EFFECT OF N AND P FERTILIZER RATES ON GROWTH, YIELD AND YIELD COMPONENTS OFWHEAT (*Triticum aestivum*.L.*)* IN JIMMA ARJO DISTRICT, WESTERN ETHIOPIA

MSc THESIS

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MSc Thesis

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DEDICATION

This thesis is dedicated to the memory of my father Mr. Tiye Bekana who was willing to see my success but passed away; to my beloved mother Mrs. Jije Negeri; to my beloved wife Mrs. Ashagire Taye and my beloved son Naol Misganu.

STATEMENT OF THE AUTHOR

First I declare that this thesis is my work and all the material sources used have been accordingly acknowledged. This thesis has been submitted in partial fulfillments of the requirements for MSc Degree in Agronomy at Jimma University College of Agriculture and Veterinary Medicine. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. It is made available at the University's Library to borrowers as per the rules and regulations of the library.

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BIOGRAPHICAL SKETCH

The author was born on 18 September 1990, from Mr. Tiye Bekana and Mrs. Jije Negeri in Jimma Arjo, East Wollaga Zone of Oromia Regional State. He attended elementary, secondary schools and preparatory School at the same town (Arjo). After passing the Ethiopian Schools Leaving Certificate Examination (ESLCE), he joined then Jimma University in September 2010 and graduated in July 2012 with B.Sc. Degree in Agriculture (Plant Sciences).

Subsequent to this, he was employed as irrigation Agronomist under the Ministry of water and Irrigation Development, at Meko Irrigation development Authority office, Buno Bedelle Zone of Oromia National Regional State.

From 2015 to 2017, he served as Team Leader of irrigation Extension at Meko in Buno Bedelle Zone, until he joined the School of Graduate Studies of the Jimma University to study for his Master of Sciences degree in agronomy.

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LIST OF ABBREVIATIONS

ATA	Agricultural Transformation Agency
cm	Centimeter
CSA	Central Statistical Agency
EC	Electro Conductivity
FOA	Food and Agriculture Organization of the United Nations
g	Gram
GB	Gross Benefit
Ha	Hectare
Kg	Kilogram
Masl	Meters Above Sea Level
NB	Net Benefit
OC	Organic Carbon
OM	Organic Matter
RCBD	Randomized Complete Block Design
SSA	Sub-Saharan Africa
T	Ton
TVC	Total Variable Cost
TSP	Triple Super Phosphate

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EFFECT OF N AND P FERTILIZER RATES ON GROWTH, YIELD AND YIELD COMPONENTS OF WHEAT (*Triticum aestivum.* L.*)* IN JIMMA ARJO DISTRICT, WESTERN ETHIOPIA

Authors: Misganu Tiye, Amsalu Nebiyu and Gezehagn Berecha

ABSTRACT

Ethiopia is one of the largest wheat producers in Sub-Saharan Africa with an estimated area of 1.696 million ha and production of 4.642 million tones. The area suitable for wheat production falls between 1,900 and 2,700 m above sea level and is produced exclusively under rain fed conditions. However there is little knowledge among farmers on the rates of N and P-fertilizer application at Jimma Arjo. Therefore, there is a need to determine the rates of N and P fertilizer application on growth and yield of wheat. Accordingly, a field experiment was conducted to evaluate the effect of different rates of N and P fertilizer application on yield and yield components of wheat at Jimma Arjo, western Ethiopia in 2018/2019 cropping season. A factorial combination of the rate (0, 23, 46 and 69 kgha^{-1}) of N and rate (0, 10, 20 and 30 kg ha^{-1}) of P was arranged in RCBD. Rates of N and P fertilizer and their interaction had significantly affected days to heading, days to physiological maturity, number of tillers, spike length, number of seeds per spike, grain yield, straw yield, total biomass yield and harvest index. Meanwhile rates of N and P fertilizer interaction had not significantly affected plant height. Application of the 69 kg N/ha and 30 kg P/ha interaction increased number of tillers per plant by 264% as compared with the control treatment. The lowest number of grains per spike (34.33) was found in control plot and while the highest number of grainsper spike (74.33) was recorded with 69 kg N and 30 kg P ha^{-1}interaction. Application of the 69kg N/ha and 30 kg P/ha interaction increased number of grains per spike by 116.5% as compared with the control treatment. The highest grain yield (6339.22 kg/ha) was obtained at treatment combinations of 69 kg N/ha and 30 kg P/ha, followed by 69 kg N/ha and 20 kg P/ha.Application of 69 kg N/ha and 30 kg P/ha interaction increased the grain yield by 145.7% as compared with the control treatment. Relatively high dry biomass yield (18708.33 kg/ha) was obtained due to treatment combination of 69 kg N/ha and 30 kg P/ha and followed by 69 kg N/ha and 20 kg P/ha which was 18236.11 kg/h. Application of the 69 kg N/ha and 30 kg P/ha interaction increased the biomass yield by 56.99%and straw yield by 32.5% as compared with the controltreatment.The effect of N on 1000-grain weight was highly significant ($P \leq 0.001$), while the interaction was significant ($P \leq 0.05$). The lowest harvest index (22%) was found in control plot and while the highest harvest index (34%) was recorded with interaction of 69 kg N and 30 kg P ha^{-1}.The economic analysis revealed that the interaction of 69 kg N and 30 kg P ha^{-1} gave marginal rate of return4617.32 Ethiopian birr ha^{-1}and considered to be recommended for farmers atJimma Arjo district. Since the increment trend of grain yield with N and P was not ceased to their maximum tested rates, more rates should be experimented in the future to investigate the declining point of the economical yield for these locations.

Keywords:*Wheat, Plant height, Tiller number, Biomass yield, grain yield*

1. INTRODUCTION

Wheat (*T. aestivum*.L,) belongs to the grass family Poaceae and to the tribe Hordeae in which several-flowered Spikelets are sessile and alternate opposite side of the rachis forming a true spike. Feldman and Sears (1981) listed 13 diploid, 12 tetraploid and 5 hexaploid species of Triticum of which, only three species are of commercial importance. These are *Triticum aestivum*, *Triticum durum* and *Triticum compactum*. Most of the wheat grown throughout the world is hexaploid (*T. aestivum*), which is commonly referred to as bread wheat. This includes the vast majority of varieties, which show great diversity in agro-ecological adaptation and utilization (Gooding and Davies, 1997).

Ethiopia is one of the largest wheat producers in SSA (Minot *et al.*, 2015) with an estimated area of 1.696 million ha and production of 4.642 million tones (CSA, 2017). The area suitable for wheat production falls between 1,900 and 2,700 m above sea level and is produced exclusively under rain fed conditions (White *et al*., 2001). Bread wheat is one of the most important cereals cultivated in Ethiopia. It ranks fourth after teff (Eragrostis tef), Maize (Zea mays) and Sorghum (Sorghum bicolor) in area coverage and third in total production (CSA, 2017). The national average yield of bread wheat in the country is 2.675 tons/ ha (CSA, 2017). According to FAO (2002), declining of soil fertility has been identified as one of the most important constraints to limit food production in Ethiopia in particular and Africa in general. This low productivity can be enhanced through improved crop management practices including application of fertilizers. High yielding wheat varieties demand adequate nutrient supply to produce maximum grain yield (Ali &Yasin, 1991).Mean wheat yields increased from 1.3 t ha^{-1} in 1994 (CSA, 1995) to 2.675 t ha^{-1} in 2016 (CSA, 2017), which is well below experimental yields of over 5 t ha^{-}1 (Mann and Warner, 2015). The yield gap of over 3 t ha^{-1} suggests that there is potential for increasing production through improved soil and crop management practices; particularly increased use of fertilizers and an adequate soil fertility maintenance programs.

Statement of the problem

Researchers in the southeastern, northwesternand southern wheat growing regions of the country have conducted series of on-farm fertilizer response trialsaccording to ATA (2016). The response of these trials indicated not only an increase in wheat yields and net return to the farmers but also demonstrated the advantages of site specific fertilizer recommendations in sustaining wheat production in the highlands of Ethiopia (Amasl *et al.,* 2000). ATA (2016) reported dramatic differences in fertilizer response and economic optimum levels across zones, suggesting the blanket recommendations on national level are not appropriate and that site specific recommendation would be more beneficial. According to Oromia National, State Agricultural Bureau Crop Production Package (2015) and ATA (2016),in the study area there is no any visible recommendation of NP for bread wheat except the blanket recommendation of UREA100 kg and 100 kgTSPha^{-1}in the study area.

For East Wollaga Zone, found in Oromia region, wheat is one of the major cereal crops. Similarly, it is one of the most widely grown crops around Jimma Arjo, and mainly produced for the purpose of both house hold consumption as well as marketing. It is grown during the main cropping season (July to December). Traditionally, the biomass of the crop after harvest is left in the field for animal feed. Straw after threshing is also used mostly as animal feed. The wheat variety Huluka is a nationally released variety in 2012 for wider cultivation. Currently, it is under production throughout east Wollaga. It was introduced to the Jima Arjo area lately and it has got good acceptance and yield performance as compared to other high yielding varieties of wheat. Additionally, farmers valued it due to its plump seed, white grain color and also in terms of grain yield Huluka was the highest. However, the response of this variety to different levels of N and P has not been experimentally tested and verified in East Wollaga Zone in general, and in Jimma Arjo area in particular. Therefore, this research is initiated with the following objectives;

General objectives

- To investigate the effect of different rates of N and P fertilizers and their combinations on wheat growth, yield and yield components

Specific objectives

- To determine effect of N on growth, yield and yield components of wheat
- To determine effect of P on growth, yield and yield components of wheat
- To determine interaction effect of N and P on growth, yield and yield components of wheat
- To identify the economic optimum N and P rates for wheat production in Jima Arjo

2. LITERATURE REVIEW

2.1. Wheat importance

Wheat is a major world food crop grown in both developed and developing countries. It stands in relative importance next to that of maize and rice as essential crops required to meet present and future food demands (Joshi, 2007). Of these crops, wheat represents approximately 30% of total cereal production (Fageria *et al.*, 1997). In 2009-2010, global wheat production was approximately 645 million tons (Quail *et al.*, 2011). It is expected that this value will need to increase significantly to match food demands of the growing world population by 2050. How this will be achieved is unknown, as simple expansion of cultivated arable land is not expected to increase but rather decrease as a result of growing urbanization, increased soil erosion and drought and salinity affected areas (Joshi, 2007).

2.2. Role of N in plant growth

N is an important factor limiting plant growth and productivity worldwide. Plants are provided N from both atmospheric air and soil minerals. The ability of plants to capture N naturally or that applied as N fertilizers, is one of the critical steps limiting the efficient use of N by plants. Despite N being one of the most abundant elements on earth, N deficiency is one of the most common problems affecting plant growth worldwide. Plants lacking N show stunted growth and yellowish leaves and will often fail to meet expected yields. Plants in general contain 3-5% N in their shoot tissue biomass, which is by far the most abundant soil derived nutrient outside of oxygen, hydrogen and carbon. Plants absorb N from the soil in the form of $NO3^-$ and $NH4^+$ ions. Most N uptake is in the form of $NO3^-$, which moves from the soil solution into the plant root cell with absorbed water. $NO3^-$ is then either stored in the vacuole or reduced in the cytosol and plastids eventually to $NH4^+$ through the activity of nitrate and nitrite reductase (NR, NiR) respectively. $NH4^+$ can then be assimilated to produce more complex N containing compounds (Lam *et al.*, 1996). These compounds include chlorophyll that captures light to be used during photosynthesis. N is also an essential component of nucleic acids (DNA and RNA), amino acids, vitamins (e.g.: biotin, thiamine, niacin and riboflavin) and all proteins and a vast array of N containing organic molecules.

Like most cereal crops, wheat is very sensitive to poor N nutrition but very responsive to N fertilization. Wheat is a fast growing crop where high levels of available N in the soil are often required to meet plant demand. When soil N is low, yield is often reduced due to a reduction in plant vegetative growth (tillering). Nitrogen deficiency symptoms in wheat are typical of most plants where older leaves yellow (due to less chlorophyll content). Plant demand for N is often met using crop rotations with N_2-fixing legume crops where legume/wheat rotations depend on less N fertilizer than wheat/wheat or wheat/rice (cereals) rotations. Most wheat production involves N fertilizer application before or at sowing or 6 to 8 weeks after sowing (McDonald *et al.,* 1992).

Nitrogen is available in most soils in the inorganic forms as $NO3^-$, $NH4^+$ and N_2 and in the organic form as amino acids and urea. The dominant form of N used by higher plants is often $NO3^-$ which is common in warm, aerated and PH balanced agricultural soils and natural ecosystems (Crawford and Glass 1998). $NH4^+$ on the other hand is found in cool soils with low pH and or under anaerobic conditions, that means irrigated rice fields (Kronzucker*et al.,* 1999). Thus depending on the soil conditions plant access to N will vary as willselectivity among different plant species. Nitrogen fertilizer application often develops initial root systems that lead to the growth of vigorous root systems that recover N fertilizer and N from the soil than the root system of an unfertilized crop (McDonald *et al.,* 1989). N uptake depends on root architecture and available soil moisture, so topdressing of N-fertilizer depends on soil moisture (rainfall) to be present soon after N application. The demand of N-fertilizer by plant at early growth stage is small because plants are young and rely on residual N in the soil. N demand will increase when plants develop into their later stages of development and maturity, this demand will be met with additional applications. The plants reach peak demand at tillering, heading and grain filling stages. When there is insufficient N at the seedling stage there is a reduction in tillering (increased tiller mortality) and loss of soil water from evaporation.While excessive seedling N causes lodging, foliar diseases and haying-off. The use of split application methods that correspond to plant demand at different growth stages is an important strategy that improves N use (NUE) by plant and reduces N loss as a result of volatilization, denitrification or leaching (Ehdaie*et al.,* 2010).

2.2.1. Nitrogen uptake by plant roots

The uptake of N-fertilizers occurs when N is readily available in the soil solution at the root zone and when plant demand for N exists. When these conditions are met, $NO3^-$ and

$NH4^+$ transporter systems (see below) are expressed across various cell types across the roots for initial uptake and redistribution across the root to the stele. The form of N ion taken up by plants depends on the plant species and soil properties including texture and chemistry. Plants that grow in low pH anaerobic soils, $NH4^+$ or amino acids are often the preferred N form. In contrast $NO3^-$ uptake is more prevalent in aerobic and neutral pH soils (Maathuis, 2009). N uptake by wheat has shown preference between N forms, where net uptake was increased 35% when supplying at least 25% of the N as $NH4^+$ compared to all of the N as $NO3^-$ (Wang and Below 1992). It is assumed this selectivity is partly a result of the energy costs required for $NO3^-$ assimilation relative to $NH4^+$. Assimilation of $NO3^-$ requires the energy equivalent of 20 ATP per mol of $NO3^-$, whereas $NH4^+$ assimilation requires only 5 ATP mol-1 of $NH4^+$ (Salsac *et al.,* 1987). This energy savings could lead to more efficient N and C capture when plants are supplied with greater amounts of $NH4^+$ (Huffman, 1989).

Nitrogen is a mobile element in the soil where its uptake from the soil solution is best met when plant demand exists. The quantity and rate of N uptake is very much dependent on the ion concentration in the soil solution, the availability of water which supplies the majority of N to the roots through mass flow and the capacity of the roots (position and density) to enable plant interception (Russell, 1977). Mass flow is a process where dissolved N ions in soil water is delivered to the root based on the hydraulic pull of water to the plant as a result of shoot evapotranspiration (Barber *et al*., 1984). The concentration of N in the soil solution close to the root may be high or low depending on the balance between the rate of supply to the root and the rate of absorption into the root. N can also diffuse to the root following a concentration gradient from high to low, however the rate of diffusion is governed by distance, thus diffusion only really becomes important close to the root surface. Root interception is influenced by root density and surface area, which varies due to soil structure, plant genetics and agronomy practice. Maximum root surface area enables greater capacity for ion absorption from the soil solution and or soil particles (Barber *et al.,* 1984).

Nitrogen has a strong influence on root development in most plants. Plants tend to develop smaller roots when N is readily available in the soil solution. Under these conditions it is the plant‘s physiological capacity to accumulate and assimilate N through the activity of N transport and assimilatory proteins rather than through changes in root morphology (Glass *et a*l., 2003). At low levels of N in the soil solution, many plants will commit extra carbon resources to further develop root systems to enable greater penetration of the soil (Garnett *et al*., 2009).

Improving the ability of root systems to recover soil $NO3^-$ by earlier and faster uptake is an efficient strategy to improve the synchronization between the availability of $NO3^-$ in the soil profile and the NO3- demand by the wheat crop (Liao *et al.*, 2004). This strategy states that roots grow fast in order to intercept and capture the $NO3^-$ before it moves below the rooting profile. Genotypic differences associated early root biomass, root branching and root length have been linked to the early uptake of N in wheat genotypes that differ in overall vigour (Liao *et al.,* 2004). When N uptake occurs, both the xylem and phloem is involved in transporting N in the plant. The xylem is the principle path for long distance transport of N solutes ($NO3^-$ and $NH4^+$) from the roots to organs that transpire (Pate *et al.,* 1980). The xylem therefore transports $NO3^-$ from the roots to shoots in addition to N reduced to $NH4^+$ in the roots (Schrader *et al.,* 1984). The phloem is the principal transport path of N stored or assimilated in the shoot and transported to other parts of the plant (that means leaf to seed) (Liao *et al*., 2006).

2.2.2. Managing nitrogen use

Nitrogen is a dynamic and highly mobile element in agricultural soils causing environmental problems through increased N pollution that acts both locally and globally (Gruber and Galloway 2008). The extensive use of N-fertilizers in agriculture has created major problems worldwide through N based pollution of surface and underground water supplies. Therefore, concentrations of $NO3^-$in agricultural products and drinking water should be minimized. Although the fact that the main source of $NO3^-$ intake is food, not water, the World Health Organization (WHO, 1970, modified in 1993) set a recommended limit for drinking water of 50 mg $NO3^-$ per liter. The main issue was the microbial conversion of $NO3^-$ to nitrite ($NO2^-$), which was associated with problems involving nitros- amines and methaemoglobin. The so-called blue-baby syndrome (methaemoglobinaemia), for example, arises from bacteria-contamination and not from ingesting too much $NO3^-$ as originally supposed. Research work even suggests that ingested $NO3^-$ provides gastro-intestinal protection against food-borne pathogens and epidemiological studies show a reduced rate of gastric and intestinal cancer in groups with a high vegetable based nitrate intake. Elevated concentrations of nitrate in streams or aquifers are mostly due to excessive or poorly used N applications in agriculture. High NO_3^- concentrations in water also occurs in years following drought. High NO_3^- concentrations in forage can cause sickness and death in livestock when grazing due to NO_3^- accumulation in plant tissue. The accumulation occurs due to high temperature, drought, other nutrients deficiency and plant disease (IFA, 2007).

Urea is a common N fertilizer used in agriculture systems worldwide. It is estimated that more than half of all fertilizer used globally is in the form of urea. The benefit of using urea as a fertilizer is due to its high N content (46% N), high solubility, and low expense to manufacture, store, and transport. However, urea is susceptible to hydrolysis followed by ammonia volatilization. During hydrolysis, urea N is converted into NH_3, which subsequently reacts with a proton to produce NH_4^+. Under alkaline conditions, the equilibrium of $NH_3 + H_2O \leftarrow \rightarrow NH_4^+ + OH^-$ shifts more to the NH_3 ion, increasing volatilization losses that leads to lower the efficiencies of fertilizer N used by plants. Soil texture and organic C content can also play an indirect role in N gaseous loss. For example, soils with high sand content generally have lower rates of N_2O production than do clay soils. Leaching intensity is controlled by soil texture. Lighter sandy soils are more prone to leaching losses than are soils with greater clay content (Gilbert *et al.,* 2006).

2.2.3. Nitrogen sustainability

Globally farmers often apply an excess of N as insurance against low yields. This approach can lead to increased losses of N from agriculture systems and poor NUE in plant production systems. One of the challenges for plant breeders will be to increase NUE in a manner that will reduce production costs and minimize environmental pollution while at the same time meeting both yield and quality measures (Daberkow *et al.,* 2000).

More sustainable agricultural practices that manage N-delivery and its use across a crop production cycle are currently highly sought. For example, the use of split N application procedures, where delivery occurs at a time when plants need N during their life cycle will help to achieve improved NUE that reduces N-loss while sustaining or improving yield and quality (Matson *et al.,* 1998). In light of the growing concern about N-fertilizer use and its direct economic costs and impacts on the environment, most nations are investigating alternative strategies to make agriculture more sustainable. A reduction in the amount of N- fertilizers applied to the field will help to achieve this but at the same time there is a requirement to maintain and or increase yield to meet future food demand. Sustainable agricultural practices, such as N-fertilization based on demand, effective use of crop rotations with N-fixing legumes and the establishment of ground covers and burial of N-rich crop residues are encouraged (Hirel *et al.,* 2007). Others strategies to improve N efficient use are to use genetic modification and/or to breed for new varieties that take up more organic or inorganic N-from the soil N-and utilize the absorbed or metabolized N-more efficiently without compromising yield (Hirel and Lemaire 2006).

2.2.4. Nitrogen and the relationship between yield and yieldcomponents in wheat

The yield of wheat is a function of many factors, among them the cultivars and nitrogen fertilization being the most important ones. Grain yield is the most integrative character because it is influenced by all factors that determine productivity. Nitrogen is the most important plant nutrient needed to obtain high wheat yields. With fertilizers becoming important inputs to maximize crop yield and nitrogen fertilizer being determinant in wheat production in Ethiopia, several N fertilizer trials have been undertaken to determine the optimum levels for economically profitable yields (DZARC, 1989). Results indicated that nitrogen rates had significant positive effect on yield up to 230 kg $ha^{-}1$. Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign *et al.*, 2001).

Thus, there is quantitative relationship between crop yield and accumulation of N by plants that means when the soil cannot supply with adequate N, the crop yield will be constrained (Sinclair, 2002). This indicates that yield can be considered as a good measure of the collective impact of environment on plant growth, (that means the more favorable the environment, the more the effective N applied is and hence the greater the yield). Thus, properly applied nitrogen fertilization has a positive effect on crop yield. At a high level of such fertilization, it is advantageous to apply it twice or three times to plants at different stages of crop development (Makowska *et al.*, 2008).

Studies on N application on Nit sols at Holetta and Vertisols at Ginchi showed that application of 50% of the total nitrogen at sowing and the rest at full tillering stage significantly increased grain yield as well as the protein content of wheat. Hence, nitrogenous fertilizers influence yield and grain protein percentage to varying degrees, depending on the rate of N application, on the level and form of soil N and on available water in the soil (Asnakew *et al.,* 1991).

Yield and yield related traits of wheat are influenced by several factors of which nitrogen fertilization is the most important. Application of nitrogen improves various yield related traits like 1000-grain weight, more productive tillers, more number of spikes per unit area, number of grains per spike and biological yield, thus resulting in higher yields. And also the plant height, flag leaf area, and tillers number and dry weight per unit area of wheat were increased with increasing N rates up to 120 kg $ha^{-}1$(Guarda *et al.,* 2004).

Alam *et al*. (2007) reported that the application of different rates of nitrogen produced significantly positive impact on yield and yield related traits of wheat. The entire yield related traits showed positive increase with the increased level of nitrogen applications. In their study, application of 140 kg N $ha^{-}1$ exhibited the highest performance among the treatments and statistically significant over the control.

A beneficial effect of nitrogen application on wheat was also reported by Sobh *et al.* (2000). They noted that numbers of tillers and spikes per m^2, plant height, spike length, number of spikelet and grains per spike, grain and straw yields of wheat increased with increasing N level. Nitrogen rates significantly influenced spike length and protein percentage too. In their experiment, increasing nitrogen rates from 70 to 110 kg N $ha^{-}1$ resulted in progressive increase in dry matter accumulation. The highest values were obtained at maximum nitrogen rate and the lowest ones at minimum nitrogen rate (Sobh *et al.,* 2000). However, Briggs (1991) indicated that grain yield related traits of cereals vary widely with cultivar, soil fertility level and other growth limiting factors such as water stress and planting dates. In general, yield and yield related traits of high yielding varieties increase with increasing levels of nitrogen (Behera *et al.,* 2000).

An increase in straw yield with nitrogen application on cereals particularly wheat and barley, is well documented. Straw yield was increased with increasing N rate up to 160 kg $ha^{-}1$ for winter wheat, but no effect on spring wheat which might be due to shorter growing period. Straw yield was increased as N rate was increased from 0 to 120 kg $ha^{-}1$, but no response beyond the latter rate. Similarly, straw yield of two durum wheat varieties has increased as N rates increased from 0 to 120 kg $ha^{-}1$. In general, N application has increased straw yield of wheat, but the effect could vary with seasonal conditions. One of the principal factor which influences yield and quality of crop is N-fertilization rates (Rachon, 2002).

Several researchers in Ethiopia have reported that the role of N in wheat production in the highlands as substantial increases in yield and yield components have been affected with the application of N fertilizer. Increasing levels of nitrogen increased grain and dry matter yields, number of kernels per head, number of tillers and plant height of wheat (Tilahun, 2017). Abdo *et al*. (2012) also reported that nitrogen rates had significant effect on durum wheat yield and yield related traits such as: plant height, spike length, biomass yield, harvest index, straw yield. Application of 69 kg N $ha^{-}1$ resulted the highest plant height (87 cm), spike length (6.1 cm), biomass yields (11363.8 kg $ha^{-}1$), straw yields (7708.5 kg $ha^{-}1$) but at nil N application results the highest harvest index (36%). Tilahun (2017) also reported that both sole N rates and N timing had highly significant difference on wheat plant parameters and as a conclusion both sole applications of 92 kg $ha^{-}1$N rate twice split application timing in the recommended form.

Nitrogen is one of the most limiting elements in natural ecosystems (Vitousek *et al.,* 2002) and in most non-fertilized agriculture will limit potential yield. As a consequence, N fertilizers are applied in order to increase yield and improve crop quality. Wheat plants respond favor ably to N-fertilization which commonly consists the addition of NH_4^+, NO_3^- or urea alone or in combination with each other. When soil N is low, N fertilizers are often supplied to meet plant demand to maintain yields in most crops. However, when N is applied in excess, it can often have a detrimental effect on yield due to increased vegetative growth relative to seed production, increased lodging and increased susceptibility to disease and haying-off (van Herwarden *et al.,* 1998). Although N can be detrimental when used in excess, the proper timing of N fertilizer application and its utilization is important in the context of maximizing growth, yield and quality. Wheat N requirements are greatest during the rapid vegetative growth stages and will most likely benefit from N application/availability during this period.

Grain yield and grain protein content are ultimately determined by the amount of N fertilizer application and its effective uptake from the soil solution. When N becomes available to the plant, primary N uptake seems to be the most promising strategy to enhance the amount of N within the plant to increase both yield and grain protein. This is further supported by the fact growers traditionally benefit from higher returns when grain protein content is high. For wheat, maximum N uptake occurs after tillering and before flowering. N accumulated during these growth stages is used primarily to establish yield potential. N accumulated after flowering has little effect on yield but can increase grain protein content under favorable conditions (Flowers *et al.,* 2007).

Variety selection that takes into accounts both quantity and quality must be adhered to when considering sustainable N management systems. The N harvest index (NHI) is the ratio of seed N to total shoot N and is considered to be a good measure of how efficiently the plant utilizes acquired N for the production of grain protein. However, the total shoot N stored in the grain can vary widely (from 40 to 90%) due to the variation of seasonal precipitation, temperature, wheat species and the type of farming practice. Drought in particular is a significant problem to rain-fed production systems when fertilizer enhanced canopy size becomes a detriment during final seed growth and filling. This response suggests grain protein content has limited genetic heritability that can be actively selected for across a range of growing conditions (Feil *et al.,* 1997).

2.3. Phosphorus fertilizers

Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly development of lateral roots and fibrous rootlets (Brady and Weil, 2002). As a result of continued land degradation and rapid population growth, addressing poor soil fertility in the farming land in the tropics including Ethiopia has become a major issue to achieve food security at household level (FAO, 1984). In the semiarid areas of Ethiopia such as in Tigray, poor soil nutrient availability in the farming land is one of the major crop production constraints next to low soil moisture stress .The root causes of the current low soil fertility problem in this part of the country are soils of inherent low fertility; continual nutrient mining due to continues cropping without replacement of nutrients taken together with the harvest and top soil removal through water erosion (Kidane Giorgis and Getachew Alemu, 1994). Even though tremendous amount of research have been conducted on phosphorus for the last many years, its behavior in the soil and availability to crops are still not fully understood. Therefore, a continued evaluation of fertilizer effectiveness should be exercised through short and long term experimentation (Tisdale *et al.,* 2002), and different methods of fertilizer application need to be assessed in-depth for a more meaningful correlation with yield and plant uptake (Mesfin, 1998).

2.3.1. Effect of phosphorus fertilizer on growth and yield of wheat

There are many investigations with respect to the effect of phosphorus fertilization on wheat productivity. Wheat experiment had been conducted in Ethiopia in major wheat growing areas of north western Ethiopia; such as Gozamen, Awabel, Machakel, Gonchasiso-Enebssie, Enarge-Enawga and Debay-Tilatgin, Burie, Banja and Wogera for three consecutive years (2000-2003). The results revealed that increased yield and yield component of wheat was observed with application of P fertilizer and the highest biological and grain yield was obtained at the application of the highest P fertilizer rate (92 kg P_2O_5/ha) with 184kg/ha of N interaction in all locations (Minale *et al.*, 2006).

Besides study conducted on Kulumsa Agricultural Research Center, Ethiopia showed that out of the measured traits; days to seedling emergence, days to heading and maturity were highly significantly ($p \leq 0.01$) affected by methods of P placement and P rates while total above ground biomass and grain yield were significantly ($p \leq 0.01$) influenced by the P rates. Moreover, days to emergence, days to heading and maturity were highly significantly affected by interaction of main plot (methods of P placement) and subplot (P rates). Application of 30 kg P/ha increased the grain yield and biomass yield of wheat by 6.5 qt/ha (23.73%) and 11.27 qt/ ha (15.17%) respectively when compared with the no P application. The response to the increased application of P was associated with improvement in the concentration and uptakes of P and N that could account for the increase in yield. On the other hand, N and P uptakes by wheat ranged from 42.01 kg N/ha with no P to 52.28 kg N/ha at the rate of 30 kg P/ha, and 20.08 kg P/ha with no P to 29.06 kg P/ha at rate of 30 kg P/ha, respectively (Endalkachew, 2006).

An experiment carried out from 2007 to 2008 in Enderta, North Ethiopia indicated that application of different rates of phosphorus fertilizers had significantly increased both grain and straw yield of wheat (Abreha *et al.*, 2008). According to this report increased application rates of 10 and 20 kg P/ha, increased the grain yields of wheat by 4 and 11 percent respectively over the control. Furthermore research conducted on Samre, North Ethiopia indicated that grain yield, plant height, above ground dry matter yield and panicle length of wheat HAR250 variety increased significantly with increasing P rates and the highest grain yield, plant height, above ground dry matter yield, panicle length and 1000 seed weight were found at 20 Kg/ha of P(Fiseha,2008). He also indicated that the highest grain yield of wheat (34.35Q), and above ground dry matter yield (92.00Q) were found at 46kg/ha P with interaction of 75kg/ha of urea.Another research conducted in northern Ethiopia Hawzen district to investigate effect of phosphorus fertilizer level on the growth and yield of wheat also indicated Phosphorus application at a rate of 46 kg P_2O_5/ha increased significantly grain and straw yields by 38 % and 46 %, respectively than control (Bereket *et al.,* 2014). According to this report the days to heading and maturity were significantly ($P \leq 0.05$) reduced as the level of phosphate fertilizer increased. However, spike length, plant height, number of nodes, number of effective tillers, lodging index, biomass yield, grain yield and harvest index increased with an increased level of phosphate fertilizer and the optimum grain yield was obtained by applying phosphate fertilizer rate of 46 kg P_2O_5/ha.

2.4. Interaction of N and P fertilizers on growth and grain yield of wheat

Nutrient deficiency is one of the major constraints to wheat (*Triticum aestivum* L.) production in Ethiopia and it has been observed that application of N and P significantly increased all crop parameters studied (Amsal *et al*., 2000). According to Amsal *et al*. (2000), the mean grain yield response to fertilizer application was 163% on Vertisols and 76% on Nitosols compared to the unfertilized control mean, whereas wheat biomass increased by 148% on Vertisol and 77% on Nitosols against the control, on both soil types. Fertilizer application produced taller plants, larger number of spike/m2, heavier thousand grain weight and more grain/m2 versus unfertilizedwheat. The new high yielding cultivars have a higher nutrient requirement because of their increased yield potential. In particular, the profitability of the wheat yield response to application of N and P fertilizers for improved crop nutrition and 2, 4-D for weed control have been verified under farmers condition across a range of soil types in Ethiopia (Minale *et al*., 1999).

Dramatic response of bread wheat to addition of N and P was demonstrated in 52 on farm fertilizer trials in a high six priority agro-ecological zones of Ethiopia (Adet in Gojam, Sinana in Bale and Gonde, Robe, Asasa and Bekoji in Arsi). These on-farm trials were conducted by established zone-specific fertilizer recommendation for bread wheat production under representative small-holder circumstances compared to the common practice of no application of fertilizer to bread wheat. The economic optimum fertilizer in these trials increased bread wheat grain yields on average by 72% generating a total rate of return of approximately 260% on farm cash investment. Wheat grain yield responded significantly to both N and P in each soil zone, although the responses to N were more pronounced (Tanner et al., 1993). Amsal *et al*. (2000) reported annual crop yields that were generally greater by 80% of two years spring wheat-fallow yields when grown in an annual cropping system with adequate N and P fertilization.

In many crop species N and P interact closely in affecting maturity. Excess N may delay plant maturity and cause the plant more susceptible to disease and insect pests. It also makes high shoot-to-root ratios while abundant P hastens maturity and in contrast to excess N, it increased root growth relative to shoot (Salisbury and Ross, 1992; Brady and Weil, 2002). Without P application, N efficiency declines thereby indicating interaction between these nutrients (FAO, 2000). Similarly nitrogen promotes phosphorus uptake by plants by increasing top and root growth, altering plant metabolism, and increasing the solubility and availability of P. Increased root mass is largely responsible for increased crop uptake of phosphorus. It has been reported that increasing levels of N and P application and their interaction significantly and positively affected grain yields of wheat and rate of N and P application had significant effects on concentration of N and P in the kernels (Eylachew, 1996).

3. MATERIALS AND METHODS

3.1. Description of the experimental site

The experiment was conducted in Jimma Arjo District Western Ethiopia in 2018/2019 under rain fall condition. Jimma Arjo is geographically located at 376 km West of Addis Ababa at an elevation of 1351-2598 meters above sea level and situated at 8° 39' 59.99''N Latitudeand36° 39' 59.99''ELongitude. The experimental site receives an average annual rainfall of 1,900-2,800 mm with maximum and minimum temperatures of 29 and 13^0C, respectively (Arjo Rural Land Users Office, 2016).

3.2. Experimental material

Wheat variety Huluka was used as experimental material.Huluka was released in 2012 for its high yield (44-70 ton per/ha), with one hundreds thirty three (133) days for physiological maturity and rain fall requirement of 500-800 mm and altitude of 2200-2600m above sea level (ATA 2016). It was selected because it is currently under production throughout east Wollaga. It was introduced to Jima Arjo area lately and it has got better acceptance and yield performance as compared to other high yielding varieties of wheat.

3.3. Treatments and experimental design

The experiment consisted of two factors, rates of N and P fertilizers which were arranged in Randomized Complete Block Design (RCBD) and replicated three times. Rates of N fertilizer consisted of application of 0, 23, 46 and 69 kgha^{-1} and Rates of Pfertilizer consisted of application of 0, 10, 20, and 30kgha^{-1}.

Table 1. Treatment Combination

Level of Nitrogen	Factorial treatment combinations			
	Level of Phosphorus			
	P_0,0 kg/h	P_1,10 kg/h	P_2, 20 kg/h)	P_3,30 kg/h
0 kg/ha(N_0)	N_0P_0	N_0P_1	N_0P_2	N_0P_3
23 kg/ha(N_1)	N_1P_0	N_1P_1	N_1P_2	N_1P_3
46 kg/ha(N_2)	N_2P_0	N_2P_1	N_2P_2	N_2P_3
69 kg/ha(N_3)	N_3P_0	N_3P_2	N_3P_2	N_3P_3

3.4. Experimental procedures

The field was plowed with oxen four times to make fine seed bed. Plot size was 1 m x 2 m ($2m^2$). Each plot consisted of five rows with no space between plants and 20 cm between rows with a row length of 2m. The distance between successive plots and adjacent blocks was 0.5 m and 1 m, respectively. P fertilizer was used as a source of different nutrients.Full doses of P fertilizers which varied depending on treatments were applied as side dressing at sowing time. Urea fertilizer was used as a source of nitrogen and 1/3 doses, which varied depending on treatments was applied as side banding at sowing time and 2/3 doses were applied at tillering stage.Other agronomic practices were kept uniform for all treatments as recommended and adopted for the location.

3.5. Soil sampling and analysis

Soilsamples analyzedfor their chemicalproperties(soilpH,OC,N,P,andOM)(AOAC,2005).Theorganicmatter content wascalculatedbymultiplyingtheresultoforganiccarbonby1.724(OM=OCx1.724).

SoilpH:wasmeasured in a 1:2 soil:waterratiousingaglasselectrodepHmeter.Tengramssoilwasweighedintoa60mlplasticshakingbottlesand20mlofdistilledwaterwasaddedtothesoilwithadispenser.Thesoil-watersolutionwasshakenthoroughlyfor10minutes,afterthis,thesuspensionwasallowedtostandfor20minutes,then,re-stirredforanothertwominutes.Themixturewasallowedtosettlefor30secondsbeforethecalibratedpHmeterwasusedtoreadthepHbyimmersingtheelectrodeintotheupperpartofthesoilsuspensionandthepHvaluesrecorded(Rhoades,1982).

Organic carbon:wasdeterminedbythemodifiedWalkleyandBlackprocedureasdescribedbyOlsonand Sommers(1982).Thisprocedureinvolvesawetcombustionoftheorganicmatterwithamixtureofpotassiumdichromateandsulphuricacid.Afterreaction,theexcessdichromateistitratedagainstferroussulphate.Onegramofsoilsamplewasweighedintoan Erlenmeyerflask.Ablanksamplewasincluded.Tenmillilitersof1.0*N*(0.1667*M*)potassiumdichromatesolutionwasaddedtothesoilandtheblankflask.Tothis,20mlofconcentratedsulphuricacidwascarefullyaddedfromameasuringcylinder,swirledandallowedtostandfor30minutesinafumechamber.Distilledwater(250ml)a ndaconcentratedorthophosphoricacid(10ml)wereaddedandallowedtocool.Onemillimeterofdiphenylamineindicatorwasaddedandtitratedwith1.0*M*ferroussulphatesolution.

Total nitrogen:wasdeterminedusingKjledahlmethodasdescribedbyBremnerandMulvaney(1982). A0.5gsoilsamplewastransferredintoaKjeldahl extraction flaskand5mldistilledwateraddedtoit.After30minutes,5mlconcentratedsulphuricacidandseleniummixturewereaddedandmixedcarefully.ThesamplewasplacedonaKjeldahlextractionapparatusfor3hoursuntilaclearextractionwasobtained.Theextractwasdilutedwith50mldistilledwaterandmixedwelluntilnomoresedimentdissolvedandallowedtocool.Thevolumeofthesolutionwasaddedto100mldistilledwaterandmixedwell.A25mlaliquotofthesolutionwastransferredtothereactionchamberand10mlof40%NaOHsolutionwasaddedfollowedbydistillation.Thedistillatewascollectedinaflaskcontaining2%boricacid.Thedistillatewastitratedwith0.02*N*HC1solutionswithbromocresolgreenasindicator.Ablankdistillationandtitrationwerealsocarriedouttotakecareoftracesofnitrogeninthereagentaswellasthewaterused.

Available phosphorus: AvailableP(PPM)wasdeterminedbyBrayIImethodEthioSIS(2014)usingammoniumfluoride(NH_4F)asthereducingagent.Thereadilyacid-solubleformsofphosphoruswereextractedwithHC1:NH_4Fmixture(Bray'sIImethod).Phosphorusextractedwasdeterminedonaspectrophotometerbytheblueammoniummolybdatemethodwithascorbicacidasareducingagent.A2gsoilsamplewasweighedintoa50mlshakingbottleand20mlofextractingsolutionofBray(0.03*M*NH_4Fand0.025*M*HC1)wasadded.Thesamplewasshakenfor a minutebyhandandthen,immediatelyfilteredthroughwhatmanNo.42filterpaper.Onemillilitreofthestandardseries,theblankandtheextract,2mlboricacidand3mlofthecolouringagent(ammoniummolybdateandantimonytartartesolution)werepipetteintoatesttubeandhomogenized.Thesolutionwasallowedtostandfor15minutesforthebluecolourtodevelopitsmaximum.TheabsorbancewasmeasuredonaSpectronic21DSpectrophotometerat660nmWavelength.Astandardseriesof0,1.2,2.4,3.6,4.8,and6.0mgwaspreparedfrom12mgP/lstocksolutionbydiluting0,10,20,30,40and50mlof12mgP/lin100mlvolumetricflaskandmadetothevolumewithdistilledwater.Aliquotsof0,1,2,4,5,and6mlofthe100mgP/lofthestandardsolutionwereputin100mlvolumetricflaskandmadetothe100mlmarkwithdistilledwater.

The analytic results indicated that the experimental soil of Jimma Arjo woreda was textured clay loam. The PH of the soil was 5.62 it is moderately acid and which is within the range of 4 to 8 suitable for wheat production (FAO, 2000). The organic carbon content (OC) of the experimental site was 1.37% (Table 1). Accordance with Sahlemedhin (1999), the soil of the location had low OC, who rated OC less than 1.74% as low. The EC of the soil was 98.85µs/cm which is non-saline. The organic matter content (OM) of the location was 2.34 which is low. According to Bashour *(*2007) P rating (mg $kg^{-}1$), P content of < 5 is very low, 5 to 10 is low, 10 to 17 is medium, and > 17 is high. Thus experimental site, available P content was very low, which was 0.48. Total N of the soil was (0.12 %), which is low; as rated by Bashour (2007) who rated total N < 0.05 very low, 0.05- 0.15 % low, 0.15-0.25 medium, 0.25-0.5 high and greater than 0.5 as very high.

Table 2. Properties of the experimental soil in Jimma Arjo District in 2081/2019.

Soil properties	Contents	Rates
pH	5.62	Moderately acid
Organic carbon	1.37	Low
Organic matter	2.34	Low
Electro conductivity (µs/cm)	98.85	Non-saline
Total nitrogen	0.11	Low
Available phosphorus	0.48	Very low

OC = organic carbon content, OM= organic matter content, EC = electro conductivity, TN = total nitrogen, Av.P=available phosphorus content

3.6. Data collection

3.6. 1. Phenology

Days to 50% heading: number of days from sowing up to the date when the tips of the panicles emerged from the main shoot, on 50% of the plant in a plot was recorded.

Days to 90% maturity: number of days from sowing up to the date when 90% of the crop stands in a plot changed to light yellow color was recorded.

3.6.2. Growth

Plant height (cm): - It was taken from ten randomly selected plants and measured from the base of the main stem to the tip of the panicle.

Spike length (cm): - length of the spike was measured by selecting ten plants randomly and measuring from the node (insertion point of panicle branch) to the tip of the panicle.

3.6.3. Yield and yield Components

Number of tillers per plant: The total number of tillers were recorded after flowering from 10 randomly selected plants per plot.

Number of grains per spike: This was determined as the total number of grains in each spike of randomly selected 10 plants per plot and it was recorded after above ground total biomass was recorded.

Total above ground biomass (kg ha^{-1}):- was measured after sun-drying for two days by sensitive balance.

Grain yield (kg ha^{-1}):- grain yield was measured by harvesting and threshing the grain from net plot area of each plot by sensitive balance and converted to kg per hectare. The grain yield was adjusted to 12.5% moisture content as (Hong and Ellis, 1996).

$$\text{Grain yield (kg ha}^{-1}\text{)} = \text{Yield obtained (kg ha}^{-1}\text{)} \times \frac{(100-\%\ \text{Actual Moisture Content})}{100-12.5}$$

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

Thousand grain weight (g):was determined based on the weight of 1000 grains sampled from the grain yield of each treatment using electronic seed counter and weighted with electronic digital balance and the weight was adjusted to 12.5% moisture content.

Harvest index:it was calculated as the ratio of grain yield per plot to total aboveground dry biomass yield per plot.

$$Harvest\ index\ (\%) = \frac{Grain\ yield\ \ per\ \ plot}{Aboveground\ dry\ biomass\ per\ plot} \times 100$$

3.7. Agronomic efficiency

Agronomic efficiency: is defined as the quantity of grain yield per unit of nutrient applied.

$$AE\ (kg/kg) = \frac{Gf - Gu}{F}$$

Where Gf is the grain yield of the fertilized plot (kg), GU is the grain yield of the unfertilized plot (kg), and F is the quantity of N plus P applied (kg).

3.8. Partial budget analysis

For economic analysis, a simple partial budget analysis was employed using CIMMYT approach. For partial budget analysis, the factors with significant effect were considered. The yield was adjusted by subtracting 10 % from average gain yieldto reflect the difference between yield obtained under the management of researchers and yield of farmers (CIMMYT, 1988).Then after, gross yield benefit was obtained by multiplying the adjusted yield by the price of grain per kg. Net benefit was calculated by subtracting total variable cost from gross benefit. The mean market price of wheat was obtained by assessing the local market at harvest (2019 cropping season). Since Profit (net revenue) is equal to total revenue (TR) minus total cost (TC), following formula was used to calculate profit.

Profit = TR- TC

$$MRR\ (\%) = \Delta NI / \Delta TVC \times 100$$

Where ΔNI = Change in Net Income; ΔTVC= change in Total Variable Cost.

3.9. Statistical data analysis

Normality of data was checked and all the measured parameters were subjected to analysis of variance (ANOVA) for factorial experiment in RCBD according to the General Linear Model (GLM) using SAS software version 9.3 (SAS, 2013) and the interpretations was made following the procedure described by Montgomory (2013). Least Significance Difference (LSD) test at 5% probability level was used for comparison of treatment means whichshowed significant differences.

3.9.1. Simple correlation analysis

The relationship between growth, yield and yiel components parameters was evaluated using Pearson's r correlation analysis following theguide lines antlined by Cohen's (1988).

4. RESULTS AND DISCUSSIONS

4.1. Crop Phenology and vegetative growth

4.1.1. Days to50 %flowering

Days to 50 % flowering was highly significantly ($p < 0.001$) affected by N rate and interaction with P, whereas the main Nhad also highly significant ($p < 0.001$)effect on days to 50 % flowering. The same to that the rate of P fertilizer had alsosignificantly affect days to 50 % flowering.The shortest duration for 50% flowering (65.3 days) was recorded at the rates of 69 kg ha^{-1} N and 30 kg ha^{-1} P (Table 3). This is due to nitrogen fertilizer is required for protein formation, which is associated with high photosynthetic reactivity, vigorous vegetative growth, and dark green color. The availability of sufficient nutrients resulted in rapid growth and hastened days to heading, while too little or no fertilizer resulted in slow growth and delayed heading (Bekelu, 2016). In line with this Fageria (2002) has also observed positive interaction of B, K and N fertilizers for improving crop yields and maturity. This result was also in line with the findings of Sewnet (2005) who reported early flowering with an increase in the rate of N application in rice.

4.1.2. Days to 90 % physiological maturity

The interaction effect of N and P fertilizer rate was highly significant ($P < 0.01$) on days to 90% physiological maturity. And also, the main effect of N and P was significantly influence days to 90% physiological maturity (Appendix table 1).

The highest number of days required for 90% physiological maturity (130 days) was recorded in the control (0 kg/ha N and P) interactionwhile (69, 20 kg/ha N and P) interaction showed the shortest growth period for days to 90% physiological maturity (127 days). The shortest time period required by the plants to reach maturity at higher rate of NP fertilizer interaction may be attributed to the increase in chlorophylls content, increased photosynthesis activity and increased energy stored to change from vegetative growth to flowering and maturity because of initiated hormones activity. This result is line with Bekelu (2016)who reported hastened days to physiological maturity of bread wheat from 158.75 to 152.96 days as nitrogen rates increased from zero to 92 kg ha^{-1}. In many crop species N and P interact closely in affecting crop maturity. Optimum supply of N might hasten plant maturity, while abundant P delays it (Brady and Weil, 2000).

4.1.3. Spike length

The interactionof N and P fertilizers significantly ($P < 0.001$) affected spike length; the effect of N alone was also highly significant ($P < 0.001$) (Appendix table 1). The highest spike length with respective value of 13.3 cm and 13.5 cm was recorded at the rate of 69/20 kg N/P ha^{-1} and 69/30 kg N/P ha^{-1} respectively which were not significantly different with each other. Increasing both N and P rates from 0, 0 to 69, 30 kg ha^{-1} increased spike length of bread wheat by 87.5%. (Table 3). These findings strongly justify, P fertilizer application by itself do not have significant effect on panicle length of wheat. But the combined effect optimum amount of P fertilizer with N fertilizer has significant effect on growth of spike length.The increase in spike length at the highest N and P interaction rate might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to the synergetic effect of the nutrients at the highest rate. This result agrees with the findings of Muluneh and Nebyou (2016) who reported the highest spike length (7.7 cm) for wheat at the rate of 50/150 kg N/P2O5 $ha^{-}1$. This result also agreed with the findings of Bekelu (2016) who reported that increasing N rate from 0 to 69 kg $ha^{-}1$ increased spike length of bread wheat by about 125%. Likewise, Tilahun *et al.,* (2017) reported the highest spike length (5.28 cm) for durum wheat at highest N rate of 92 kg $ha^{-}1$. Meanwhile excessive application of N fertilizer has toxic effect on wheat growth and results for stunted growth and reduced spike length (Smith and Hamel (1999).

Table 3. Effect of N and P fertilizer rates on phenology and spike length of wheat in 2018/2019 in Jimma Arjo district.

Treatments (kg ha^{-1})		Days to 50% flowering	Days to90% physiological maturity	Spike length(cm)
Nitrogen	Phosphorus			
0	0	71.0^{a}	130.7^{a}	7.2^{e}
0	10	71.0^{a}	129.0^{c}	7.5^{de}
0	20	71.0^{a}	129.3^{bc}	7.9^{cde}
0	30	71.0^{a}	130.3^{a}	8.3^{bcde}
23	0	71.0^{a}	129.0^{c}	8.6^{bc}
23	10	69.0^{c}	129.0^{c}	8.1^{cde}
23	20	69.0^{c}	129.3^{bc}	8.0^{cde}
23	30	70.0^{b}	130.0^{ab}	8.4^{bcd}
46	0	68.0^{d}	128.0^{d}	8.5^{bcd}
46	10	68.0^{d}	128.0^{d}	8.8^{bc}
46	20	68.0^{d}	128.0^{d}	8.8^{bc}
46	30	68.0^{d}	129.0^{c}	8.8^{bc}
69	0	65.0^{f}	127.0^{e}	9.3^{b}
69	10	65.0^{f}	127.0^{e}	8.8^{bc}
69	20	65.0^{f}	127.0^{e}	13.3^{a}
69	30	65.3^{e}	128.0^{d}	13.5^{a}
LSD		0.24	0.75	1.07
CV		0.21	0.35	7.14

Figures followed by same letter with in a column for a given variable are not significantly different (P > 0.05),

4.1.4. Plant height

Plant height showed significant difference ($P < 0.05$) due to the effect of N and P levels, butthe interaction between the two factors was not significant ($P>0.05$)(Table 4 and Appendix Table 1). The highest plant height(87.3cm) was recorder from 69 kg N/ha. At 30 kg N/ha the plant height was (13.3cm) height more than the control.Application of 69 kg N/ha increased the plant height by 17.97%over the control treatment, while application of 30 kg P/ha increased the plant height by only 7.6% as compared with the control treatment.The increase in plant height in response to increasing rate of nitrogen application could probably be due to the vital role of N in promoting vegetative growth of plants. In agreement with this result, Abdo *et al.* (2012) have observed tallest plants (89.4 cm) of durumwheat at maximum application rate of (69 kg N ha^{-1}). Similarly, Tilahun *et al.* (2017) have also reported the highest plant height of 65.5 cm for durum wheat at maximum application rate of 92 kg ha^{-1} of nitrogen. Similar result has also been reported by Bereket *et al.*, (2014) where increasing N rate up to 138 kg ha^{-1} increased the number of productive tillers to 3.69 per plant.

Table 4. Main effect of nitrogen and phosphorus rates on wheat plant height in 2018/2019 in Jimma Arjo district

Treatments Nitrogen levels (kg/ha)	Plant height (cm)
0	74.0^{d}
23	78.7^{c}
46	83.1^{b}
69	87.3^{a}
LSD%	2.71
Phosphorus levels (kg/ha)	
0	77.8^{c}
10	79.8^{bc}
20	81.8^{ab}
30	83.7^{a}
LSD%	2.71
CV%	4.03

Mean values within column followed the same letters are not significantly different (P > 0.05),

4.2. Crop yield and yield components

4.2.1. Number of tillers per plant

Both N and P fertilizer rates and their interaction significantly ($P<0.001$) affected number of tillers per plant with highest values, 5.53 and 5.57 recorded at combined application of 69 kg N and 20 kg P ha^{-1} and 69 kg N and 30 kg P ha^{-1}respectively which were not significantly different(Table 5). Application of 69 kg N/ha plus 30 kg P/ha increased the number of tillers per plant by 264% as compared with the control treatment. The increase in numbers of tillers in response to increasing the interaction rate of N and P fertilizer may indicate the importance of availability of balanced nutrients for better growth and development of the plant. And also N fertilizer can synthesis's cytokinins which is used for growth promoters. In line with this Tilahun *et al.* (2017) have reported highest number of wheat tillers per plant (1.97) at N rate of 92 kg ha^{-1}. Firehiwot (2014) has also reported the highest tillers per plant (5.58) with combined application of 32 kg N and 46 kg P_2O_5 ha^{-1} for bread wheat. SimilarlyGenene, (2003) has indicated that greater tillering as well as higher percentage of survival of the tillers was observed due to higher rate of N and P application increased in bread wheat. It has been reported that variations in the rate of fertilizer application had significant effect on the number of tillers (Bekelu *et al.,* 2016). FurthermoreHaftom *et al*. (2009) have also reported that the highest number of tillers per plant (4.94) was obtained from application of 69 kg N/ha plus 20 kg P/ha.

4.2.2. Number of grains per spike

Number of grains per spike was significantly affected ($P < 0.001$) by N and P interaction. Their mean values showed an increasing trend with increased rate of applied N and P interaction, and also affected significantly by main effects of N and P fertilizer rates (Table 5). The highest grains per spike (70.67) and (74.33) were recorded at the combination of 69 kg N and 20 kg P ha^{-1} and 69 kg N and 30 kg P ha^{-1} respectively which was not significantly different. The lowest number of grains per spike (34.33) was found in control plot and while the highest grains (74.33) were recorded at the interaction of 69 kg N and 30 kg P ha^{-1}. Application of 69 kg N/ha and 30 kg P/ha interaction increased number of grains per spike by 116.5% as compared to the control treatment(Table 5).This indicated that the number of grains per spike was more enhanced by interaction of N and P rates, which might be due to the fact that P is essential in development of grains. Readily availability of P during early season gave plants from early stresses and its higher uptake at higher levels resulted into enhanced number of grains per spike due to its involvement in grain formation and development. Number of grains per spike associated with the number of spikelets per spike, number of florets per spikelet as well as efficiency of pollination and seed developing in florets. Wang (1988) has reported that N applied at sowing and at 3 leaf stage of wheat enhanced spikelets differentiation and development, seed set and number of grains/spike.In agreement with this result, Seyoum (2017) has reported that increasing the rates of both NPS and N increased the number of kernels produced per spike where the maximum numbers of kernels per spike (49.5) was produced at the combination of highest rate of NPS fertilizers (200 kg ha^{-1} NPS) and N rates of 23 and 46 kg ha^{-1}. Similarly, Tilahun *et al.*, (2017) have reported higher number of kernels per spike for durum wheat (28.39) at the highest rate of N (92 kg N ha^{-1}). Daniel *et al.*, (1998) also reported that readily availability of P during early season gave plants from early stresses and its higher uptake at higher levels resulted into enhanced number of grains per spike due to its involvement in grain formation and development.

Successive increase in N at each level of P showed a tendency to increase the number of grains per spike indicating the effectiveness of N and P interaction at optimum ratio towards seed formation and grain filling (Kaishtha and Marwahs, 1977).

4.2.3. Grain yield

Grain yield was highly significantly ($p < 0.001$) affected by the interaction of N and P application rates. Accordingly,highest grain yield (6339.22 kg/ha) was obtained from treatment combinations of 69 kg N/ha and 30 kg P/ha, followed by 69 kg N/ha and 100 kg P/ha (Table 5). Application of 69 kg N/ha plus 30 kg P/ha interaction increased the grain yield by 145.7% over the control treatment. The highest grain yield at the highest rates of both N and P might have resulted from improved root growth and increased uptake of nutrients and thus better plant growth and enhanced yield components due to the synergistic effect of the two nutrients. Nitrogen affects vegetative growth as well as yields, whereas phosphorus plays a fundamental role in metabolism and energy producing reaction and can withstand the adverse environmental effects, thus resulting in enhanced grain yield. In line with this, Tilahun (2017) has reported the highest grain yield (5274 kg ha^{-1}) of durum wheat in response to application of 200 kg ha^{-1} blended NPS. Bereket *et al.*, (2014) have also reported that grain yield of bread wheat significantly increased due to the main effect of nitrogen and phosphorus fertilization and obtained highest grain yields (4443 kg ha^{-1}) and (3988 kg ha^{-1}) at application of 138 kg N $ha^{-1}$and 69 kg P_2O_5 ha^{-1}, respectively. Similarly Kaleem *et al.,* (2009) have also recorded maximum yield of 3557 kg ha^{-1} by the application of 128 N -128 P kg ha^{-1}.Furthermore Abreha *et al.*,(2008) have observed that application of different rates of phosphorus fertilizers significantly increased both grain and straw yield of wheat. In the present study increased yield and yield components of wheat was recorded for the highest P rate (30 kg/ha) with 69kg/ha of N. Similar results have been reported by Eylachew, (1996) and Minale*et al.*,(2006).

Table 5. Interaction effect of nitrogen and phosphorus rates on yield and yield components of wheat in 2018/2019 in Jimma Arjo district

Treatments (kg ha^{-1})		Number of tillers per plant	Number of grains per spike	Grain yield(kg ha^{-1})
Nitrogen	Phosphorus			
0	0	1.53^{g}	34.33^{h}	2579.63^{l}
0	10	1.67^{g}	43.67^{fg}	2814.44^{k}
0	20	1.90^{fg}	39.67^{gh}	2970.16^{k}
0	30	2.50^{d}	45.33^{ef}	4318.39^{ef}
23	0	1.77^{g}	47.00^{ef}	3250.83^{j}
23	10	1.93^{fg}	44.67^{efg}	3482.40^{i}
23	20	2.2^{def}	42.00^{fg}	3978.98^{h}
23	30	2.33^{de}	49.67^{de}	4399.79^{e}
46	0	2.47^{d}	45.33^{ef}	4115.28^{gh}
46	10	2.57^{d}	55.33^{c}	4177.82^{fg}
46	20	3.87^{b}	61.00^{b}	4737.48^{d}
46	30	3.50^{b}	54.33^{cd}	5174.13^{c}
69	0	3.00^{c}	58.00bc	4178.94^{fg}
69	10	3.50^{b}	53.67^{cd}	5181.45^{c}
69	20	5.33^{a}	70.67^{a}	6119.19^{b}
69	30	5.57^{a}	74.33^{a}	6339.22^{a}
LSD (5%)		0.43	5.42	198.05
CV (%)		9.09	6.35	2.8

Figures followed by same letter with in a column for a given variable are not significantly different (P > 0.05),

4.2.4. Straw yield

Straw yield significantly ($p< 0.001$) and linearly increased with increasing N and P rates. The interaction between N and P rates was also significantly affected straw yield ($p< 0.001$). Application of the 69 kg N/ha plus 30 kg P/ha interaction increased the straw yield by 3.03 t/ha as compared to the control treatment (Table 6). The highest straw yields 12116.9 kg/ha and 12369.1 kg/ha were recorded at the combination of 69 kg N and 20 kg P ha^{-1} and 69 kg N and 30 kg P ha^{-1} respectively which were not significantly different (Table 6).Application of 69 kg N/ha plus 30 kg P/ha increased the straw yield by 32.5% as compared with the control treatment. This is due to the increment of N and P interaction rates there was an increment of number of tillers per plant, due to that the straw yields increase. The result wasin consistent with that of Nasser (2009) who reported increased straw yield of wheat with anincrease in NP fertilizers up to 90/45 kg ha^{-1}. Similarly, Amsal *et al.,* (2000) have reported that N rate significantly enhanced the straw yield of wheat since N usually promotes the vegetative growth of a plant. Bereket *et al.,* (2014) have also reported highest straw yield of bread wheat (6827 kg ha^{-1}) at phosphorus rate of 92 kg P ha^{-1} and nitrogen rate of 138 kg N ha^{-1}. Tilahun *et al.,* (2017) have also obtained the highest straw yield (8 t ha^{-1}) at 92 kg N ha^{-1} for durum wheat. Furthermore it has been found that application of different rates of phosphorus fertilizer had significantly increased both grain and straw yield of wheat (Abreha *et al.,* 2008).

4.2.5. Total biomass yield

Total above ground biomass of the crop was highly significantly influenced by N and P rates and by their interaction.The highest dry biomass yield (18708.33 kg ha^{-1}) was obtained due to treatment combination of 69 kg N/ha and 30 kg P/ha (Table 6). Application of 69 kg N/ha and 30 kg P/ha interaction increased the biomass yield by 56.99% as compared with the control treatment.Application of 69 kg N/ha gave higher mean biomass yields 14758.33 kg/ha. Compared to the control plots, mean biomass increment of 2841.66 kg/ha was observed due to application of 69kg N/ha. In general, aboveground dry biomass increased with an increase in NP interaction rates which might be due to improved root growth and increased uptake of nutrients, favoring better vegetative growth increased plant height and number of tillersand delayed senescence of leaves of the crop due to synergetic effect of the nutrients (NP). It has been reported thatN and P fertilizer application at optimum amount significantly enhanced biomass yield of wheat, which was linearly correlated with the amount of essential nutrient (Genene, 2003).

4.2.6. Thousand grain weight

The effect of N and Pinteraction was significant ($P<0.05$) on 1000-grain weightwhilethe effect of Nwas highly significant ($P<0.001$)(Appendix 1, Table 6). On the other hand, notthe main effect of P was not significant for 1000-grain weight (Appendix 2, Table 6). Application of 69 kg N/ha plus 30 kg P/ha decreasedthousand grain weight by 7.8% as compared with the control treatment. This is due to the rates of N and P interaction increased there was an increment of number of seeds per spike, when number of seeds per spike increased there is a competition for nutrient between seeds per spike, due to that there was decrease in seed size, seed volume and seed weight. Similar results were reported by Gooding and Davies (1997), who found significant reduction in 1000-grain weight of wheat by N fertilizer application, despite increases in yields. The authors furtherconcluded that N fertilizer applied at rates and timings to optimize yield response would not necessarily give a comparable improvement in 1000-grain weight.

4.2.7. Harvest index

The interaction between N and P resulted in highly significant ($P< 0.001$) difference among the indices while highly significant ($P< 0.001$) and significant ($p< 0.05$) differences was observed due toapplications of N and P fertilizers, respectively(Appendix table 2). The lowest harvest index (22%) was recorded for the control plot and while the highest (34%) was for 69 kg N plus 30 kg P ha^{-1}. Application of 69 kg N/ha plus 30 kg P/ha increased the harvest index by 56.5% as compared with the control treatment. When N and P interaction rates increased the grain yield increased, when the grain yield increased harvest index also increased. Most of the indices obtained due to different combinations of N and P rates ranged from 28 to 34 % (Table 5), which was in line with the finding of Mengel and Kirkby (1996), who reported that harvest indices of modern wheat cultivars normally range from 30%to 40%.

Table 6. Interaction effect of nitrogen and phosphorus on yield and yield components of wheat in 2018/2019 in Jimma Arjo district

Treatments ($kg\ ha^{-1}$)		Biomass yield($kg\ ha^{-1}$)	Straw yield($kg\ ha^{-1}$)	Thousand grain weight (g)	Harvest index(%)
Nitrogen	Phosphorus				
0	0	11916.67^{l}	9337.0^{k}	44.01^{abcd}	21.65^{g}
0	10	12225^{k}	9410.6^{jk}	44.15^{abc}	23.02^{fg}
0	20	12611.11^{j}	9641.0^{ij}	44.31^{ab}	23.56^{f}
0	30	14375^{f}	10056.6^{fg}	44.31^{ab}	30.05^{bc}
23	0	12938.89^{i}	9688.1^{hi}	43.6^{bcde}	25.12^{e}
23	10	13402.78^{h}	9920.4^{gh}	43.33^{bcde}	25.98^{e}
23	20	14000^{g}	10021.0^{g}	43.58^{bcde}	28.42^{d}
23	30	14902.78^{e}	10503.0^{de}	44.43^{ab}	29.52^{cd}
46	0	14402.78^{f}	10287.5^{ef}	42.98^{bcde}	28.58^{d}
46	10	14838.89^{e}	10661.1^{d}	42.76^{cde}	28.16^{d}
46	20	15763.89^{d}	11026.4^{c}	45.35^{a}	30.06^{bc}
46	30	16583.33^{c}	11409.2^{b}	42.33^{ef}	31.2^{b}
69	0	14758.33^{e}	10579.4^{d}	42.56^{def}	28.32^{d}
69	10	16638.89^{c}	11457.4^{b}	42.13^{efg}	31.14^{b}
69	20	18236.11^{b}	12116.9^{a}	41.25^{fg}	33.55^{a}
69	30	18708.33^{a}	12369.1^{a}	40.83^{g}	33.88^{a}
LSD (5%)		187.8	256.29	1.49	1.37
CV (%)		0.76	1.46	2.06	2.91

Figures followed by same letter with in a column for a given variable are not significantly different (P > 0.05),

4.3. Agronomic efficiency ($kg\ kg^{-1}$)

The interaction of N and P fertilizer rates was highly significant effect ($p < 0.001$) on agronomic efficiency. The highest value of agronomic efficiency (39.77 kg/kg) was recorded at 69 kg/ha N plus 20 kg/ha P which is not significantly different with the value of agronomic efficiency (37.97 kg/kg) recorded from 69 kg/ha N plus 30 kg/ha P. The lowest agronomic efficiency (19.53 kg/kg) was recorded from 0 kg/ha N plus 20 kg/ha P which is not significantly different with the value of (23.48 kg/kg) recorded from 0 kg/ha N plus 10 kg/ha P. The results showed a significant difference and increased response to N plus P fertilizer at higher application rates, which indicated efficient use of nitrogen plus phosphorus at higher rate of application (69 kg N plus 20 kg P ha^{-1}), which is in agreement with previous results reported by other investigators Gebreyes (2008), who reported higher AE under the application of higher levels of nitrogen.

Table 7. Interaction effects of N and P on Agronomic efficiency in 2018/2019 in Jimma Arjo District

Nitrogen kg/ha	Phosphorus kg/ha	Agronomic efficiency (kg/kg)
0	10	23.48[bc]
0	20	19.53[c]
0	30	30.96[b]
23	0	29.18[b]
23	10	27.36[bc]
23	20	32.54[ab]
23	30	34.34[ab]
46	0	33.38[ab]
46	10	28.54[b]
46	20	32.69[ab]
46	30	34.14[ab]
69	0	23.18[bc]
69	10	32.93[ab]
69	20	39.77[a]
69	30	37.97[ab]
LSD (5 %)		8.74
CV (%)		16.51

Mean values within column followed the same letters are not significantly different (P > 0.05)

4.4.Correlation between agronomic characteristics

Number of tillers per plant was highly significant by (P< 0.01) and strongly correlated to plant height (r =0.84), spike length (r =0.89), number of kernels per spike (r = 0.85), biomass yield (r = 0.95), straw yield (r =0.95), grain yield (r =0.92) and harvest index (r =0.82), while it washighly significantly and negatively correlated todays to 50% flowering (r =-0.79), days to 90% physiological maturity (r =-0.59) and thousand seed weight (r =-0.51). Total above ground biomass showed highly significant and positive correlatin with grain yield (r = 0.99), plant height (r = 0.88), spike length (r =0.81), number of kernels per spike (r = 0.84), straw yield (r = 0.98), and harvest index (r = 0.93), while it was highly significantly and negatively correlated with days to 50% flowering (r =-0.82), days to 90% physiological maturity (r =-0.58) and thousand seed weight (r =-0.58).

There was highly significant and positive correlation between grain yield and plant height (r =0.86), spike length (r =0.80), number of kernels per spike (r =0.84), straw yield (r =0.94) and harvest index (r =0.97). Straw yield was highly significantly and positively correlated with plant height (r =0.87), spike length (r =0.81), number of kernels per spike (r =0.83) and harvest index (r =0.85), but it had significant ($P < 0.01$) and negative correlation with days to 50% flowering (r = -0.83), days to 90% physiological maturity (r =-0.47) and thousand seed weight (r =-0.58). There washighly significant ($P\leq 0.01$) and positive correlation between plant highet and spike length (r =0.76), number of kernels per spike (r =0.77) and harvest index (r =0.82), but it was significantly ($P \leq 0.01$) and negatively correlated with 1000- grain weight (r = -0.57), days to 50% flowering (r = -0.76) and days to 90% physiological maturity (r =-59). Spike length washighly significantly ($P<0.01$) and positivelycorrelated with number of kernels per spike (r =0.78) and harvest index (r =0.70), but it was highly significant and negatively correlated with 1000- grain weight (r = -0.59), days to 50% flowering (r = -0.68) and days to 90% physiological maturity (r =-51).

Number of kernels per spike was highly significantly and positively correlated with harvest index (r =0.78), but it was highly significantly and negatively correlated with 1000grain weight (r = -0.48), days to 50% flowering(r = -0.75) and days to 90% physiological maturity (r =-64). Days to 50% flowering was highly significantly and positively correlated with days to 90% physiological maturity (r =0.83) and thousand seed weight (r =0.64). Days to 90% physiological maturity was highly significantly and positively correlated with thousand seed weight (r =0.50 (Table 6). Similar correlations were reported for barley by Mekonnen (2005) and by Albert*et al.* (2005) and Getachew (2004) for bread wheat.

Table 8. Results of simple correlation analysis for agronomic parameters of wheat in 2018/2019 in Jimma Arjo district

Variable	DF	NT	DP	PH	SL	NS	BY	GY	SY	SW	HI
DF	1.00	-0.79**	0.83**	-0.76**	-0.68**	-0.75**	-0.82**	-0.79**	-0.83**	0.64**	-0.72**
NT		1.00	-0.59**	0.84**	0.89**	0.85**	0.95**	0.92**	0.95**	-0.51**	0.82**
DP			1.00	-0.59**	-0.51**	-0.64**	-0.58**	-0.53**	-0.62**	0.50**	-0.47**
PH				1.00	0.76**	0.77**	0.88**	0.86**	0.87**	-0.57**	0.82**
SL					1.00	0.78**	0.81**	0.80**	0.81**	-0.59**	0.70**
NS						1.00	0.84**	0.84**	0.83**	-0.48**	0.78**
BY							1.00	0.99**	0.98**	-0.58**	0.93**
GY								1.00	0.94**	-0.58**	0.97**
SY									1.00	-0.56**	0.85**
SW										1.00	-0.52**
HI											1.00

Days to 50 % flowering, NT = Number of tillers per plant, DP = Days to 90 % physiological maturity, PH = Plant height, SL = Spike length, NS = number of seeds per spike,BY = Total biomass yield, GY= Grain yield, SY = Straw yield, SW= Thousand seed weight and HI = Harvest index%

4.5. Partial budget analysis

The economic analysis indicate that application of higher N and P amount gave a better net benefit over the lower N and P rates (Table 7). In this particular study, different values of net benefit were calculated for the different fertilizer levels. The highest net benefitwas calculated for the treatment where 69 kg N and 30 kg/ha P was applied. It was closely followed by the net benefit, which was recorded for the treatment receiving 69 kg N and 20 kg/ha P. The lowest net benefit was recorded for the control plot.

Table 9. Amount of input, total variable cost, gross and net benefit analysis for the bread wheat N and P fertilizer experiment on bread wheat in 2018/2019 in Jimma Arjo district

N kg/ha	P kg/ha	UREA (kg/ha)	NPSB (kg/ha)	AGY	GB	NB	TVC	MRR	MRR%
0	0	0	0	2321.667	25538.34	25538.34	0	-	-
0	10	0	26.5	2532.996	27862.96	27812.96	347.42	6.55	654.73
23	0	50	0	2925.747	32183.22	32183.22	640.00	14.94	1493.67
0	20	0	53	2673.144	29404.58	29304.58	694.83	D	-
23	10	39.1	26.5	3134.16	34475.76	34425.76	847.90	33.46	3345.75
0	30	0	79.6	3886.551	42752.06	42602.06	1043.56	41.79	4178.81
23	20	28.3	53	3581.082	39391.9	39291.9	1057.07	D	-
23	30	17.4	79.6	3959.811	43557.92	43407.92	1266.28	D	-
46	0	100	0	3703.752	40741.27	40741.27	1280.00	D	-
46	10	89.1	26.5	3760.038	41360.42	41310.42	1487.90	2.74	273.77
46	20	78.3	53	4263.732	46901.05	46801.05	1697.07	26.25	2624.90
46	30	67.4	79.6	4656.717	51223.89	51073.89	1906.28	20.42	2042.41
69	0	150	0	3761.046	41371.51	41371.51	1920.00	D	-
69	10	139.1	26.5	4663.305	51296.36	51246.36	2127.90	D	-
69	20	128.3	53	5507.271	60579.98	60479.98	2337.07	44.14	4414.31
69	30	117.4	79.6	5705.298	62758.28	62608.28	2546.28	46.17	4617.32

Key: N=nitrogen, P=phosphorus, AGY=adjusted grain yield, TVC=total variable cost (Et birr), GB=gross benefit(Et birr), NB= net benefit(Et birr), MRR= Marginal rate of return

Cost of Urea =12.80 birr/kg NPSB=13.11 birr/kg, Cost of wheat grain= 11 birr/kg

5. SUMMARY AND CONCLUSION

The current study revealed that nitrogen and phosphorus fertilizers play an important role in maximizing yield of bread wheat. The synergic effect of N and P was also more apparent than their individual effect except for plant height. Application of 69 kg N/ha plus 30 kg P/ha increased number of tillers per plant by 264% as compared with the control treatment. The lowest number of grains per spike (34.33) was recorded for the control plot, while the maximum values (74.33) was recorded from 69 kg N plus 30 kg Pha^{-1}.

Application of 69 kg N/ha plus 30 kg P/ha increased number of grains per spike by 116.5% over the control treatment. The highest grain yield (6339.22 kg/ha) was recordedat treatment combination of 69 kg N/ha and 30 kg P/ha, followed by 69 kg N plus 20 kg P/ha. Application of 69 kg N/ha plus 30 kg P/ha increased the grain yield by 145.7% over the control treatment. Similarly, it increased straw yield by 32.5 % as compared to control treatment.The lowest harvest index (22%) was recorded for the control plot, while the highest value (34%) was for 69 kg N plus 30 kg P ha^{-1}.The economic analysis revealed that application of 69 kg N plus 30 kg P ha^{-1} gave net benefit of 62608.28-birr ha^{-1} and marginal rate of return 4617.32-birr ha^{-1}and hence, could be recommended for wheat producing farmers in Jimma Arjo district.

However as the study site may not be representative of the entire zone, there is a need to conduct extensive research in the following aspects:

- Since the increment in grain yield with increasing rates of N and P was not ceased over maximum rates in the present study, higher rates should be experimented at different sites and in different seasons in the future to determine the point at which economical yield starts declining in the area.
- Evaluation of soil fertility status and plant nutrient requirements.
- Studies on phosphorus fixation in soils of the area should also be considered in future studies.

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7. APPENDIX

APPENDIX

Appendix 1. ANOVA table for Effect of N and P-fertilizer rates and their interaction on days of 50 % flowering (DF), Number of tillers per plant (NT), Days of 90 % physiological maturity (DP), Plant height (PH), Spike length (SL) and number of seeds per spike (NS)

Source of variations		Mean square					
	Df	DF	NT	DP	PH	SL	NS
R	2	0.02	0.17	0.27	11.22	0.06	212.31
N	3	78.92**	15.37**	15.94**	392.43**	28.85**	1255.91**
P	3	0.75**	4.95**	2.72**	77.57**	6.64**	222.47**
N x P	9	0.69**	0.74**	0.44*	8.06^{ns}	4.49**	100.47**
Error	30	0.02	0.07	0.20	10.58	0.41	10.58
Mean		68.46	2.85	128.67	80.79	8.98	51.19
CV (%)		0.21	9.09	0.35	4.03	7.14	6.65

Df = Degree of freedom, DF= Days of 50 % flowering, NT = Number of tillers per plant, DP = Days of 90 % physiological maturity, PH = Plant height, SL = Spike length and NS = number of seeds per spike

Appendix 2. ANOVA table for Effect of N and P-fertilizer rates and their interaction on Biomass yield (BY), Grain yield (GY), Straw yield (SY), Thousand seed weight (SW) and Harvest index (HI) on wheat at Jimma Arjo East wollaga.

Source of variations		Mean square					
	Df	BY	GY	SY	SW	HI	AE
R	2	78211.80	53093.29	248421.82	2.77	4.41	27.46
N	3	42505542.80**	11717034.53**	9609569.12**	14.26**	112.61**	734.51**
P	3	15503505.60**	5289339.64**	2700625.48**	0.96^{ns}	62.92**	375.44**
N x P	9	897314.30**	338328.07**	193197.51**	2.41*	5.83**	782.39**
Error	30	12683.70	14106.52	23621.93	0.80	0.68	27.46
Mean		14762.92	4238	10530.29	43.25	28.26	459.99
CV (%)		0.76	2.8	1.46	2.06	2.91	16.51

Df = degree of freedom, BY = Biomass yield, GY= Grain yield, SY = Straw yield, SW= Thousand seed weight and HI = Harvest index, AE = Agronomic efficiency