.22^{a}
LSD (0.05)	0.88	1.095
CV (%)	1.5	1.08

DM=days to 505 heading, DM=days to75% physiological maturity. Figures in parenthesis indicate the fraction of N applied during sowing, mid-tillering and anthesis stage of the crop in their order of placement. LSD: Least significant difference, CV: Coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.1.2. Days to 75% physiological maturity

The main effects of varieties and N split applications were highly significant ($P<0.01$) and significant ($P<0.05$) on days to 75% physiological maturity(Appendix 1).Conversely, the interaction effect did not showed significant effect. Variety Hidase taken earlier to mature when compared to the rest of the varieties. Variety Hidasetook 92.8days to reach 75% of physiological maturity and it is followed by variety Ogolcho 104.3and Danda’a 116.6. Significant variation regarding days to 75% physiological maturity was observed due to the varietal difference or genetic constituents and combined effect during the growth stage of the crops (Table 4). This result is in line with the result of Dereje (2018) who reported that significant difference between bread wheat verities were observed on days to 75% physiological maturity. Moreover, Wogene and Agena (2017) reported significant difference in bread wheat variety on days to 75% physiological maturity at southern Ethiopia.

The shortest days to75% physiological maturity were recorded from N split of $^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis stage(99.56) while the longest from$^{1}/_{3}$at sowing, $^{1}/_{3}$at tillering, $^{1}/_{3}$at anthesis stage (107.1) and which is statistically similar with N split of $^{1}/_{2}$sowing, $^{1}/_{2}$mid-tillering, 0anthesis (107.2) split N application. This might be attributed to the role of N, which increases vegetative growth of crops whereby it delays maturity time and the difference in N-split application may cause the bread wheat to delay in maturity due to the N amount difference on the same rates and difference split N application. Similar result was reported by Woinshet (2007) in which N-fertilizer supply delayed maturity in malt barley.

4.2 Growth Parameter

4.2.1Number of effective tillers

The analysis of variance revealed that main effect of varieties and split N applicationshad highly significant($P<0.01$) effect on number of effective tillers. On the other hand, the interaction of varieties and split N applicationshadnon-significant effect (Appendix 1) effect. Corresponding to this growth parameter, varietyOgolcho(65) had better performance on number of effective tillers while, varietyHidase (54) was the least performed; this is due to the genetic make-up of the varieties Table 5).This result is consistent with finding of Biruk and Demelash(2016) number of fertile tillers highly significantly affected by the difference between barley varieties.

Results of ANOVA also revealed that number of effective tillerscount at physiological maturity wasinfluenced by splitN applications**.** Significantly,more numbers of effective tillers (63) were recorded when N was applied in three splits, i.e. ¼ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis stage while minimum number of effective tillers (58) was noted in $^{1}/_{2}$at sowing + $^{1}/_{2}$at mid-tillering treatment 0 at anthesis (Table5).More applicationsN at sowing may have resulted inleaching or volatilization of the nutrient that subsequently resulted in significantly lower number of effectivetillers though,split N applications at sowing and tillering stage also lead to have lower number effective tillers, this is due to the volatility and leaching nature of N fertilizer. Applications of nutrients beyond the requirements of the crops leads to lose of nutrients. Thereason for the increased number of effectivetillers in plots receiving split Napplications of ¼ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis stagemay be due to sufficientavailability of N during tillering and anthesis stage. This might be due to the effect of N split on the critical need of nutrient of the crop cause in promoting andflourishing green vegetative growth and effectivetiller. As a result, greater number of effectivetillers by using split N application of $^{1}/_{4}$at sowing + $^{1}/_{2}$mid-tillering and$^{1}/_{4}$ at anthesis is recommended for the experimental area and similar agro ecology.

Less number of effective tillers with the applications of N in the three split applications of $^{1}/_{3}$at sowing, $^{1}/_{3}$at tillering,$^{1}/_{3}$at anthesis and in two split applicationsof $^{1}/_{2}$at sowing, $^{1}/_{2}$at tillering and 0 at anthesis ,as opposed to $^{1}/_{4}$at sowing, $^{1}/_{2}$ at tillering, and the remaining $^{1}/_{4}$at anthesis might be attributed to higher amount of N applications during sowing but not taken up by the plant (Table 5).The results of this study clearly suggests that shifting away from some portion of N applications at sowing and applying more of the N at mid-tillering and some proportion at anthesis stages in the season has better for improving tillers. This result is agreed with the finding of Beyenesh*et al.* (2017) who stated that N split applications on bread wheat varieties in response of $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$at anthesis stagehad better when compared to $^{1}/_{3}$at sowing, $^{1}/_{3}$at tillering, and $^{1}/_{3}$at anthesis, and $^{1}/_{2}$at sowing and $^{1}/_{2}$at tillering 0 at anthesis.

Table 5. Number of Effective Tillers and Plant height as influenced by main effect of varieties and split N applications

VARIETY	NET ($0.25m^2$)	PH (cm)
HIDASE	54.5^{c}	74.8^{c}
OGOLCHO	65.1^{a}	79.5^{b}
DANDA'A	63^{b}	86.6^{a}
LSD (0.05)	0.81	0.07
CV (%)	1.5	2.7
N-Splitting		

N_1 ($^1/_4$, $^1/_2$,$^1/_4$)	65.5^a	78.79^c
N_2 ($^1/_3$, $^1/_3$,$^1/_3$)	60.4^b	79.8^b
N_3 ($^1/_2$, $^1/_2$, 0)	58.8^c	83.16^a
LSD (0.05)	0.95	0.64
CV (%)	1.125	0.56

NET=Number of Effective Tillers and PH=Plant height.LSD: Least significant difference, CV: Coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.2.2. Plant height

Results of ANOVA for plant height measured at physiological maturity showed plant height hadhighly and significantly($P<0.01$) affected by main effectsvarieties and split N applications(Appendix 1). Conversely, the interaction effects were non-significant. VarietyDanda'a(86.6cm) had taller plant height thanOgolcho (79.5cm) andHidase (74.8 cm) respectively. Plant height is an important growth-related parameterit might be due to a genetic character that was influenced least by environmental factors such as nutrientsand others **(**Dunjana, N.*et al*, 2015). Similarly, the difference in plant height of the varieties should be attributed to the difference in their genetic makeup (Jemal*et al*., 2015).Consequently, this variation might be related to the inherent character of the variety.

Crops receiving split N applications $^1/_2$at sowing, $^1/_2$at tillering and 0 at anthesis stages were taller(83.16 cm) than those receiving split N applicationstiming used in the $^1/_3$ sowing, $^1/_3$ mid-tillering$^1/_3$ anthesis (79.8cm) and on $^1/_4$ at sowing + $^1/_2$ at mid-tillering and ¼at anthesis (78.79cm) stage.Abdul *et al.* (2005) realized that plant height was responsive towardNapplications. According to Ramu (2008) early applications of N fertilizer favored plant height and this wasseen two equal splits resulted in taller plant than three splits. Likewise, Zewdie*et al.* (1992) reported that earlyapplications of N split applications increased plant height, while late applications resulted inshorter plant height. The enhancement in plant height in response to split N applications was probably due to Navailability at early stage. Plots in which split N applications was extended up to anthesis stage had relativelyshorter height than the others. This indicated that applying N at very late stage contributed little increment inheight. The tallest (83.16cm) plants were obtained from plots provided with $^1/_2$ at sowing, $^1/_2$at anthesis, but the shortest height was recorded (78.1 cm) and (79.8 cm) on $^1/_4$at sowing + $^1/_2$ at mid-tillering and ¼at anthesis stageand $^1/_3$atsowing, $^1/_3$ at mid-tillering $^{1}/_{3}$atanthesis, respectively**.** The height difference between the tallest plants with shortest plantswere 6 % (Table 5). This difference led to the evidence that the extent of N fertilizer is essential in the earlyperiod of growth to get maximum plant height than later time of applications. This finding is similar with the result of Admasu and Hunduma (2017) who reported that significant different for plant height in N splitapplications measured at physiological maturity, and the highest plant height was recorded in two N split applications rather than three N split applications.

4.3Yield and Yield Component

4.3.1 Length of spike

Spike length recorded at physiological maturity was highly and significantly ($P<0.01$) influenced by main effects of varieties and split N applications, but not for their interaction (Appendix 2). The longest spikewas observed with Ogolcho(9.75cm)while,the shortest spike length was observed with Hidase (8.9cm) variety(Table 6) and the difference could be due to the genotypicvariation between bread wheat varieties.

Significantly,the longer spike length (10.8cm) was recorded in response to split N applicationsof $^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis stage. However, the shorter spike length (8.3 cm) was obtained from split N applicationsof $^{1}/_{2}$ sowing $^{1}/_{2}$mid-tillering stages and 0 anthesis.The enhancement of spike length development of bread wheat receiving split applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis might have been due to synchronization of N supply and demand which resulted in high uptake of N, resulting in cells expansion, enlargement and over and above the grain filling (Legesse and Sakatu, 2017). This result is similar with the finding of Chibsa *et al*. (2017) who reported that spike length was significantly influenced by trice split N applied.Generally, several reports indicated trice split applications of N fertilizer has positiveeffect on spike length (Haile *et al.;* 2012; Leta, 2013; Fana*et al*., 2012).

4.3.2. Number of seeds per spike

Number of seeds per spike had highly significant ($P\leq0.01$) difference due to the main effects of varieties and split nitrogen applications, but their interactions were non-significant (Appendix2). Higher number of seeds per spike was recorded in variety Ogolcho (53)than

Danda’a (50.55) and Hidase (Table 6). Variety Ogolcho (53) was the weightiest,whereas, lighter number of seeds per spike was recorded on varietyHidase(46.77). This may indicate that the variation might be due to the genotypicor the growing situation. The result of this study agree with Majid and Mohsen (2012) who reported that significant differences were found among bread wheat varieties in terms of the number of kernels spike^{-1}.

Split N applicationshad significantly ($P<0.05$) affected number of seeds per spike. Split N applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis gave maximum (52.77) number of seeds per spike. In this respect, this split N applications produced greater mean number of seeds per spike compared with split N applications1/3 at sowing + 1/3 at mid-tillering and 1/3at anthesis (49.66). Minimum number of seeds per spike (47.8) was recorded from$^{1}/_{2}$at sowing + $^{1}/_{2}$at mid-tillering and 0 at anthesis stage (Table 6). This implies that increased number of seeds per spike due to split N applicationsof$^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis stage can be attributed to improved crop performance or higher nutrient availability in such . According to Shanahan *et al.* (2008) the applications oftotal N before or at sowing results in fewer kernels per ear, ears per area and reduced grainyield due to poor synchrony.

Table 6. Main effect of varieties and split N applications affects LSPP, NSPS, TSW and TB in Dedesa District 2018.

Variety	LSPP (cm)	NSPS (no)	TSW (g)	TBM (Kg ha^{-1})
HIDASE	8.98^{c}	46.77^{c}	38.78^{c}	6616^{c}
OGOLCHO	9.75^{a}	53.0^{a}	43.55^{a}	7411^{b}
DANDA’A	9.32^{b}	50.5^{b}	42.5^{b}	7754.4^{a}
LSD (0.05)	0.005	0.35	0.2	354.1
CV (%)	2.35	2.03	2.2	4.5
N-Splitting				
N$_1$ ($^{1}/_{4}$, $^{1}/_{2}$,$^{1}/_{4}$)	10.83^{a}	52.77^{a}	45.2^{a}	6930^{b}
N$_2$ ($^{1}/_{3}$, $^{1}/_{3}$,$^{1}/_{3}$)	8.90^{b}	49.6^{b}	40.9^{b}	7084^{b}
N$_3$ ($^{1}/_{2}$, $^{1}/_{2}$, 0)	8.33^{c}	47.8^{c}	38.67^{c}	7636.7^{a}
LSD (0.05)	0.224	0.99	0.95	333.4
CV (%)	135	1.78	2	3.69

LSPP= length of spike per plant, NSPS= Number of seed per spike and TB= total biomass Means sharing the same letter(s) in each column do not differ significantly at 5% p level according to the LSD test.

4.3.3 Thousand seed weight (g^{-})

Varieties and split N applications had highly significant ($P<0.01$) effect on thousand seed weight, but interaction effects were non-significant (Appendix 2). The data showed that heavierthousand seed weight of varieties wererecorded onOgolcho variety(43.55g) while lighter thousand seed weight wasrecorded with Hidase (38.78 g) variety (Table 6). This signifying that suitable genetic behavior of verities which may leads to an increased in photosynthesis process and accumulations of carbohydrate in seed to produce heavy kernels weight and consequently increased thousand seed weight per spike. This finding is similar with the suggestion of Biruk and Demelash (2016) stated that thousand kernels weight of three barely varieties were highly significant influenced by the main effect of varieties.

Significantly, higher thousand kernel weight (45.2g) was attained bycrops nourished with split N $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and ¼ at anthesis.However, the lighter thousand seed weight (38.67)is recorded in crop nourished at 1/2 at sowing + 1/2 mid-tillering and 0 at anthesis(Table 6). This could be due to sufficient applications of split N fertilizer at anthesis stage that which gave maximum thousand seed weight on both of split N applications. This result is agree with the finding of (El-Kramany, 2001) who recommend that optimumamount of N fertilizerwithin right split gave better grain weight on wheat. Similarly,Channabasavanna and Shetty (1994) reported that there were a positive response of rice grainweight to N applications.

4.3.4Total biomass

Total biomass yield is one of the yield components of bread wheat. The data regarding total biomass yield under different bread wheat varieties were highly and significantly ($P<0.01$) influenced by varieties and significantly by split N applications($P<0.05$) but there is non-significant interaction effect (Appendix 2). The higher total biomass yield was obtained from Danda’a (7715 kg ha^{1}) varieties, while lower totalbiomass yield was obtained from Hidase (6616 kg ha^{-1}) variety. This is might be due to the genetic make-up of the bread wheat varieties and the respective plant height difference which shows that, the higher the plant height may increase the total biomass yield of the crops.

Among split N applications, the highest total biological yield (7636.7 kgha^{-1}) was recorded when N was applied $^{1}/_{2}$sowing, $^{1}/_{2}$mid-tillering and 0 at anthesis while, the lowest biological yield (7061 kgha^{-1}) was recorded at $^{1}/_{4}$sowing, $^{1}/_{2}$mid-tillering and $^{1}/_{4}$at anthesis, however, statistical similarity (6930kg ha^{-1}) with split N applications of $^{1}/_{3}$at sowing + $^{1}/_{3}$at mid-tillering +$^{1}/_{3}$at anthesis (Table 6). The possible reason for increased total biomass yield in these treatments were might be due to the effect of higher plant height and longer days to heading and physiological maturity. This in turn might be due to adequate availability of nutrient at sowing and tillering which may triggered physiological growth processes and produced more biomass yield. Similarly, this finding is in line with Chibsa *et al.* (2017) who state that the best N timing of double split applications at sowing and mid-tillering resulted in the maximum biomass yield of 12.29 t ha^{-1}as compared to three of N split applications on durum wheat plant.

4.3.5 Grainyield

Grain yield ofbreadwheat was highly and significantly($P<0.01$) affected by varieties, split N applications andtheir interaction ($P<0.05$)effect (Appendix 3). Maximum grain yield had recorded from varieties Ogolcho (3965kgha^{-1}), whereasleast grain yield was obtained on Hidase variety (3370kgha^{-1}). The probable reason might bedifferent varieties have different yield potential due to geneticmake-up and growing environment. The genetic makeup of variety may determines theproductivity of the varieties, but the growing environment has a great role. This result is similar with the finding of Wogene and Agena (2017) who reported that significant difference among the bread wheat varieties were recorded (Table 7).

Results of grain yield indicated that bread wheat require more of their N to be applied at mid-tillering than at sowing because need of N requirement is maximum at the mid-tillering stage of the crop; hence much amount of N applied at this stageincrease more number of effective tillers and length of spike. Higher response on split N applications may improve the growth and yield enhancing effect of applying N in particularly in three splits. For instance, this research result showed that split N of $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$ anthesis when compared withsplit N of$^{1}/_{3}$ at sowing + $^{1}/_{3}$at mid-tillering + $^{1}/_{3}$ at anthesis exhibited 15.7%, 7.1% and 8% of grain yield advance over the varieties of Ogolcho, Danda'a and Hidase, respectively. This may be attributed to the synchrony between the high demand of the crop for

N uptake and availability of adequatenutrient in the soil at the specified growth stages. The yield enhancing effect of the three split applications of N on the variety may also be attributed to reduction in loss of nitrate by leaching during the wet growing season. Thus, the high need for N, the plant may have taken most of the N from the soil, leaving less of it available for leaching by the percolating rain water. Research report suggested by Zafar and Muhammad (2007) indicated that in-season N applications improves synchrony between crop demand and nutrient supply, especially in high rainfall areas where nitrate leaching is very common, was meant to enhance crop yield by improving N use efficiency.

Most of the investigations on N fertilizer applications geared towards split-applications to synchronize timing of fertilization according to the crop demand and increase grain yield. This N applications timing might have enhanced uptake of N and thereby increased crop performance and ultimately grain yield.Ayup *et al.* (2001) also reported that the highest bread wheat yield can be obtained by applying N in three split applications. Thus, there could be more potential to increase the productivity of both varieties if farmers use N fertilizer with three split applications of $^1/_4$ at sowing + $^1/_2$ at mid-tillering and $^1/_4$ at anthesis. According to Bekele *et al*. (2000) suggested that farmers in the area apply urea only once or twice contributing to lower yield of the wheat varieties.

Results of ANOVA on interaction effect of varieties and split N applications showed that grain yield had significantly influenced by interaction effects($P<0.05$). Thus, highest grain yield was recorded from variety Ogolcho (4080 kg ha^{-1}) with split N applications of $^1/_4$ at sowing + $^1/_2$ at mid-tillering and $^1/_4$ at anthesis while the least grain yield was recorded from variety Hidase (3180 kg ha^{-1}) with $^1/_2$at sowing + $^1/_2$at mid-tillering and 0 at anthesis stage (Table 8).In general, the interaction effect showed that all the three varieties in combination with split N applications of $^1/_4$ at sowing + $^1/_2$ at mid-tillering and $^1/_4$ at anthesis gives better performed regarding grain yield, while the rest of split N applications with those varieties gave the least grain yield. This implies that split N applications of $^1/_4$ at sowing + $^1/_2$ at mid-tillering and $^1/_4$ at anthesis is met the crop nutrient demand at the latter stage or when flower fully opened and this application method is more responsive likeOgolchovarieties,which was need to recommend for the farmer in studied area. This finding is agree with the result of Haile *et al*, (2012) who stated that maximum grain yield was obtained from different wheat varieties with split N applications of $^1/_4$ at sowing + $^1/_2$at mid-tillering and $^1/_4$ at anthesis stage when compared to the two splits (sowing and tillering) andone applications (sowing).

4.3.6. Strawyield

Straw yield was highly and significant ($P<0.01$) influenced by main effects of varieties and split N applicationsand significantlyby($P<0.05$) an interactioneffect (Appendix 2).Hidase and Ogolchovariety was less productive in straw yield than Danda'a variety. Danda'a variety gave (5060 kg ha^{-1}) more straw yield advantage than Hidase and Ogolchovariety (Table 7). This difference might be attributed to thehigher productivity of growth and yield components of Danda'a variety. It has substantially the tallest in plant height and spike length; as a result, itgave the highest straw yield and this is might be due to inherent characteristics of crop.This result is in consistent with this result Biruk and Demelash (2016) who reported thatconsiderable difference in straw yield was attained between barley varieties.

Maximum straw yield was recorded by split N applicationsof $^1/_2$at sowing + $^1/_2$at mid-tillering (5202kgha^{-1}), followed by $^1/_3$at sowing + $^1/_3$at mid-tillering + $^1/_3$anthesis (4542 kgha^{-1}) whereas, the minimumwas from$^1/_4$at sowing + $^1/_2$at mid-tillering and $^1/_4$at anthesis (4023 kgha^{-1}).This might be due the difference in applications that was necessary at anthesis stages leads to high in straw yield than grain yield. These results are in agreement with Tila*et al.*, (1987) who reported maximum straw yield when N is applied in split doses at different growth stages.

Results of ANOVA concerning the interaction effect of varieties and split N applications exhibited that the highest straw yield was showed as of variety Danda'a (5627 kg ha^{-1}) with split N applications of $^1/_2$ at sowing + $^1/_2$ at mid-tillering and 0 at anthesis, while the least straw yield had recorded from Ogolcho (3684 kg ha^{-1}) with $^1/_4$ at sowing + $^1/_2$ at mid-tillering and $^1/_4$ at anthesis. Higher straw yield recorded in Danda'a variety when combined with split N applications of $^1/_2$ at sowing + $^1/_2$ at mid-tillering and 0 at anthesis (Table 8), it was due to height difference from the rest variety and the rest split N applications. Moreover, the least straw yield recorded from the rest variety with other split N applications might be due to difference in applications that was necessary at anthesis stage that leads to high in straw yield than grain yield. These results are in agreement with Tila *et al.*, (1987) who reported maximum straw yield were obtained on wheat variety when N and S was applied in split doses at different growth stages.

Table 7 Main effect of varieties and split N applications influences Grain Yield, Straw yield, harvest index and partial factor productivity in Dedesa District 2018.

VARIETIES	GY (Kg ha^{-1})	SY (Kg ha^{-1})	HI (%)	PFP (Grain/ Kg N)
HIDASE	3370^{c}	4241^{b}	44.7^{b}	48.8^{c}
OGOLCHO	3965^{a}	4462^{b}	47.2^{a}	57.46^{a}
DANDA’A	3691^{b}	5060^{a}	42.3^{c}	53.5^{b}
LSD (0.05)	92.2	442.7	3.06	0.56
CV (%)	3.2	7.23	10.2	3.21
N-Splitting				
N_1 ($^1/_4$, $^1/_2$, $^1/_4$)	4025^{a}	4023^{c}	50.06^{a}	57.72^{a}
N_2 ($^1/_3$, $^1/_3$, $^1/_3$)	3595^{b}	4542^{b}	44.34^{b}	52.1^{b}
N_3 ($^1/_2$, $^1/_2$, 0)	3404^{c}	5202^{a}	39.5^{c}	49.3^{c}
LSD (0.05)	120.4	284.6	2.4	0.798
CV (%)	1.9	6.10	7.9	1.79

GY=Grain Yield, SY=Straw Yield, HI=Harvest Index and PFP=Partial Factor Productivity. LSD: Least significant difference, CV: Coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% p level according to the LSD test.

4.3.7.Harvest index

Harvest indexwas significantly affected by bread wheatvarieties ($P<0.05$), split N fertilizer applications($P<0.01$)and their interaction($P<0.05$). Among the varieties the highest HI were recorded from Ogolcho (47.2%) varieties which is followed by Hidase (44.7%). The least harvest index was recorded from Danda’a (42.8%) varieties (Table 7). Harvest index had inter- relationship with grain yield and total biomass yield that the highest harvest index was the result of greater grain yield of varieties. It means that increased of grain yield results increased harvest index. Similarly,it might be due to difference among the three varieties in partitioning efficiency ofnutrient from source to sink.The present result is in agreement with the findings of Amare (2017) who confirmed that harvest indexis indicators of the genetic potential of plant to produce economic yield.

Results of ANOVA revealed that, HI had highly and significantly influenced by split N applications.Greater harvest index was obtained with the split applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$ at anthesis (50.06 %)**,** however ,$^{1}/_{2}$ at sowing + $^{1}/_{2}$ at mid-tillering and 0 at anthesis (39.5%) gave the least HI (Table6).In split N applications of $^{1}/_{4}$at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis, higher HI was obtained due to the additional N applications at anthesis stage. Dividing N applications into three split resulted in a harvest index greater than treatments involving into two splitapplications with responsive variety.This result is in agreed with the result of Mazid *et al.* (2013) who suggested that the more photo assimilate in to the grain resulted the higher ratio of economic yield to biological yield.

Harvest index significantly affected by interaction ($P<0.05$) effects of varieties and split N applications.Mean performance of harvest index due to the interaction effect showed that variety Ogolcho (52.5%) with split N applications of $^{1}/_{4}$at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis had maximum HI, while the least HI had recorded from Hidase (39.2%), and Danda’a (39.26%) on split N applications of $^{1}/_{2}$at sowing + $^{1}/_{2}$at mid-tillering and 0 at anthesis and with the same split N applications which is statistically the similar (Table 8).It means that increased of grain yield results increased harvest index. This might be due to difference among the three varieties in partitioning efficiency ofnutrient from source to sinkwith split N applications of $^{1}/_{4}$at sowing + $^{1}/_{2}$at mid-tillering and $^{1}/_{4}$at anthesis.This result is in agreed with the result of Mazid *et al.* (2013) who suggested that the more photo assimilate in to the grain resulted the higher ratio of economic yield to biological yield observed in wheat .

Table 8. Grain yield, straw yield, Harvest index and partial factor productivity of bread wheat significantly influenced by interaction effects of varieties and split N applications.

VARIETIES	Split N applications	Interaction Effects			
		Grain Yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	HI (%)	PFP (kg GY/Kg N)

HIDASE	N$_1$(¼, $^1/_2$, ¼)	3613^d	3903^d	48.13^b	24.06^d
	N$_2$($^1/_3$, $^1/_3$, $^1/_3$)	3313^e	3873^d	46.1^b	22^{ef}
	N$_3$ (½,$^1/_2$,0)	3180^e	4934^{bc}	39.2^d	21.20^f
OGOLCHO	N$_1$(¼, $^1/_2$, ¼)	4083^a	3684^d	52.5^a	30.23^a
	N$_2$($^1/_3$, $^1/_3$, $^1/_3$)	3826^{bc}	4673^{bc}	45^{bc}	25.467^{bc}
	N$_3$ (½,1/2,0)	3530^d	5026^{bc}	38.2^d	23.50^d
DANDA’A	N$_1$(¼, $^1/_2$, ¼)	3923^b	4493^c	46.6^b	26.10^b
	N$_2$($^1/_3$, $^1/_3$, $^1/_3$)	3646^{cd}	5060^b	41.9^{cd}	24.30^{cd}
	N$_3$ (½,$^1/_2$,0)	3503^d	5627^a	43.017^d	23.30^{de}
LSD (5%)		187.89	535.5	3.68	1.24
CV (%)		2.967	6.8	2.11	2.93

Figures in parenthesis indicate the fraction of N applied during sowing, mid-tillering and anthesis stage of the crop in their order of placement, LSD = least significant difference’s coefficient of variation. Means in a column followed by the same letters are not significantly different at 5%

4.3.8. Partial factor productivity

Partialfactor productivityof bread wheathad highlyand significantly affected by main effects of varietiesandsplit N applications ($P<0.01$) and their interaction ($P<0.05$), (Appendix 2). Among the varieties, the highest partial factor productivity were recorded from varieties Ogolcho (26.41Kg grains kg^{-1} N) and Danda’a (24.52kg grains kg^{-1} N) and the least was obtained from Hidase (22.44 Kg grains kg^{-1} N).Significantly, the difference in grain yield among varieties which is due to the difference in partial factor productivit**y,** because PFP is the result of grain yield divided by amount N applied(Table 7).

Considerably, higher partial factor productivitywas attained when N was applied in split of $^1/_4$ at sowing + $^1/_2$at mid-tillering and $^1/_4$at anthesis (26.80 Kg grains kg^{-1} N),but split N applications of $^1/_3$ at sowing + $^1/_3$ at mid-tillering + $^1/_3$ at anthesis (23.94 kg grains kg^{-1} N) and $^1/_2$at sowing + $^1/_2$mid-tillering (22.67kg grains kg^{-1} N**)** were gave the least partial factor productivity**.** In the applications of $^1/_4$ at sowing + $^1/_2$ at mid-tillering and $^1/_4$at anthesis, highest value was recorded, this might be due to thedifference in the grain yieldand with greater number ofN splits ($^1/_4$at sowing + $^1/_2$ at mid-tillering and $^1/_4$ at anthesis) as compared with minimum split applications.Results are comparable to findingofAmanullahand Almas (2009**)** who suggested that efficient use of N split applications for maize production isimportant for increasing grain yield, maximizing economic returns, and high partial factor productivity.

Mean ofpartial factor productivitydue to the interaction effect of varieties and split N applications revealed that the maximum partial factor productivitywas recorded on variety Ogolcho (27.23 Kg grains kg^{-1} N) with split N applications$^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$ at anthesis **,** while the least partial factor productivity had recorded from Hidase (21.2 Kg grains kg^{-1} N) with split N applications of $^{1}/_{2}$ at sowing + $^{1}/_{2}$ at mid-tillering and 0 at anthesis (Table 8). This interaction effects results may be due to efficient use of N in three split applications with responsive variety produce more grain yield per applied N and results increased partial factor productivity.

4.4. Nitrogen Concentration and Uptake

4.4.1. Grain N concentration

Main effects of variety, split N applications and interaction effects had highly significantly (P<0.01) influence grain N concentration (Appendix 3). Mean performance of varieties Ogolcho (1.95%) combined with split N applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$ at anthesis gave the highest grain N concentrationwith split N applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$ at anthesis while, variety Hidase (1.25%) with split N applications of $^{1}/_{2}$ at sowing + $^{1}/_{2}$ at mid-tillering and 0 at anthesis gave the least grain N concentration(Table 9). This might be due to efficient variety with the sufficient availability of nitrogen at anthesis stage may increase N mobilization to the grain. This result was in consistence with results of Lopez-Bellido *et al.* (2004) who reported that genotypic variability in grain N concentration may be affected not only by physiological traitsbut also by N supply. Similar result was recorded by Tilahun *et al* (2017) who reported that durum wheat exhibited the highest N concentration in grain with three split applications of N.

4.4.2 Straw N concentration

Straw N concentration of bread wheat was highlyand significantly(P<0.01) influenced by main effects of varieties, split N applicationsand interaction (Appendix 3).Results of (ANOVA) showed that variety Ogolcho (1.77%) with split N applications $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$ at anthesis gave the highest straw N concentration, whereas, variety Hidase (1.17%) with split N applications of $^{1}/_{2}$ at sowing + $^{1}/_{2}$ at mid-tillering and 0 at anthesis gave the least straw N content (Table 9). This implying that, there is a positive response of the variety Ogolcho to split N fertilizer applications of ¼ at sowing, ½ at mid-tillering and ¼ at anthesis, for straw N contents. The results of this study was agree with the finding of Daba (2017)who recorded that straw N concentration increase to the increased split N applications.

4.4.3Grain N uptake

Grain N uptakewas highly and significantly affected by varieties, split N applications and their interaction (P<0.01) on grain N uptake (Appendix 4).The result of mean performance revealed thatvarieties Ogolcho (7961kg h^{-1}) with split N applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$at anthesis gave the highest grain N uptake, while,varieties Hidase (3972 kg ha^{-1}) with and split N applications of $^{1}/_{2}$at sowing + $^{1}/_{2}$ at mid-tillering and 0 at anthesis gave the least (Table 9).Thedifferences in grain N uptake is due to differenttreatments were associated mainly with yield differencesand partly with nitrogen content in grain.This result is in agreement with Belete *et al* (2018) who state that the interaction effect produced the highest grain Nuptake when N was splited into three and the lowest was recorded when Nwas split into twoapplication. Furthermore,Fageria and Baligar (2005) reported that split applications of nitrogen fertilizer cause high amount of nitrogen content to be taken by the grain rather than by straw of wheat.Therefore, N split applications$^{1}/_{4}$ at sowing + $^{1}/_{2}$ at mid-tillering and $^{1}/_{4}$at anthesis stage was the best split N applications to record higher grain N uptake. This N split applications might have enhanced grain N uptake during these stages and thus improved crop performance and ultimately grain yield.

Table 99. Nitrogen content and uptake of bread wheat significantly influenced by interaction effects of varieties and split N applications.

Varieties	Split N applications	GNC (%)	SNC (%)	GNU kg ha^{-1}	SNU (kg ha^{-1})	TNU (kg ha^{-1})
Hidase	N_1(¼,$^{1}/_{2}$,$^{1}/_{4}$)	1.56^{c}	1.24^{de}	5661^{c}	4841.1^{c}	10502de
	N_2 ($^{1}/_{3}$, $^{1}/_{3}$, $^{1}/_{3}$)	1.37^{c}	1.3^{cd}	4533^{e}	4989.7^{c}	9522^{e}
	N_3 (½,$^{1}/_{2}$,0)	1.25^{d}	1.17^{f}	3972^{f}	5509.7^{bc}	9481.7^{e}
Ogolcho	N_1(¼,$^{1}/_{2}$,$^{1}/_{4}$)	1.95^{a}	1.77^{a}	7961^{a}	6499^{ab}	14460.8^{a}
	$N_2$$^{1}/_{3}$, $^{1}/_{3}$, $^{1}/_{3}$)	1.62^{b}	1.2^{ef}	6243^{b}	5473.3^{bc}	11716.3^{bc}
	N_3 (½,$^{1}/_{2}$,0)	1.43^{d}	1.3^{cd}	5062^{d}	6394^{ab}	11456^{bc}

Danda’a	N_1 (¼,$^1/_2$,$^1/_4$)	1.59^b	1.43^b	6243^b	6400^{ab}	12643^b
	N_2 ($^1/_3$, $^1/_3$, $^1/_3$)	1.44^d	1.35^{cb}	5235^{cd}	7028.0^a	12263^{cb}
	N_3 (½,$^1/_2$,0)	1.4^d	1.2^{de}	5020^d	6867.3^a	11887.3^{cb}
	LSD (%)	0.053	0.0549	4.3	1066	10.33
	CV (%)	3.4	4.08	4.6	10.3	6

GNC=Grain N content, SNC=Straw N content, GNU= Grain N Uptake, TNU=Total N uptake LSD: Least significant difference, CV: Coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% p level according to the LSD test. Means sharing the same letter(s) in each column do not differ significantly at 5% p level according to the LSD test.

4.4.4Total Nuptake

Main effects of varieties, split N applications and their interaction effects washighly and significantly (P< 0.01)influences total N uptake (Appendix 4).The interaction effects of varieties and split N applications showedthat the highest total N uptakewas recorded in Ogolcho (14460.8 kg ha^{-1})variety combined with three split N applications (¼ at sowing, 1/2, at mid-tillering and ¼ anthesis)but, the least wasrecorded on Hidase (9481.7kg ha^{-1}) varieties with split N applications of $^1/_2$at sowing + $^1/_2$at mid-tillering and 0at anthesis stage had minimum (Table 9). The high total N uptake by the bread wheat varieties under three split N applications (¼ at sowing, 1/2, at mid-tillering and ¼ anthesis)might be due to thefavorable growth environment for development of wheat root hairs and growth might have led to enhanced Nuptake by the roots of the plant, resulting in enhanced uptake of the nutrient and its concentration in the grainand straw tissues**.**Moreover, the result of this study was similar with that of Belete *et al* (2018) who state that interaction of Nrate by split time of Napplications, also revealed a significant effect on total nitrogen uptake.Similarly, (Wild, 1988) suggest that, split N applications significantly increased total N uptake to cultivated crops has little or residual effects due to plant consumptive use and /or losses through leaching volatilization, denitrification.

4.4.5 Straw N uptake

Analysis of variance (ANOVA) for the straw nitrogen uptake showed significant (P<0.05) difference due to varieties, but it was non-significant to split N applications andtheir interactions (Appendix 3). The data further revealed that the uptake of N by straw of wheatvarieties ranged from 51.1 to 6765 kg ha^{-1} and the highest (6765 kg ha^{-1}) was recorded from the varieties Danda'a,which was statistically similar with Ogolcho (6122 kg ha^{-1}), while thelowest (5113.7 kg ha^{-1}) was recorded fromthe Hidasevarieties (Table 10). Though a significant difference was observed among the wheat cultivars in uptake of N by straw, nosignificant difference was obtained between the two cultivars Danda'a and Ogolcho in uptake of N by straw.Similar results were reported byDaba (2017) andGouis *et al.* (2000).

Table 10. Main effect of varieties significantly influences straw N uptake of bread wheat.

VARIETY	SNU (kg ha^{-1})
HIDASE	5113.7^{b}
OGOLCHO	6122^{a}
DANDA'A	6765^{a}
LSD (0.05)	6.5
CV (%)	8.9

SNU=straw N uptake LSD: Least significant difference, CV: Coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% p level according to the LSD test.

4.5 After Harvest Soil Analysis

Selected physico-chemical properties were analyzed for composite surface soil (0-30m) samples collected from each replication after harvest.The current result showed that the main effect of bread wheat varieties, were significant influence on OC and TN but, splitN applications interaction effects were non-significant. On the other hand, the main effect of bread wheat varieties and splitN applicationsand interaction effects were non-significant on pH, Cation Exchange Capacity, Ava. Phosphorus.

4.5.1 Organic contents (%)

The main effects of varieties showed significant ($P< 0.05$) effect oforganic matter content of the experimental soil. On the other hand, split N applications and their interaction effect are non-significant difference in soil (Appendix 4).The plot on which variety Hidase (3.56%) rested had the highest% OC, and followed by Danda'a (1.486%) and Ogolcho (0.97%). Hidasevariety which grown under experimental field might have contributed tohigher in organic contents of the soil or may be due to the more amount of N in Hidase plot which may favor more organic matters (Table 11). This results is in line with Merkeb and Amsalu (2018) who state that higher amount of fragments of live anddecomposing root tissues of crops and biological N fixation byvarious crops grown under sequential cropping since longtime at the experimental field might have contributed tohigher total N and organic contents of the surface soil. Furthermore, concerning the split N applications on the OC%, it does not show significance among the split N applications.

4.5.2 Total Nitrogen (%)

Results onafter harvest analysis showed that the main effects of bread wheat varieties significant ($P<0.05$)influenced total N of the soil. Conversely N-split applications and interaction effect were non- significant on total soil N (Appendix 4) .The data regarding bread wheat varieties reveled that variety Hidase had the highest soil N (0.226%) while variety Danda’a(0.93%) had the least (Table 11) but, this result is statistically non-significant with variety Ogolcho (0.96%). This difference might be due to the nature N uptake efficiency of the varieties, for instance, variety Hidase was the least in both grain and straw Nitrogen uptake this shows that the variety better in N uptake results the least on soil N as the after harvestsoil analysis. Total Nitrogen of the soil (%) is rated by Havlin *et al.* (1999) as very low (<0.1), low (0.1 to 0.15), medium (0.15 to 0.25), and high (> 0.25). Based on the above delineation, the plot treated by Hidase variety were medium (0.226%), conversely, the plot on which Ogolcho(0.10%) and Danda’a (0.083%) was rested has low which is statistically non-significant.

Table 10. Mean squares of analysis of variance for varieties and split N applications influences on post sowing soil analysis results of OC % and TN%

VARIETY	OC (%)	TN (%)
HIDASE	2.65^a	0.226^a
OGOLCHO	0.97^b	0.96^b
DANDA’A	1.28^b	0.93^b
CV (%)	25.4	23.6
LSD (0.05)	0.28	0.047
N-SPLITTING		
N_1 ($^1/_4$, $^1/_2$,$^1/_4$)	1.8	0.16
N_2 ($^1/_3$, $^1/_3$,$^1/_3$)	1.6	0.136
N_3 ($^1/_2$, $^1/_2$, 0)	1.4	0.121
LSD (0.5)	NS	NS

CV (%)	16.6	9.2

% OC= percent Organic Carbon, % TN= percent Total Nitrogen and.CV: Coefficient of variation, LSD: Least significant difference, Means sharing the same letter(s) in each column do not differ significantly at 5% p level according to the LSD test.

4.6. Correlation Analysis of Grain Yield with Yield and Yield Components

Correlation analysis among growth parameters, yield and yield related traits is indicated (Table 12). The current result showed, grain yield was positively and significantly associated withnumber ofeffective tillers (r=0.889**), number of seed perspike (r=0.921**), length of spikeper plant (0.821**), harvest index (0.728**), thousand seed weight (r=0.9026**) and partial factor productivity, (r= 0.99**).This indicated that increasing those attributes, concurrentlymay result in increased in grain yield. Grain yield was non-significant with days to 75% physiological maturity (r=0.35), plant height (r=0.00934) and total biomass (r=0.16). On the other hand, grain yieldwasnegatively and significantly associated with straw yield (r= -0.4112*); this implies that increased straw yield leads to decreased grain yield.

Total biomass yield of bread wheat was positivelyand significantly correlated with DH(0.766**),DM (r=0.785**) and plant height (r=0.8112**)while,negatively and significantly associated withHI (r=0.561**). Number of effective tillers per plant was significantly and positively correlate with some yield and yield related traits ofbread wheat such as, number of kernel per spike (r=0.850**), length of spike (r=0.864**), thousand kernels weight(r=0.908**), HI (r=0.759**) and partial factor productivity (r=0.889**); on the other hand,negatively and significantly associated with straw yield (r=-0.516*) (Table 11).

Harvest index was also significantly and positivelycorrelated with some parameters of bread wheat, such as: number of spike per plant (r=0.573**) and length of spike per plant (r=0.8015**) on the other hand,HI was negatively and significantly correlated with plant height (r=-0.5364**), total biomass (0.5614**) and straw yield (r=-0.9143**)(Table 12) .The present result is in agreement with the finding of Bishaw*et al.* (2014) who reported a positiveassociation between biomass yield and plant height. Similar correlations were reported in barley by (Bekalu andMamo 2016) and Alam*et al.*(2005).

Generally, the correlation analysis within crop phenology, growth parameters and yield and yield components asaffected by the main effects of varieties and split N applications shows that there were a positive and significantly correlate with each other except straw yield which is negatively and significantlycorrelate with grain yield.

Table 11. Correlation of grain yield with growth and yield and yield components on bread wheat varieties and split N applications

	D50%H	D75%PM	NET	PH	NKPS	LSPP	TB	SY	HI	TSW	PFP	GY
D50%H	1.00	0.964**	0.327*	0.8457**	0.5496**	0.10886	0.7662**	0.480*	7385	0.45178*	0.406*	0.409*
D75%PM		1.00	0.25516	0.8886**	0.4905**	0.05217	0.785**	0.54179**	-0.238	0.3894*	0.3445	0.347
NET			1.00	-0.11907	0.85**	0.8645**	-0.02106	-0.5165**	0.759**	0.9078**	0.889**	0.889**
PH				1.00	0.14247	-0.24637	0.811**	0.743**	-0.536**	0.06223	0.00665	0.00934
LSPP						1.00	-0.16845	-0.633**	0.8015**	0.883**	0.82**	0.821**
NKPS					1.00	0.749**	0.26996	-0.25407	0.5734**	0.8878**	0.920**	0.921**
TB							1.00	0.8271**	-0.561**	0.17742	0.15105	0.153
SY								1.00	-0.914**	-0.35713	-0.4131*	-0.411*
HI									1.00	0.6299**	0.729**	0.728**
TSW										1.00	0.9026**	0.9036**
PFP											1.00	0.9999**
GY												1.00

Where, *Correlation is significant at the 0.05 level, **.Correlation is significant at the 0.01 level, NS=Non-Significant, DH=Days to heading, ETL=effective tillers, PH= Pant Height, NKPS=number of kernel per spike, LSPP= Length spike per plant, TBM= Total Biomass, SY= Straw Yield, HI= Harvest Index, TSW= Thousand Seed Weight, PFP=partial factor productivity GY=Grain yield.

5. SUMMARY AND CONCLUSIONS

Wheat is the most important food crop for one third of world's population. Ethiopia is the second largest wheat producer in Sub-Saharan Africa next to South Africa. However, wheat productivity in the country in terms of yield per unit area of land is very low due to poor agronomic and soil management practices. Soil acidity, low soil fertility and poor nitrogen fertilizer managements are some of the factors limiting crops productivity in the highlands of southwest areas of the country. In southwest highlands of Ethiopia, wheat is grown during the highrain-fall season and losses of applied N through leaching may be decreased through proper split time of Napplication. However little has been studied on split of N fertilizer application on wheat grown in high rainfall environments such as Dedessa district**.** Moreover, there was a need tostudy the role of N fertilizer in study area and more information was required onthe response of bread wheat variety to different split timing of Nfertilizer applications.

There are three improved recently released bread wheat varieties namely Ogolcho, Denda'a and Hidase were sown using three split N fertilizer applications ($^1/_4$at sowing + $^1/_2$at mid-tillering and $^1/_4$at anthesis*)*, ($^1/_3$at sowing, $^1/_3$at tillering, and the remaining $^1/_3$at anthesis) and ($^1/_2$at sowing + $^1/_2$at mid-tillering 0 at anthesis) in split plot design with factorial arrangement in three replications. The recommended N fertilizer 69 kg ha^{-1} (150 kg ha $^{-1}$ urea) which is sole N rate and Phosphorus fertilizer at the recommended rate of 46 kg P_2O_5 ha^{-1} in the form of TSP was applied equally to all plots.

Study results indicated that, main effects of varieties and split N applications(69 N kgha^{-1}) showed that there is a highly and significant difference ($P<0.01$) and ($P<0.05$) on most of the studied parameters. Days to 50% heading, days to 75% physiological maturity, plant height, , number of effective tillers, number of seeds per spike,length of spike per plant, thousand seed weight and straw N uptake were significantly affected by main effects of variety and split N fertilizer application, but not for their interactions.Straw yield, grain yield, harvestindex, partial factor productivity and grain N contents, straw Nitrogen contents, grain N uptake and total N uptake were significantly affected by main effect of varieties, split N applications and their interaction.Corresponding to growth parameters, variety Ogolchohad better performance than variety Danda'aandHidase. Ogolcho(3965 kgha^{-1}) variety was more productive than the early maturing Hidase (3370kgha^{-1}) variety at split N applications on $^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering treatment $^{1}/_{4}$ at anthesis with 69 kg N/ha^{-1}. With respect to grain N contents and uptake, Ogolchovariety had the highest score (1.67 %) and (67.1kg Nha^{-1}) than the variety Hidase (1.4 %) and (47.2kg Nha^{-1}) respectively.

The soil sample was analyzed at Jimma University (JUCAVM) soil laboratory for selected physico-chemical properties, namely soil pH,organic carbon, total nitrogen (TN %), available phosphorus (P), cations exchange capacity (CEC) and textural class analysis were done before sowing and after harvest.

Generally, the result of this study indicates thatvariety Ogolcho had the highest grain yield and total N uptake than the rest varieties with split N fertilizer applications of $^{1}/_{4}$ at sowing + $^{1}/_{2}$at mid-tillering$^{1}/_{4}$ at anthesis on sole N applications of 69 kg ha^{-1}and can be suggested for higher bread wheat production in the study area. However, it is advisable to undertake further research on other bread wheat varieties and on different split N applications fertilizer with different sole N rate across different soil types, years and locations to draw sound recommendation on a wider scale.

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7. APPENDIX

Appendix Table 1. Analysis of Variance (ANOVA) for days to heading, days to physiological maturity, number of effective tiller, plant height as affected by main effect of bread wheat variety and split N applications.

Source Variation	D.F	Mean Square			
		DH (no)	DM (no)	NET (no)	PH (cm)
Rep	2	0.38^{ns}	0.26^{ns}	0.107^{ns}	0.0112^{ns}
Varieties	2	276.7**	446.7**	282.9**	316.28**
Error (a)	4	1.92	0.36	0.38	0.2077
Fertilizer (N)	2	3.67*	5.25*	42.28**	40.1**
Interaction	4	0.8^{ns}	0.92ns	0.33^{ns}	1.2^{ns}
Error (b)	12	0.75	15.01	0.47	0.47
Mean		59.3	90.6	60.9	80.35
CV (%)		1.5	1.2	1.5	0.79
LSD (5%)		0.88	1.095	0.95	0.876

Whereas, **, *, ns, highly Significant at 1%, significant at 5% and non-significant, respectively. Rep = Replication; CV= Coefficient of variance (%); DF=degree of freedom; DM= Days to 50% heading, DM= Days to 75% maturity, ETL= Number of effective tiller and PH=Plant height.

Appendix Table 2. Analysis of variance (ANOVA) for Length of spike, number of kernels, total biomass, grain yield, straw yield, harvest index, thousand seed weight and partial factor productivity as influenced by main effect of variety and split N applications.

Source Variation	D.F	Mean Square							
		LSPP (cm)	NKPS (no)	TSW (g^{-})	TBM (Kg ha^{-1})	GY (Kg ha^{-1})	SY (Kg ha^{-1})	HI (%)	PFP (GY/N)
Rep	2	0.09ns	0.99^{ns}	0.649^{ns}	133254^{ns}	13441^{ns}	17879^{ns}	7.86^{ns}	0.65^{ns}
Varieties	2	1.30**	88.4**	56.69**	3065337**	802737**	1632893*	54.46*	35.26**
Error(a)	4	0.015	1.04	0.61	73233.5	4965.5	114460	5.48	0.18
Fertilizer(N)	2	9.1**	28.31**	60.9**	604755*	504336**	1783297**	148**	22.3**
Interaction	4	0.067^{ns}	2.39^{ns}	2.06^{ns}	227990^{ns}	54369*	391171*	21.5*	2.44*
Error(b)	12	0.048	0.79	0.61	107334	13996	78102.4	3.53	0.614
Mean		9.353	50.11	41.61	72.6	3675	4585	44.65	24.47
CV (%)		2.3	1.78	2.24	4.5	3.2	6.10	7.9	3.2
LSD (5%)		0.2242	0.99	0.951	333.4	120.4	284.6	2.4	0.79

Whereas, **, *, ns highly Significant at 1%, significant at 5% and non-significant, respectively. Rep = Replication; CV= Coefficient of variance (%); DF=degree of freedom; NKPS=Number of kernels per spike, LSPP=Length of spike per plant, TBM = Total biomass; YLD= Grain yield, SYLD = Straw yield; HI=Harvest index, TSW= Thousand seed weight and PFP= Partial factor productivity.

Appendix Table 3. Analysis of variance (ANOVA) for grain nitrogen contents, straw nitrogen contents, grain nitrogen uptake, straw nitrogen uptake, total nitrogen uptake as affected by interaction effect of varieties and split N applications.

Source Variation	D.F	**Mean Square**				
		GNC ($Kgha^{-1}$)	SNC ($Kgha^{-1}$)	GNU ($Kgha^{-1}$)	SNU ($Kgha^{-1}$)	TNU ($Kgha^{-1}$)
Replication	2	0.0040^{ns}	0.0035^{ns}	4.0775^{ns}	23.67^{ns}	47.159^{ns}
Varieties	2	0.1753*	0.0823**	902.95**	623.5*	2280.5**
Error(a)	4	0.0028	0.0025	6.6	29.51	33.575
Fertilizer	2	0.2034**	0.089**	817.71**	84.21^{ns}	574.73**
Interaction	4	0.0123*	0.089**	91.817**	42.77^{ns}	206.19**
Error(b)	12	0.0026	0.0029	6.5087	40.75	34.9
Mean		1.52	1.32	4.5	60.7	101.55
CV (%)		3.38	4.1	2.59	10.6	5.76
LSD (5%)		0.0523	0.0549	56.4	6.5	5.96

Whereas, **, *, ns highly Significant at 1%, significant at 5% and non-significant, respectively. Rep=Replication; CV= Coefficient of variance (%); DF=degree of freedom; GNC=Grain nitrogen content, SNC=Straw nitrogen content, GNU = Grainnitrogen uptake; SNU= Straw nitrogen uptake; SNU=Straw nitrogen uptake, TNU= Total nitrogen uptake.

Appendix Table 4. Analysis of Variance (ANOVA) for pH, OC%, TN%, CEC, P ppm as affected by main effects of bread wheat variety and split N applications.

Source of Variation	D.F	Mean Square				
		pH	OC %	TN%	CEC	P in ppm
		MS	MS	MS	MS	MS
Rep	2	0.0087^{ns}	0.228^{ns}	0.00095^{ns}	0.97^{ns}	0.093^{ns}
Variety	2	0.0062^{ns}	6.95*	0.052*	1.97^{ns}	0.1945^{ns}
Error (a)	4	0.015	0.36	0.001	1.94	0.0185
Nitrogen	2	0.0157^{ns}	0.042^{ns}	0.00058^{ns}	5.24^{ns}	0.02^{ns}
Interact	4	0.0073^{ns}	1.302^{ns}	0.0034^{ns}	2.77^{ns}	0.038^{ns}
Error(b)	12	0.04	0.48	0.0025	2.5	0.17
Mean		4.80	1.61	0.14	18.6	1.38
CV (%)		4.131	25.4	23.6	8.5	29.7
LSD (5%)		NS	0.035	0.036	NS	NS

Whereas, *, ns =significant at 5% and non-significant, respectively. Rep = Replication; CV=Coefficient of variance (%); DF=degree of freedom; pH= pH of the soil, OC= Organic Carbon, TN= Total Nitrogen and CEC=Cation Exchange Capacity.