INTEGRATED USE OF NPS BLENDED FERTILIZER AND CATTLE MANURE FOR GROWTH, YIELD AND QUALITY OF POTATO (*Solanum tuberosum* L.) UNDER DABO GHIBE, KEBELE, SEKA WERADA OF JIMMA ZONE, SOUTHWEST ETHIOPIA

M.Sc. THESIS

AMIN ABABIYA ABABULGU

FEBRUARY, 2018

JIMMA, ETHIOPIA

INTEGRATED USE OF NPS BLENDED FERTILIZER AND CATTLE MANURE ON GROWTH, YIELD AND QUALITY OF POTATO (*Solanum tuberosum* L.) UNDER DABO GHIBE KEBELE,SEKA Werada OF JIMMA ZONE, SOUTHWEST ETHIOPIA

Amin Ababiya Ababulgu

M.Sc. Thesis

Submitted to the School of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture (Agronomy)

February, 2018
Jimma, Ethiopia

DEDICATION

I dedicate this thesis to my parents.

STATEMENT OF AUTHOR

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

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is for scholarly interest. In all other instances, however, permission must be obtained from the author.

Name: Amin Ababiya Ababulgu Signature: _____________

Place: Jimma University

Date of Submission: ______________

BIOGRAPHICAL SKETCH

The author, Amin Ababiya Ababulgu, was born in Damma Keble, Shabe Sombo werada, Jimma Zone of Oromia Regional State in Ethiopia in 1979. He attended elementary and secondary school education at Sombo and Jimma secondary Schools, respectively. In 1995, he joined Asalla Agricultural College and graduated with Diploma in plant Science in July 1997. After graduation, he was employed in Shabe Sombo Rural Development Office in September 1998 where he worked as a senior officer in the field of irrigation and crop production. He joined Jimma University in 2003 and graduated with the degree of Bachelor of Science in Plant Science in July 2004. He joined the School of Graduate Studies Jimma University in 2015 to pursue a study leading to the Degree of Master of Science in Agriculture (Agronomy).

ACKNOWLEDGMENTS

First and foremost, I would like to praise and glorify the supreme Almighty Allah for providing me with the strength and patience that I required to complete the study.

I would also like to express my deepest and heartfelt thanks as well as my most sincere appreciation and gratitude to my major advisor Dr. Ambecha Olika and my co-adviser Dr. Amsalu Nebiyu for their keen interest, dedicated and meticulous supervision, for amicably motivating and scientifically supporting me during the whole period of the study. I also thank them for genuinely and constructively criticizing my work from the time of inception of the research work up to its completion and thesis write-up. The visits they made to my research field on a number of occasions and the scientific discussions I held with them in the research undertaking were exemplary and worthy of deepest gratitude.

I would also like to thank LIVES (Livestock and Irrigation Value-chains for Ethiopian Smallholders) project for providing me the opportunity to pursue the study leading to the Degree of Master of Science and Jimma University for facilitating my study. I would also like to thank Mr. Amenti Chali LIVES project advisor, for his overall support and encouragement throughout the period of my study.

Moreover, I am indebted to my best friends Bazabe for his encouragement and sharing experience and skills during data collection periods and all stage of research. I would like to express my sincere gratitude to my mother Mardiya A/simal, my father Ababiya Ababulgu, my sisters Nazifa Ababiya, my best friend Muhamadkabir and my family for their dedication and strong support throughout my study.

LIST OF ABBREVIATIONS AND ACRONYMS

AGY	Adjusted Grain Yield
BCR	Cost Benefit Ratio
CM	Cattle Manure
CSA	Central Statistical Agency
DMC	Dray Matter Content
EARO	Ethiopian Agricultural Research Organization
M.A.S.L	Meter Above Sea Level
MB	Marginal Benefit
MC	Marginal Total Cost
MRR	Marginal Rate Of Return
MOA	Ministry of Agriculture
MSN	Main Stem Number
NPS	Nitrogen, Phosphorus and Sulfur
NR	Net Return
TC	Total Production Cost Per Ha
SIS	Soil Information System
SRDI	Soil Resources Development Institute

TABLE OF CONTENTS

Contents **Page**

TABLE OF CONTENTS *(Continued)*

LIST OF TABLES

Table **Page**

LIST OF FIGURE

LIST OF TABLES IN THE APPENDIX

ABSTRACT

Irish potato (Solonaum tuberosum L.) is An important leading tuber crop in Ethiopia. It is an important food security and cash crop for smallholder farmers in Ethiopia. However, the yield of the crop is low at national as well as regional levels which, constrained mainly by low soil fertility. A new blended fertilizer (NPS) containing nitrogen (19% N), phosphorous (38% P_2O_5) and sulfur (7% S) is recently introduced aiming at substituting DAP in Ethiopian agriculture. There is a need to optimize the fertilizer under farmers' conditions particularly its use along with organic resources. Therefore, a field experiment was conducted to investigate the effect of combined application of NPS blended fertilizer and cattle manure (CM) on growth, tuber yield and quality of potato on a Nitisol at Dabo-Gibe Kebele, Seka werada in 2016/2017 under irrigation. The objective of this study was to determine the optimum rate of mineral NPS blended fertilizer and CM rate on growth, yield and quality of potato. The treatments consisted of four NPS blended fertilizer levels (0, 50,100 and 150kg ha^{-1}) and four Cattle Manure levels (0, 10, 20 and 30t ha^{-1}).The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times. Data on days to 50% flowering, days to 75% physiological maturity, plant height, main stem number, total tuber yield (t ha^{-1}), marketable tuber yield (t ha^{-1}), unmarketable tuber yield (t ha^{-1}), total tuber number per hill, marketable tuber number per hill per plant, unmarketable tuber number per hill per plant, dry matter content and specific gravity were collected and statistically analyzed using SAS version 9.3 software. Results revealed that combined application of NPS blended fertilizer and CM significantly ($P<0.05$) influenced days to 50% flowering, days to 75% physiological maturity, plant height, total tuber yield (t ha^{-1}), marketable tuber yield (t ha^{-1}), total tuber number per hill, marketable tuber number per hill and specific gravity. However, main stem number and dry matter content were not affected by the combined application of NPS blended fertilizer and cattle manure. Unmarketable tuber number and yield was also not affected by the main effects of NPS blended fertilizer and CM and as well as their interaction. The highest total tuber yield (40.23 t ha^{-1}) was obtained by applying 150 kg ha^{-1} NPS bended fertilizers+30 t ha^{-1}CM. Based on the partial budget analysis, combined application of 100 kg ha^{-1}NPS bended fertilizers+30tha^{-1}CM gave the maximum net return of Birr 138,513 ha^{-1} with an acceptable marginal rate of return (51.1%). The total nitrogen, available phosphorus and organic carbon content of the experimental soil were also increased due to the interaction of mineral NPS blended fertilizers and cattle manure at their highest rates. In conclusion, the results revealed that combined application of 150 kg ha^{-1}NPS fertilizers and cattle manure at 30 t ha^{-1} significantly increased total tuber yield (40.23tha^{-1}) of potato and restore of N, P and organic carbon of soil. In economic point of view, combined application of 100 kg ha^{-1}NPS blended fertilizers and 30 t ha^{-1}CM is found economically feasible and can be recommended for potato growers around Seka Wereda.

Keywords*:* Mineral fertilizer, Organic fertilizer, Tuber quality, Tuber Yield.

1. INTRODUCTION

Irish potato (*Solonaum tuberosum* L.*)* is originated from the Lake Titicaca region in Peru and Bolivia of South America (Hoops and Plaisted, 1987).Irish potato is also a food for more than three billion people Worldwide (Woldegiorgis and Chindi, 2016). It is a starchy, tuberous crop of the *Solanaceae* family (van den Berg and Jacobs, 2007). It is a crop of major economic importance worldwide (FAO, 2008). It ranks fourth after wheat, rice and maize crops with an estimated cultivated area of 19 million hectares with production of 332 million metric tons annually (FAOSTAT, 2012) and followed by cassava, sweet potato and yam from root and tuber crops (FAO, 2010).In Africa about 1,765,617 ha of potato cultivated with production of about 17,625,680 t. Studies show that the demand for potato will increase over the next two decade years in developing countries (Zandstra, 2000). It is an important staple and cash crop in Eastern and Central Africa, playing a major role in national food and nutrition securities, poverty alleviation and income generation and provides employment in the potato production, processing and marketing sub-sectors (Lung'aho *et al.,* 2007).

Potato was first introduced to Ethiopia in 1858 by the German Botanist, Schemper (Pankhurst, 1964 cf. Woldegiorgis and Chindi, 2016). Ethiopia has possibly the greatest potential for potato production; seventy percent of its arable land mainly in highland areas, above 1500 m.a.s.l, are believed to be suitable for potato (Harnet *et al.,* 2014). Since the highlands are also home to almost over half of Ethiopian population, the potato could play a key role in ensuring national food security (FAO, 2008).

Mineral fertilizers are used to supplement the natural soil nutrient supply in order to satisfy the demand of crops with a high yield potential, compensate for the nutrients lost by the removal of plant products and by leaching. Mineral fertilizers have the merit of being readily soluble in soil solution, less bulky and easy to manipulate but their constitution in most cases does not include the much needed essential minor elements as compared to cattle manures which meet this requirement (Bekunda *et al*., 2010).

In Ethiopia, potato ranks first among the major tuber crop in volume of production and consumption followed by enset, sweet potato, yam and taro (Olango, 2008). About 1,571,806 farmers are engaged in potato growing with an area of 74, 935 ha per season with an annual production of 8.6 M. quintal (CSA, 2013). It is identified as hunger breaking crop during a period when cereal crops are not ready for harvest in the highland. Potato is grown in diverse soil types ranging from vertisol to nitosols in the highlands of Ethiopia. The national average yield stands at 11.8 tha^{-1} (CSA ,2014), which is low compared to the world's average productivity of 16.4 t ha^{-1} (FAOSTAT, 2012).One of the contributing factors to the low yield and yield components of potato is substandard agronomic practices including suboptimum fertilizer amount application, use of substandard quality tubers and shortage of improved and adaptable cultivars (Shaweno, 2017).Potato is a heavy feeder requiring large quantities of fertilizers to produce highest marketable tuber yield and total tuber yield.

Low soil fertility is one of the limiting factors to sustain potato production and productivity in Ethiopia (Olango, 2008).Ethiopian soils are very diverse in terms of inherent and dynamic soil quality (Zelleke *et al*., 2010). Fertilizer recommendations made based on preliminary studies vary across diverse agro ecologies in the country. Economically feasible fertilizer amount varies with soil type, fertility status, moisture amount, climatic variables, variety, crop rotation and crop management practices (Smith, 1977, Berihun and Woldegiorgis, 2012). In fact, the Ethiopian agricultural Institution(EIAR) generally recommends to farmers the blanket rates of 195 kg DAP ha^{-1} and 165 kg Urea ha^{-1} regardless of cultivar and location or soil type, which together sums up to account for 111 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1}(EARO, 2004).However, Gildemacher *et al.*(2009) reported that potato farmers in the central highlands of Ethiopia applied on average only 3.0 t manure, 30.6 kg N and 33.4 kg P/ha. This shows that farmers apply sub-optimum levels of nutrients to the potato crop. A participatory rural appraisal in the study area indicated that farmers use smaller rates of DAP and Urea that amount only to 100 kg each, which is equivalent to 46 kg P_2O_5 and 64 kg N ha^{-1} (Dechassa *et al*., 2012).

According to Ethiopia soil data base majority of soils in South western Ethiopia are deficient in macronutrients (N, P and S) and micronutrients (Cu, B and Zn) because of long years frequent cultivations of staple crops (Ethio SIS, 2014), thus the majority of potato growers depend on P in the form Di-ammonium phosphate (DAP) and N in the form of urea (Ethio SIS, 2014).Recently ministry of agriculture (MoA) has introduced a new brand of NPS blended fertilizer having proportion of 19% N, 38% P_2O_5 and 7% S, substituting DAP for adoption by farmers. Besides the application of mineral fertilizers to potatoes, the importance of cattle manure is being recognized because of the increased cost of mineral fertilizers from time to time vis-a-vis price of potato product on the market and their long term effects on soil chemical properties (Negassa *et al*., 2001).It is also useful in improving the efficiency of fertilizer recovery thereby resulting in higher crop yield and quality (Gedam *et al*., 2008).Cattle manure is a potential source of organic fertilizer in Ethiopia, as the country has the highest livestock number in Africa (Zinash, 2001).Cattle manure seems to act directly in increasing crop growth and yields either by accelerating respiratory process with increasing cell permeability and hormonal growth action or by the combination of all of these processes which supplies N, P and S in available form to the plants via biological decomposition and improves physical properties of soil such as aggregation, permeability and water holding capacity (Purakayastha and Bhatnagar, 1997). Cattle manure, contains large amount of nutrients and influences plant growth and production via improving chemical, physical and biological fertility (Benedek, 2010). However, the use of cattle manure alone may not be enough to maintain crop production because of its limited availability and relatively high application rates, high labour requirements (Palm *et al*., 1997; Gunapala and Scow, 1998).Therefore, combined application of mineral NPS and cattle manure is essential to sustain high yields, better tuber quality and more profit and to improve soil physico-chemical properties (Emana and Gebremedhin, 2007).in one study the highest total tuber yield was observed with the combined application of 10 t FYM ha^{-1} and 75% recommended N and P (Daniel *et al*., 2008). Application of two-third of the recommended mineral NP fertilizers combined with 20-30 t FYM ha^{-1} were suggested for vertisol and nitisol in West Shewa Zone (Balemi, 2012). According to Darzi *et al*., (2012), maximum tuber yield (36.8 t ha^{-1}) was obtained using 20 t ha^{-1}cattle manure +150 kg N ha^{-1}.The application of cattle manure had positively influenced potato vegetative growth characters, whereas plant height, stem number $plant^{-1}$ and whole plant dry weight were increased with increasing cattle manure levels up to 20 t ha^{-1}(Alam *et al.,* 2007).The application of compost in combination with mineral blended NPS to soils increased onion bulb diameter (Gebrekiros A.2013).

Potato growers in Dabo Gibe Kebele, Seka Werada of Jimma Zone usually use cattle manure and household leftover empirically for growing potatoes, maize and others in their homestead without scientific information. Amin *et al*. (2007) observed that application of 100 kg N, 80 kg P and 30 kg S ha^{-1} along with 50 kg K ha^{-1}significantly increased yield components of onion over the lower rates and the check. Application of balanced amount of mineral N, P and S have a cumulative positive effect on crop growth because N improved the vegetative growth and accelerated the photosynthates in storage organs of bulbs via an increased diameter and weight of the bulb (Sharma, 1992).Furthermore, if cattle manure is supplemented with mineral NP fertilizers could enhance yield and nutrient uptake of potatoes (Bayu *et al*., 2006).However, information on the effect of the application of cattle manure along with mineral NPS blended fertilizers is not available on the growth, yield components and quality of potato in Dabo Gibe Kebele in Seka Werada of Jimma zone, Southwestern Ethiopia. Therefore, it is imperative to develop recommendation/database on the use of mineral NPS blended fertilizers along with cattle manure for the optimum production of potato.

Thus, the study was carried out with the following objectives:

- To assess the combined effect of mineral NPS blended fertilizers and cattle manure on yield and yield components of potato in Seka Werada.

- To determine agronomic ally and economically optimum rate of mineral NPS blended fertilizer and cattle manure for potato production in Seka Werada.

2. LITERATURE REVIEW

2.1.Potato production in Ethiopia

Irish potato (*Solonaum tuberosum* L.*)* is a leading vegetable crop in Ethiopia. It is a crop with high potential to contribute to poverty reduction and becoming an important food crop in Ethiopia. The potato crop can contribute to improving food and nutritional security. It is regarded as a high potential food security crop for densely populated highland regions because of its ability to provide a high yield per unit input with a short crop cycle than major cereal crops (Hirpa *et al*., 2010), hence the Ethiopian government has identified it as one of the priority crops for agricultural growth programme (Tesfaye *et al.*, 2012). Especially in rain fed systems this is of essence, as it makes potato one of the first crops that can be harvested after the onset of the rainy season. In conditions of food shortage this makes potato an essential 'hunger breaking' crop to assure staple food before grains can be harvested.

Recently, the government of Ethiopia declared that Irish potato to be a national strategic food security crop (Abebe, 2017). This main policy pronouncement, qualified Irish potato for government initiated farmer support initiatives supervised by Agricultural Research Centers through on farmer's plot seed multiplication and small scale semi-modern irrigation building. The growing importance of potato as a food crop is prefaced on rising food insecurity in the country. Increasing potato production on a sustainable basis will enable the crop to assert as a national strategic food security crop and help ease the food security challenges of the country.

2.2. Ecological Requirement

Potato (*Solanum tuberosum* L.) is a weather sensitive crop with a wide variation among cultivars. It is a crop of temperate climate and it is moderately tolerant to frost (Rezaul Karim *et al*., 2011).Elevations range between 1800 to 2500 meters above sea level is regarded as suitable for seed and ware potato growth (Woldegiorgis and Chindi, 2016). However, recently released cultivars are performing well at intermediate elevation of Ethiopia (Adamu and

Asnakech, 2010).A rainfall ranging between 500 and 750 mm uniformly distributed during the growing period is required for optimum growth (Stol *et al*., 1991). Irrigation is required where rainfall is unreliable (Makani *et al*., 2013). In Seka Werada of Jimma Zone, potato production involved fertilizers application with frequent irrigation during dry season is usual practice for a good growth and high yield of the potato.

2.3. Mineral Nutrients Affecting Growth and Yield of Potato

Application of mineral fertilizers in the tropics had stagnated, and this was explained by poor marketing and inadequate profitability from mineral fertilizer use (Hartemink, 2002). In the past years, mineral fertilizer was advocated for crop production to ameliorate low inherent fertility of soils in the tropics (Stoorvogel and Smaling, 1990). However, currently it is well recognized that the use of mineral fertilizer has not been helpful in intensive agriculture because it is often associated with reduced crop yield, soil acidity, and nutrient imbalance (Kumar *et al*., 2013). However, appropriate mineral fertilizer application, especially nitrogen and phosphorus are required to correct the nutrient imbalance in infertile soils (Peter *et al*., 2015).

2.4. Effect of N fertilizer on growth and yield components of potato

Potatoes can generally grow on organic and mineral soils with pH of 5.0 - 6.5, light soils with good aeration to produce high tuber yield (Gebre *et al*., 2005). Nitrogen (N) is very important nutrient in potato production that the value of the other inputs cannot be fully realized unless N is applied to the crop in an optimum amount ((Grewal *et al*., 1992; Baniuniene and Zekaite, 2008; Ruža *et al*., 2013). Several N fertilization rates have been advised as optimum for potato production in some European countries and the USA (Li *et al*., 1999; Ruža *et al*., 2013).Potatoes require high amount of nutrients in order to produce high quantity of tubers per unit area (White *et al*., 2007; Dechassa *et al*.,2003).

Plant tissues usually contain more N than any other nutrient normally applied as a fertilizer. N is an integral component of many essential plant compounds. It is a major part of all amino acids and many other molecules essential for plant growth and other critical nitrogenous plant components *viz.*, the nucleic acids and chlorophyll. N is also essential for carbohydrate use within plants. All vegetative growth parameters were gradually and significantly increased by increasing the level of N fertilizer application up to optimum level (Asmaa *et al.*, 2010). However, an excess of this nutrient in relation to other nutrients (P, K and S) leads to low dry matter yield in other parts of the plant than the tubers, promoting excessive stolon and leaf growth (Marti and Mills, 1991).Both leaf maturation and tuber differentiation are delayed and the length of tuber bulking period, yield and tuber dry matter are reduced (Goffart *et al*., 2008). Conversely, a shortage of N restricts the growth of all plant organs, roots, stems, leaves, flowers, fruits including seeds and plants become stunted and yellow in appearance (Barker and Bryson, 2007). Shortage of N also restricts tuber size due to reduced leaf area and early defoliation (Vos, 1995; Goffart *etal*., 2008).Nitrogen supply also play an essential role in the balance between vegetative and reproductive growth for potato (White *et al*., 2007).N fertilization has been reported to increase the average fresh tuber, plant height, leaf number and tuber weight per plant (Kandil, 2011).

Dry matter content, starch, protein, sugar in potato tubers can increase or decrease, depending on the mineral fertilizers forms and rates and their correlation (Makaraviciutte, 2003). In some European countries and the USA that have a potato growth cycle of 4-5 months (WPC, 2003),the recommended N fertilization rates vary from 70 to 330 kg ha^{-1} and the most economically efficient rates from 147 to 201 kg ha^{-1} (Fontes *et al*., 2010). Researchers in the Czech Republic advice a fertilization rate of 140 kg ha^{-1}N as the optimum for tuber yield above 30 t ha^{-1} (Ruža *et al*., 2013). Riley (2000), found that the optimum N levels was 80 kg N ha^{-1} for yield of 15 t ha^{-1} up to 120 kg N ha^{-1} for a yield of 40 t ha^{-1} in Norway. Zelalem *et al*. (2009) showed that application of 207 kg N ha^{-1} increased total tuber yield, tuber number and average tuber weight by 119, 34 and 82% respectively relative to the control in Debrebirhan, Ethiopia. In another study (Lakachew, 2007) reported at Adet Ethiopia application of 23 kg N ha^{-1}increased 16% more total yield compared to the control treatments. Similarly, Frezgi (2007) obtained maximum total tuber yield (40.17 t ha^{-1}) with 150 kg N ha^{-1} than other N rates (50 and 100 kg ha^{-1}) while minimum value (17.28 tha^{-1}) was recorded with control at Enderta, Southern Tigray.

2.5. Effect of P fertilizer on growth and yield components of potato

The potato crop is phosphorus (P) inefficient (Nigussie, 2001). Fontes (1997) further stated that plant growth is delayed with low-P levels already at initial stages; besides tuber yield, number and length of roots and stolon are reduced. Phosphorus is known to be involved in several physiological and biochemical processes of plants being components of membranes, chloroplasts, mitochondria (Sanchez, 2007) and constituent of sugar phosphate, such as adenosine diphosphate (ADP), adenosine triphosphate (ATP), nucleic acid, phospholipids and phosphate (Hue, 1995). In many soils plant-available P is deficient and has to be supplemented with fertilizer and organic amendments (Mikhailova *et al*., 2003; Dechassa *et al*., 2003; Osono and Takeda, 2005). Potato is highly responsive to soil-applied nutrients, especially to phosphorus (P), due to its short cycle and high yield potential (Fernandes and Soratto, 2012).

Depending on soil type, potato variety, crop rotation, moisture supply and management practices, a normal potato crop may remove an estimated 90 to 192 kg N and 13.8 to 25.8 kg P from the soil (Sikka, 1982). Tubers accounted for over 70% of the nutrient removed (Getu, 1998).P is abundantly available in soils (Khan *et al.*, 2006) but availability for plants is generally low, because at least 70 to 90% of the P that enters the soil is fixed by Fe, Al and Mn in soils (McBeath *et al.*, 2006). Phosphorus is a nutrient that should therefore be available in adequate quantities from the early growth stages to maintain a high photosynthetic rate during tuber bulking (Hu *et al*., 2010). However, the application of high P doses may cause environmental and economic problems as well as a nutritional imbalance in potato plants (Hopkins *et al*., 2008). Assefa (2005) reported that stem number per hill was not significantly affected by the application of N and P.

Potato tuber yield increased with increasing P fertilizer (Jenkins and Ali, 1999). Phosphorus deficiencies conversely significantly reduced tuber size and yield and specific gravity (Bryan *et al.*, 2005).Potato tuber yield is influenced by P fertilizers through its effect on the number of tubers produced, the size of the tubers and the time at which maximum yields are obtained (Sharma and Arora, 1987). A report by Mohr and Tomasiewicz (2008), total tuber yield increased linearly with increasing P fertilizer rate leveled at 0,34, 67 and 100 kg P_2O_5 ha^{-1} with 34 kg P_2O_5 ha^{-1} gave numerically lower yield than any other treatments. Similarly, Wijewardena (1996) reported high tuber yield by applying 100 kg P ha^{-1} followed by 50 and 25 kg P ha^{-1}, respectively. Increasing the rate of P from 0 to 138 kg P significantly increased tuber number $plant^{-1}$ from 6.4 to 7.9 (Firew Gebremariam, 2014). Israel *et al*. (2012) and Zelalem *et al.* (2009) reported that increasing the rates of P increased the number of tubers set $plant^{-1}$.

2.6. Effect of S fertilizer on growth and yield components of potato

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis and is required in similar amount as that of P (Ali *al.,* 2008). Sulfur deficiency has become widespread over the past several decades in most of the agricultural areas of the world, becoming a limiting factor to higher yields and fertilizer efficiency (SRDI, 1999). Crop responses to applied S have been reported in a wide range of soils in many parts of the world (Brady and Weil, 2002). It is a building block of protein and a key ingredient in the formation of chlorophyll (Duke and Reisenaue, 1986). Without adequate S, crops cannot reach their full potential in terms of yield or protein content (Zhao *et al.,* 1999). It is required for the synthesis of S containing amino acids such as cystine, and methionine. The symptoms of S deficit are observed not only in plant species of high S requirements (Sahota, 2006), but also in plant species of relatively low S requirements, including potato (Klikocka *et al*., 2003). Their deficiency results in stunted growth, reduced plant height, tillers and delayed maturity also less resistance under stress conditions (Doberman and Fairhurst, 2000).

Application of S fertilizer is a feasible technique to suppress the uptake of undesired toxic elements (Na and Cl) because of the antagonistic relationship, thus its application is useful not only for increasing crop production and quality of the produce but also improves soil conditions for healthy crop growth (Zhang *et al*., 1999). S improves K and Na selectivity and increases the capability of calcium ion to decrease the injurious effects of sodium ions in plants (Wilson et al., 2000). S is also reported to enhance the photosynthetic assimilation of N in crop plants (Anderson, 1990; Ahmad and Abdin, 2000). Hence, the application of N and S fertilizers increases the net photosynthetic rate in crop plants, which in turn increases their dry matter and grain yield, as 90% of the plant's dry weight is considered to be derived from products formed during photosynthesis (Peoples et al., 1980).The requirement of N by plants increases when N is fertilized with S, as their metabolism is coupled in the synthesis of S-containing amino acids, membrane lipids, enzymes and coenzymes (Anderson, 1990).

According to (Diriba Shiferaw *et al.*,2015) the growth, yield and yield attributes of garlic bulbs increased significantly with the application of NPS blended fertilizers and with further increased growth stages of the plant, especially after 60 days of growth. Many previous studies have shown that N fertilizer applications can increase dry matter content, protein content of potato tubers, total and/or marketable tuber yield (Zelalem *et al*., 2009).Poor use efficiency of N by the plant is caused by insufficient S availability to convert N into biomass production, which in turn may increase N losses from cultivated soils (Ceccotti, 1996).Response of crop growth and yield to the application of S has been reported for many crops (Singh, 2006), where an insufficient S supply can affect yield and quality of crops, caused by the S requirement for protein and enzyme synthesis (Zhao et al., 1999). According to Sud (1996) significant responses of potato tuber yield to P and S application was obtained at individual application rates of 22 kg ha^{-1}. Sud *et al*. (1992) indicated that increasing levels of N fertilizer recorded a significant increase in quality attributes in potato. The yield-promotion by S on potato was already observed by Klikocka and Sachajko (2007), who found that the highest tuber yields were recorded when applying 25 kg S ha^{-1} in the ionic form or 50 kg S·ha^{-1} in the elemental form, as well as by Mondal *et al.* (1993), Pavlista (2008) and Sharma *et al.* (2011).

2.7. Effect of Organic Manure in Crop Production

Organic manures are all forms of organic soil amendments that originate from both livestock waste and crop residues, with the nutrients in them being mineralized by soil microbes and slowly making them available to plants over a long period of time (Lampkin, 2000). The application of organic manure can contribute to agricultural sustainability (Wells *et al.*, 2000) as continuous and adequate use of manure with proper management has been shown to have many advantages, which include providing a whole array of nutrients to soils, increasing soil organic matter (Verma *et al*., 2005), improving water holding capacity and other physical properties of soil like bulk density, penetration resistance and soil aggregation (Wells *et al*., 2000).

There is also evidence that it may contain other growth-promoting substances like natural hormones and B vitamins, increasing beneficial soil organisms, reducing plant pathogens and showing a beneficial effect on the growth of variety of plants (Montemurro *et al*., 2006). Supply of nutrients from the organic materials can be complemented by enriching them with inorganic nutrients that will be released fast and utilized by crops to compensate for their late start in nutrient release (Ayoola and Makinde, 2009). The availability of P in cattle manure is estimated to be about 50% compared to commercial P fertilizer and the response to the P depends on the availability of other nutrients in the manure such as N (Schoenau, 1997).

2.7.1. Effect of cattle manure on growth and yield component of potato

Organic manures and their extracts have been used to improve soil fertility and in combating pests and diseases (Khadem, *et al*., 2010).Using of animal manure such as cattle manure has positively beneficial effects on vegetative growth, yield and tuber quality (Balemi *et al.*, 2012; Najm *et al.*, 2013). Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma, 1991), supporting better root development, leading to higher crop yields (Abou El-Magd *et al*., 2005).Cattle manure is the main source of nutrients for the maintenance of soil fertility in settled agriculture until the advent of mineral fertilizers (Oforiand Santana, 1990).The advantage of cattle manure application depends on application methods, which increase the value, reduce cost and effectiveness (Teklu *et al*., 2004). According to Jayramaiah *et al*. (2005) have shown that the increased plant height, shoot number, leaves area, and total dry matter accumulation were obtained by the application of appropriate amount of animal manure.

The increase in yield is due to more availability of essential nutrients to plants and improvement in physico- chemical properties of soil, resulting in better tuberization Khan *et* *al. (*2000).All these might have accelerated metabolic activities leading to better photo syntheses and efficient translocation of photosynthesis from sink to sources resulting in improvement of leaf yield and its related attributes (Mohadeen, 2008).Regular application of organic amendments can sustain soil N fertility and increase marketable potato yields by 2.5 to 16.4 t ha^{-1}, compared to the un amended and unfertilized soil (N'Dayegamiye *et al*., 2013). Canali *et al*. (2010) reported that application of FYM substantially increased the total potato yield by 25% as compared to control. Powon *et al*. (2006) reported that high ware potato yield was obtained with 20 t FYM ha^{-1}. Olaoye *et al*. (2013) report at that 10 t organic matter ha^{-1}increased the number of marketable storage roots of sweet potato. Mehdizadeh *et al*. (2013) showed that application of swine/poultry applied at 10t ha^{-1} resulted in best growth and 47 t fruit yield ha^{-1}of tomatoes.

2.8. Effect of Combined Use of Inorganic Fertilizers and Cattle Manure on Growth and Yield Components of Potatoes

Inorganic fertilizers are considered to be an important source of major elements in crop production. Continuous use of inorganic fertilizer resulted in deficiency of micro nutrients, imbalance in soil physicochemical properties and unsustainable crop production (Jeyathilake *et al*., 2006). To ensure soil productivity, plants must have an adequate and balanced supply of nutrients that can be realized through integrated nutrient management where both natural and man-made sources of plant nutrients are used (Gruhn *et al.,* 2000).Combining inorganic and organic fertilizers result in greater benefits than either input alone through positive interactions on soil biological, chemical and physical properties (Bekunda *et al*., 2010).

Drechsel *et al.* (2001) reported that the application of recommended mineral fertilizers do not improve the negative nutrient balance due to the higher nutrient removal from the soils. Many researches recommend integrated soil amendment practices because single application or practices could not reverse the existing problem (Eichler *et al.,* 2007). It is crucial to note that greater crop productivity induced by the use of mineral fertilizers does not translate into better soil fertility in the long term when large amounts of carbon and nutrients are removed every season from the fields with the crop harvests residue (Bekunda *et al.,* 2010). Therefore, the use of integrated nutrient management is very important and best approach to maintain and improve soil fertility (Lander *et al.*, 1998) thereby to increase crop productivity in an efficient and environmentally freindly manner without sacrificing soil productivity of future generations.

Integration of inorganic NPS and cattle manure exhibited an increase in tuber yield of potato. This could be due to balanced C/N ratio, more organic matter build up, enhanced microbial activity, improvement in soil properties, better root proliferation, sustainable availability and accelerated transport and higher concentration of plant nutrients. All these might have accelerated metabolically activities, leading to better photosynthesis and efficient translocation of photosynthesis from sink to sources (Ouda and Mohadeen, 2008).

Under Ethiopian condition particularly in the highlands, integrated soil fertility management can give better yields as high as balanced application of fertilizer and significantly higher yields than the traditional cultivation method. To recovering the soil to its productive state it was not enough to apply mineral fertilizer alone, therefore integrated nutrient management was considered for the area (Zelalem, 2012). The combined use of organic manure and inorganic fertilizers helps to maintain soil health and sustain productivity especially in heavy feeder crop like potato (N'Dayegamiye, 2009).

2.8.1. Phenology and Growth Parameters of potato

Potato is the most sensitive crop to nutrient stress and its growth can be enhanced significantly with balanced fertilization (Sharma and Sud, 2001; Khan and Joergensen, 2012). Potato assimilates nutrients from organic and mineral fertilizers rather intensively to satisfy its Vegetative growth (Makaraviciutte, 2003; Geremew *et al*., 2007). Therefore, a crop with more nitrogen will mature later in the season than a crop with less nitrogen because extended vegetative growth is related to excessive haulm development whereas early tuber growth to less abundant haulm growth (Israel *et al.*, 2012, Barbara,. 2007 **)**. The significant effects of combined use of mineral NP and cattle manure on growth parameters, like main stem number, plant height, number of leaves could be ascribed to a synergistic effect of the combined application of N and P and organic manure (carbon) in promoting cell division, cell growth, and proliferation of leaves and axillary branches (Oliveira, 2000). However increasing the rate of compost and NP-fertilizer did not influence stem number and unmarketable tuber number (Getachew Alemayehu, 2006).

Contrary to this result, several researchers reported that stem number was not influenced by inorganic nutrients but by other factors such as physiological age of the seed tuber (Asiedu *et al*., 2003), storage condition of tubers, number of viable sprouts at planting, sprout damage at the time of planting and growing conditions (Firman and Allen, 2007), variety and tuber size (Park *et al*., 2009).Suh *et al.* (2015) demonstrated that the highest values of plant height, stem diameter and leaf size were registered by plants fertilized with cattle manure at 20 t NPK (20:10:10) kg ha^{-1} compared to sole cattle manure or inorganic NPK fertilizer application. Nebret (2012) reported also that the application of N resulted in significantly delayed physiological maturity. Increase in N application rate from 0 to 46 kg N ha^{-1} led to a significant increase in the number of days required to reach physiological maturity. EARO (2004) stated also that days to maturity of potato varieties varied from 90 to 120 days and the variation is accounted for by variety, growing environment and cultural practices.

Organic manure activates many species of living organisms which release phytohormones and may stimulate the plant growth and absorption of nutrients (Arisha *et al*., 2003). Such organisms need N for multiplication. This may be a plausible reason that use of organic manure with inorganic fertilizer leads to increase the leaf area which increases the amount of solar radiation intercepted thereby increasing days to flowering, physiological maturity, plant height and dry matter accumulation (Ouda and Mahadeen, 2008).Synthesis of proteins and formation of new tissues are stimulated resulting in vigorous vegetative growth. This extends the days of physiological maturity (Lincoln and Edvardo, 2006).The number of days to reach maturity is the important parameter for potato producers in that it enables the growers to develop a suitable production calendar the marketing plan (Khalafalla, 2001).

As Gonzalez *et al.* (2001) reported inorganic NP fertilizer and cattle manure applied at seedling stage increased plant height. The maximum plant height, shoot dry matter and tuber yield were obtained with combined application of vermin compost and chemical fertilizer (Alam *et al*., 2007). Bwembya and Yerokun (2001) reported also that plants treated with both

N and P fertilizer and cattle manure were significantly taller than those in the control plots. Similar to the combined NP fertilizer, increasing the rate of cattle manure significantly enhanced plant height. Farooque and Baten (1993) reported that the application of both K and S either individually or in combination increased plant height, leaves number, bulb diameter, bulb weight and yield.

2.8.2. Tuber number

Tuber number is also determined by the number of stems produced which in turn depends up on the tuber size and variety as reported by Ebwongu *et al*. (2001). It is further indicated any increase in the stem density over the economical range (which varies with the soil type, climate, management etc.) resulted in a reduction in the number of tubers set per stem. (Annad and Krishinapp, 1989) who stated that the increase in total tuber number per plant is in response to the increased application of the combined NP fertilizers and CM might be due to the increased photosynthetic activity and translocation of photosynthetic to the root, which is probably helped in the initiation of more stolon in potato. Taheri *et al*. (2010) also found the highest ratio (13.07%) of number of large tubers as a result of application of 20 t compost ha^{-1}of combined with 225 kg P ha^{-1} and 50 kg zinc ha^{-1}.

Increasing the rate of cattle manure and NP-fertilizer significantly increased major yield components such as plant height, marketable tuber number and average tuber weight and significantly decreased days to flowering and maturity. This might be due to its higher nutrient composition and capacity to increase availability of native soil nutrient through higher biological activity (Pengthamkeerati *et al*., 2011). At any given level of P the total tuber number plant^{-1}, increased with increase in cattle manure application. This is because the application of cattle manure to soil results in an increase in carbon mineralization from the soil due to available carbon for microbial respiration, provision of nitrogen and P. The N and P are important in tuber initiation and tuber enlargement. Thus, tuber number increased with increase in P and FYM application (Powon *et al*., 2006).

Contradicting results have also been reported by different investigators regarding the effect of mineral nutrition on the number of tubers set plant^{-1}. For instance, Sharma and Arora (1987 cf. Yibekal, 1998) have reported no significant difference in the total number of tubers per square meter of land area as a result of N, P and K fertilizer application, while Lynch and Rowberry (1997) have reported significant difference in tuber numbers due to N fertilization.

2.8.3. Yield and yield components

The yield of potato tubers is considered to be a function of four processes: radiation interception, conversion of intercepted radiation to dry matter, partitioning of the dry matter between the tuber and the rest of the plant and regulation of tuber dry matter (Millard and Marshall, 1986). Potato crop has strict requirement for a balanced fertilization management, without which growth and development of the crop are poor and both yield and quality of tubers are diminished (Sharma and Sud, 2001). Total tuber yield was significantly influenced by the cattle manure + NP fertilizers Tasfaye, (2005).

The application of 100 kg P ha^{-1} + 20 t cattle manure ha^{-1} resulted to highest ($P< 0.05$) total tuber yield whereas control treatments and the application of 50 kg P ha^{-1}, showed the lowest total tuber yield Mugambi (1979). Taheri *et al.* (2011) found the highest average tuber weight of potato from plots treated with 20 t ha^{-1} compost and 225 kg ha^{-1} phosphorus in combined manner. Matiwos and Shashidhar (2011) found maximum mean tuber weight (65.23 g) where 100% recommended rate fertilizer was combined with 25 t ha^{-1} of FYM in India. For instance at Kobo district of North Wollo, application of 20.5 kg N ha^{-1}and 22.9 kg P_2O_5 ha^{-1} along with 15 t ha^{-1} FYM produced 4.2 t ha^{-1} of sorghum grain compared to 3.3 t ha^{-1} when the same rates of NP were used alone (Bayu *et al*., 2006). Maximum tuber yield (36.8 t ha^{-1}) was obtained by the utilization of 150 kg N + 20 t cattle manure ha^{-1} Fazeli (2013). Nasreen *et al*. (2007) obtained the highest onion yield in response to the combined application of 120 kg N + 40 kg S ha^{-1} with a blanket dose of 40 kg P, 75 kg K, 5 kg Zn ha^{-1} and 5 t ha^{-1} of cow dung.

According to Baniuniene and Zekaite (2008) have also indicated that FYM increased tuber yield by 35-82%, depending on inorganic fertilizer combination. Besides, Balemi (2012) showed that application of 20 or 30 t ha^{-1} FYM + 66.6% of the recommended inorganic NP fertilizers significantly increased total tubers yield. Alam *et al.* (2007) evidenced that the maximum tuber yield (36.8 tha^{-1}) was obtained by combined application of cattle manure and N fertilizer at the concentrations of 20 tha^{-1} and 150 kg N ha^{-1}respectively. The application of compost and combinations of N, P and S to soils increased the bulb diameter of onion Gebrekiros A. (2013).Yeng *et al*. (2012) reported the combination of 150 NPK ha^{-1} + 1.5 t ha^{-1}cattle manure (CM) and 100 kg NPK ha^{-1} + 3.0 t ha^{-1} CM to produce the highest marketable root yield of sweet potato for the Guinea savanna and forest-savanna transition zones, respectively. There is substantial evidence demonstrating gains in crop productivity from nutrient additions through mixtures of organic and inorganic sources of nutrients compared with inputs alone Ferdoushi *et al*., 2010).

According to Mohammadi *et al*. (2013) reported that the presence of nutrients in manure and balanced supplement of nitrogen and phosphorus through mineral fertilizers might have contributed to increased cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters .According to Darzi, et al., (2012) maximum tuber yield (36.8 t ha^{-1}) was obtained by using150 kg N ha^{-1} + 20 t CM ha^{-1}.For instance, in Kenya, Powon *et al*. (2006) reported that a combination of P at 100.4 kg ha^{-1} and FYM at 20t ha^{-1} resulted in an increase of 62% of fresh tuber yield compared to the control. Studies by Porter *et al*. (1999) showed that soil amended with 45 t ha^{-1} FYM increased in potato yield by 23% compared to the yields from non-amended soils. Similarly, Siddique and Rashid (1990) recorded higher tuber yield of potato when mineral NPK fertilizers were applied at the rate of 95.2, 66.7, and 145.2 kg ha^{-1}, respectively along with 10 t ha^{-1} cow dung compared to that of without cow dung application.

Marketable yield is a function of total biomass production, the percentage of biomass that is partitioned to the tubers, the moisture content of the tubers and the proportion of tubers that are acceptable to the market, in terms of size and lack of defects and great opportunities exist to increase potato yield and quality by improving nutrient management (Ewing, 1997), previous research results in different parts of Ethiopia indicated that potato showed significantly different response to the applied fertilizer. Application of 10 t ha^{-1} compost with mineral fertilizers (73.4 kg N and 59.5 kg P_2O_5 ha^{-1}) gave yield advantage of 8.4t ha^{-1} in southern Ethiopia (Abay and Tesfaye, 2011).

According to Teklu *et al*. (2004) reported that high tuber yield was observed with a combination of 2 t CM ha^{-1} with 92 kg N ha^{-1} and 105 kg P_2O_5 ha^{-1} on Andosols of Debre Zeit of Ethiopia. Hosseny and Ahmed (2009) ascribed that larger head diameter and weight of lettuce were recorded with 120 kg N ha^{-1} combined with 3 and 6 t FYM ha^{-1}. Nyangani (2010) observed 130 and 140% yield increment with 10 and 20 t ha^{-1} FYM along with mineral NPK fertilizers at 100, 50 and 25 kg ha^{-1} than control treatment, respectively in onion. Besides Najm *et al.* (2013) indicated that maximum tubers yield (36.8 t ha^{-1}) was obtained with 150 kg N ha^{-1} + 20 tha^{-1}CM. Suh *et al.* (2015) observed also that tuber yield was increased by the combined use of cow dung and NPK (20: 10: 10) compared to sole application of cow dung or NPK.

2.8.4. Tuber quality

The quality is associated with nutritional value and suitability for wide range of cooking purposes. Quality of tuber may include many characters so that a simple definition may be misleading (Dean, 1994). These are represented by specific gravity, dry matter content, texture, starch, reducing sugars, pulp pH, titratable acidity (TA), crude protein and total soluble solids content which might be influenced by cultivar (Feltrán *et al*., 2004) and growing conditions such as fertilizers application (Kandil *et al*., 2011; Taheri *et al*.,2011).The factors contributing to quality are various and affected to differing extents by the cultivar and environmental conditions and the interactions between them (Storey and Davies, 1992).

Fertilizer application has important effects on the quality of potato (Westermann, 2005).Joy *et al.* (2005) reported the possibility of substituting up to 25% inorganic fertilizers with the application of 30 t ha^{-1} cattle manure while still maintaining the highest rhizome yield and quality of black musli. Sud *et al*. (1992) found that increasing levels of N fertilizer recorded a significant increase in quality attributes in potato. The addition of various organic sources enhanced the fertility status of soil and improve the soil physiochemical properties that created the favorable condition in rhizosphere, increase the uptake of nutrients also the secretion of certain enzymes and auxins and other growth promoting substances which ultimately improve the quality of potato (Singh *et al.,* 2007).

The most appropriate integration for N as inorganic and organic fertilizer in different forms and levels for improving vegetative growth, obtaining the optimum potato yield and good tubers quality Ahmed *et al.* (2009). Sud *et al*. (1992) reported that increasing levels of N fertilizer recorded a significant increase in quality attributes in potato Kumar *et al*. (2006). Joy *et al.* (2005) reported the possibility of substituting up to 25% inorganic fertilizers by the application of 30 t ha^{-1}CM while still maintaining the highest rhizome yield and quality in black musli.

2.8.4.1. Dry matter content

The dry matter content of tuber is an important measure of quality and is used to assess suitability for processing purposes as it affected process efficiency, product yield and oil absorption. It was observed that tubers with high dry matter content required less energy input during frying or dehydration to remove water; resulted in greater product yield per unit fresh weight than tubers with lower solids content and absorbed less oil during frying (Abera,2001). According to Abera (2001; in citation of Nelson and Shaw, 1976) the dry matter content of potatoes largely governed the weight of processed products which might be obtained from a given weight of raw tubers. According to these authors observation dry matter content is the main determinants of quality for both processing and cooking since high dry matter content with less sugar accumulation and water content were desirable.

The tuber dry matter content was affected by a wide range of factors that affected the growth and development of the crop including most importantly, environmental factors such as intercepted solar radiation, soil temperature, available soil moisture and cultural treatments (Abera, 2001). Other worker (Abera, 2001) found that the applied N and K usually reduced tuber dry matter but the effects were not always consistent and the dry matter changes however were usually small over the range of fertilizer levels used to give optimum yield.

According to Alemayehu (1998) application of N and P significantly decreased per cent dry matter and found no significant difference in dry matter content between potato tubers in Wondo Genet area of Ethiopia. The highest amount of dry matter is limited by cultivar characteristics of the potato (Tesfaye *et al.*, 2012). It also influenced by a wide range of factors that affected the growth and development of the crop including most importantly, environmental factors such as intercepted solar radiation, soil temperature, available soil moisture and cultural treatments (Storey and Davies, 1992).

According to Beukema and Van der Zaag (1990) stated that excessive N may cause low dry matter content and high protein and nitrate content, especially if it leads to harvesting the crop before it reaches its physiological maturity. Sud *et al.* (1992) found that increasing levels of N fertilizer recorded a significant increase in quality attributes in potato. This might be due to the reason that the plant supplied with N had higher K content, implying that these have absorbed more K which contributed in carbohydrate and proteins synthesis, starch break down and neutralization important organic acids resulted in higher quality tuber. Baniumiene and Zekaite (2008) reported that higher starch and dry matter content were observed in potato tubers grown without FYM. In a similar way the highest dry matter and starch content were accumulated in the tubers of crops fertilized with mineral not organic fertilizers (Stimumar *et al*., 1990).

Dry matter content, starch, protein, sugar in potato tubers can increase or decrease, depending on the mineral fertilizers forms and rates as well as their correlation (Makaraviciutte, 2003). The increase in plant height with the increased application of S might be due to its role in the growth and physiological functioning of plants, thus improving its quality by increasing the dry matter contents of the crop (Barker and Pilbeam, 2007).This might be associated with the influence of N on gibberellins biosynthesis and other phyto-hormonal activities which have direct influence on plant growth and dry matter accumulation. High levels of endogenous GA promote shoot growth and delay or inhibit tuberization (Menzel, 1980). Abdella *et al*. (1995) impede the accumulation of starch, protein and other tuber specific gravity Vreugdenhil *et al*., (1999). According to Najm *et al*. (2010) the increase in the NP fertilizer might have enhanced chlorophyll concentration, the photosynthetic rates, the leaf expansion, the total number of leaves and the dry matter accumulation.

2.8.4.2. Specific gravity

Specific gravity is one of the essential traits in potato to provide a fast and easy measure of dry matter content (Tahiri *et al.,* 1985 cf. Abera, 2001). Specific gravity is the measure of choice for estimating dry matter, total solids and starch content and ultimately for determining the processing quality of potato cultivars (Baritelle and Hyde, 2003; Tesfaye *et al*., 2013). The specific gravity also provided an estimate of starch content of tuber as it is the major component of the dry matter, usually comprising 65-75 per cent of the total soluble solids (Storey and Davies, 1992). The relationship between specific gravity and per cent dry matter has been reported by anumber of workers but slight differences were found because of evaluations with different cultivars and on crops grown under a range of environmental conditions (Storey and Davies, 1992). They attributed these cultivar differences in part to differences in intercellular spaces between the tuber and differences in the composition of dry matter. High and uniform specific gravity in potato tubers is essential to the growers and the processors. For example, Kabira and Berga (2003) pointed that potato tubers should have a specific gravity value of more than 1.080 and tubers with specific gravity value less than 1.070 are generally unacceptable for processing.

N'Dayegamiye *et al*. (2013) reported that specific gravity of tubers ranged from 1.070 to 1.073 and was significantly increased with organic fertilizers amendment and mineral fertilizer application. An increase in tuber specific gravity with increasing rates of N, cattle and chicken manure (Abou-Hussein *et al*., 2003) and combined application of chicken manure and NPK (Soliman *et al*.,2008) were also reported. Higher specific gravity value being associated with the lower N rate (50 kg ha^{-1}) while the higher rates gave lower specific gravity when averaged overall cultivars and time of N application (Abera, 2001). Contrary to this, Gautam *et al*. (2013) noted non-significant difference in specific gravity of tubers due to N application. Abo-Sedra and Shehata (1994) reported also that specific gravity of potato tubers was not affected by N application rate of 180 kg N ha^{-1}. According to him increased specific gravity with mineral P and 5 t FYM ha^{-1}with 200 kg K_2O ha^{-1} resulted in higher specific gravity (1.091) compared to sole application of K fertilizer and the control treatment (Pervez *et al*., 2000). Kandil *et al*. (2011) found that highest specific gravity (1.064 g cm^3) with 60% mineral N (238 kg N ha^{-1}) was combined with 40% chicken manure (158 kg N ha^{-1}).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted on a farmer's field in Seka Wereda of Jimma zone of the Oromia Regional State from December to march during the irrigation cropping season of 2016. Seka wereda is located at a distance of 375 km, south -West of Addis Abeba and 18 km from Jimma town. Dabo Ghibe keble is 15 km from Jimma City. Seka wereda shares a boundary with Gomma and Manna districts in the North, Gera wereda in the South, Dedo wereda and Jimma town in the East and Shabe Sombo wereda in the West. Geographical coordinates of the research site is 7.67^{0}'N latitude and 36.83^{0}'E longitude having an altitude of 1780 meters above sea level (from GPS reading, 2016). The experimental area is characterized by a mono modal pattern of rainfall. Total annual rainfall is 1553 mm. The peak rainy months are July, August and September.

The mean annual maximum and minimum temperatures are 28.8^{o}C and 8.9^{o}C, respectively. The coldest months are October-January whereas February to April is the hottest month. The soil type of the site is nitisol, which is typically formed from highly basic rocks such as basalt in climates that are seasonally humid or subject to erratic, droughts and floods, or to impede drainage (Seka wereda Agriculture and Rural development Office, 2009, Annual Report Unpublished).

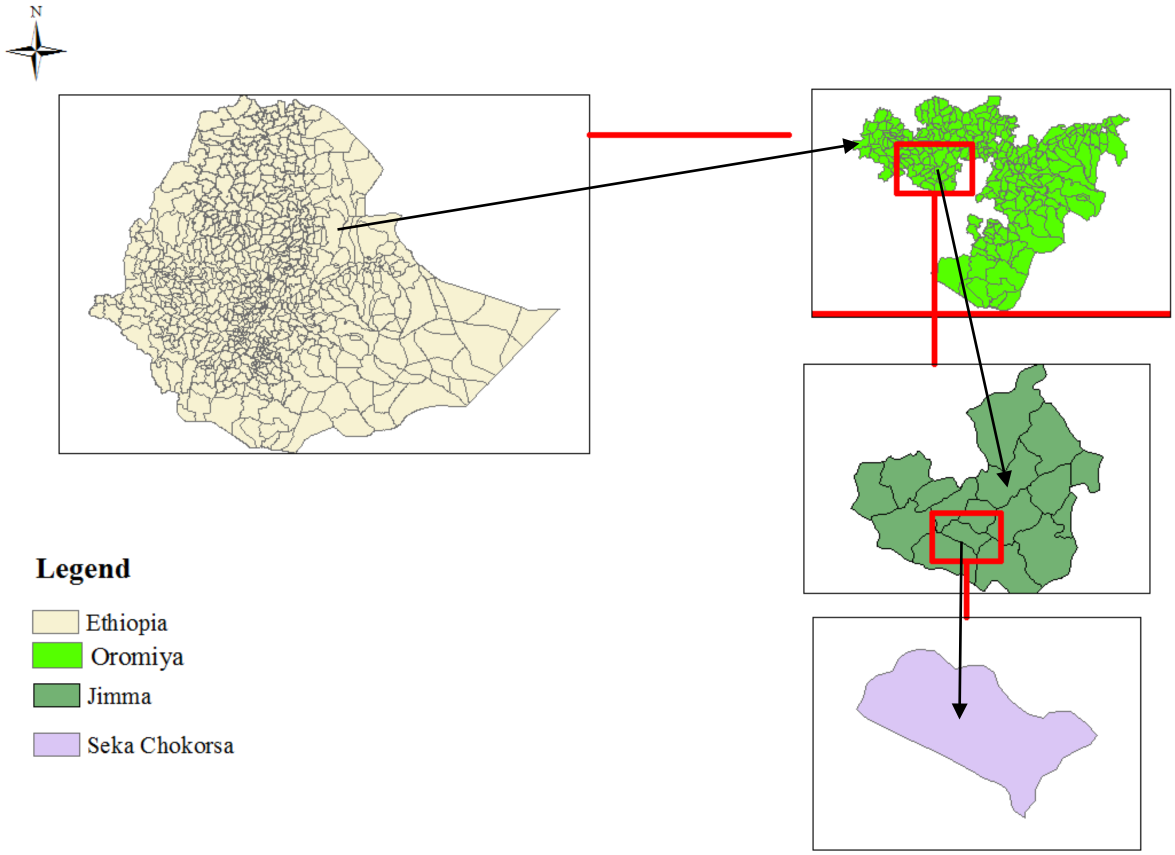


Figure1: Map of the Study Area

3.2. Experimental Materials

Potato cultivar "Gudane" which was obtained from Jaldu farmer’s cooperative union via Holetta Agricultural Research center was used for the study in 2006. Gudane is adapted to areas located in 1600-2800 meters above sea level and receiving an annual rainfall of 750-1000 mm (Habtamu *et al*., 2016).

3.3. Treatments and Experimental Design

The treatments was two factors namely four level of NPS blended fertilizer application rates (0, 50, 100 and 150kg ha^{-1}) based on agricultural transformation agency tentative fertilizer recommendation rate on the study area (100kg ha^{-1} NPS blended fertilizer was tentative recommendation) and four level of cattle manure rates (0, 10, 20 and 30t ha^{-1}) and (30t ha^{-1} CM used as a base). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times. There were sixteen treatment combinations, which were assigned to each plot randomly.

Table 1: Description of treatment combination

Treatment	Description
T1	Control (0 NPS + 0 CM)kg/t ha^{-1}
T2	50 kg ha^{-1} NPS blended fertilizers + 0 t ha^{-1} cattle manure
T3	100 kg ha^{-1} NPS blended fertilizers + 0 t ha^{-1} cattle manure
T4	150 kg ha^{-1} NPS blended fertilizers + 0 t ha^{-1} cattle manure
T5	10 t ha^{-1} cattle manure
T6	10 t ha^{-1} Cattle manure + 50kg ha^{-1} NPS blended fertilizers
T7	10 t ha^{-1}Cattle manure + 100kg ha^{-1} NPS blended fertilizers
T8	10 t ha^{-1}Cattle manure + 150kg ha^{-1} NPS blended fertilizers
T9	20 t ha^{-1} cattle manure
T10	20 t ha^{-1} Cattle manure + 50kg ha^{-1} NPS blended fertilizers
T11	20 t ha^{-1} Cattle manure + 100kg ha^{-1} NPS blended fertilizers
T12	20 t ha^{-1} Cattle manure + 150kg ha^{-1} NPS blended fertilizers
T13	30 t ha^{-1} Cattle manure
T14	30 t ha^{-1} Cattle manure + 50kg ha^{-1} NPS blended fertilizers
T15	30 t ha^{-1} Cattle manure + 100kg ha^{-1} NPS blended fertilizers
T16	30 t ha^{-1} Cattle manure + 150 kg ha^{-1}NPS blended fertilizers

3.4. Experimental Procedure and crop management

The experimental field was ploughed using oxen and plots were leveled manually. Sowing was done on December, 4, 2016 at Seka district Dabo Gibe kebele farmers' field site. The experimental site measuring 57m by 12m was cleared and ploughed to a depth of about 25 - 30 cm. There were 48 plot each measuring 3x3 m (9m^2) and was separated by a buffer of 0.5 m.The distance between blocks was 1 meter. The seed tubers were planted at the depth of 5 cm in the soil (Mahmood *et al.*, 2001) at the spacing of 75 cm between rows and 30 cm between seed tubers. The two outer rows were considered as border. NPS were used as a source of mineral nutrients and full doses which varied depending on treatments were applied as side banding at planting time and decomposed cattle manure also used as sources of nutrients and full doses which varied depending on treatments was applied as two week before planting the potato tubers and homogeneously applied and distributed into desired plots, then incorporated into the soil at the depth of 20 cm. Uniform and well sprouted, two and more than two sprouted potato tubers were planted at 5-7cm depth of planting and soon after planting, a ridge was done to cover the potato tubers by excavating the soil from both the sides.

The experiment was carried out using furrow irrigation starting from planting date to the harvesting date at seven-day irrigation intervals based on weather condition of the area. Plots were irrigated until the soil was saturated. Other agronomic practices were kept uniform for all treatments as recommended and adopted for the location.

3.5. Soil and Cattle Manure Sampling and Analysis

Before planting, physical and chemical properties of the experimental field soil were determined. Therefore, representative soil samples were collected from the experimental field randomly in a zigzag pattern at depth of 0-30 cm before planting using an auger. The soil samples were composited and a one kg sample was taken as a working sample. Crumbs of soil were broken into pieces and sieved. The collected composite samples were air-dried on paper trays, ground, and sieved to pass through a 2 mm sieve for chemical analysis.

The soil analysis included determination of total nitrogen, available phosphorus, textural analysis (sand, silt and clay), soil pH, Cation exchangeable capacity and organic carbon. Cattle manure was also analyzed for selected chemical composition such as total nitrogen, soil pH, organic carbon and available phosphorus using the appropriate laboratory procedures. Soil texture analysis was performed by Bouyoucous hydrometer method (Day, 1965).Total nitrogen was determined using the Kjeldhal method (Dewis and Freites 1970).The pH of the soil was measured in water at soil to water ratio of 1:2.5 potentiometric pH meters with glass electrode (Hazelton and Murphy, 2007), and determination of cation exchange capacity (CEC) was done using 1N ammonium acetate (NH_4-AOC) method as described by Cottenie (1965). The available phosphorus content of the soil was determined by Bray II method (Olsen *et al*., 1954).

Table 2: Initial physico- chemical properties of soil and cattle manure

No	**Parameter**	**Soil**			Cattle manure	
		Values	**Rating**	**Reference**	**Values**	**rating**
1	pH	6.5	Slightly acid	Hazelton and Murphy,2007	7.5	
2	%OC	2.5	Medium	Hazelton & Murphy(2007)	5.4	
3	%TN	0.22	Medium	Bruce & Rayment (1982)	0.469	
4	av.P(ppm)	11.34	medium	Bray II (1954)	20.19	
5	CEC(cmol)	19.26	Medium	Landon J.R.(1991)	ND	
6	Soil Texture	-				
	Sand	12.67				
	Clay	42				
	Silt	45.33				
	Textural classes	Silt clay				

Where Cmol = Cent mole, pH = hydrogen power, % OC = percent of organic carbon, %TN = Percent of total nitrogen, Av.p.ppm = available phosphorus in parts per million, CEC = Cation exchange capacity, ND = Not determined and CM = Cattle manure.

3.6. Data Collection

Data on different growth and yield components were recorded on sample plants and plot basis. The detailed methodologies adopted for collection of different data are described below.

3.6.1. Phenological data

Days to 50 percent flowering: It was recorded as number of days from emergence to the time when 50 percent of the plant stand in each experimental plot yielded flowers

Days to maturity: Number of days from emergence to physiological maturity was registered when 75 % of the plants per plot were ready for harvest as observed by the senescence of the haulms or plants leaves turned yellowish.

3.6.2. Growth parameters

Plant height (cm): Plant height was measured in cm from the soil surface to the tip of stem aboveground growth point at 75% physiological maturity. The plant height was measured from 10 randomly selected plants in each plot and the mean was recorded from the plot.

Main stems number per hill: the actual number of main stems per hill was recorded as the average stem count of 10 hills per plot at 50% flowering. Only stems that emerged independently above the soil as single stems were considered as main stems (Stems arising from the mother tuber were considered as main stems). Stems branching from other stems above the soil were not considered as main stems.

3.6.3. Yield and yield components

Marketable Tuber Number per hill: Number of tubers harvested from randomly selected five plants per plot which were counted as marketable after sorting tubers which had greater or equal to 25 g weight free from disease and insect attack. The average number of marketable tubers was counted and recorded (Lung'aho *et al.*, 2007).

Unmarketable Tuber Number per hill: The tubers that are sorted as diseased, insect attacked and small-sized (< 25 g) from randomly selected five plants per plot as indicated above was recorded as unmarketable tuber number. The average number of unmarketable tubers was counted and registered from the plot (Lung'aho *et al.*, 2007).

Total Tuber Number hill^{-1}: The total tuber number per hill was obtained by counting and adding up the number of marketable and unmarketable tubers (Zelalem *et al.*, 2009).

Marketable Tuber Yield (t ha^{-1}): The tubers that were sorted and counted from randomly selected plants as marketable were weighted and converted to marketable tuber yield in tons per hectare from net plot (Zelalem *et al.*, 2009).

Unmarketable Tuber Yield (t ha^{-1}): The average weight of tubers which were unhealthy, injured by insect pests, with defects and less than 25g weight category from net plots tubers were recorded and calculated to t ha^{-1}.

Total Tuber Yield (t ha^{-1}): The total tuber yield per plot was recorded by adding up the weights of marketable and unmarketable tuber and later extrapolated to per hectare (Zelalem *et al.*, 2009).

Dry Matter Content of Tuber (%): Five potato tubers were randomly selected from each plot, chopped into small 1-2 cm, mixed thoroughly, and two sub-samples each weighing 200 g were weighed. The exact weight of each sub-sample was determined and recorded as fresh weight. Each sub-sample was placed in a paper bag and put in an oven at 70^{o}C until a constant dry weight was attained. The sample was immediately weighed and recorded as dry weight. Percent dry matter content was calculated based on the formula described by Bonierbale *et al.* (2006).

$$\textbf{Dry matter}\ (\%) = \frac{\boldsymbol{weight\ of sample\ after\ drying\ (g)}}{\boldsymbol{Initial\ weight\ of sample\ (g)}} \times \mathbf{100}$$

Specific Gravity of Tubers (gcm^{-3}): Tubers of all size categories weighing about five kilogram was randomly taken from each plot and washed with water. Following this step, the sample was first weighed in air and then re-weighed suspended in water. Specific gravity was finally determined as described by Kleinkopf *et al.* (1987).

$$\textbf{Specific gravity}\ (\mathrm{g\ cm^{-3}}) = \frac{\textbf{Weight of tubers in air}}{\textbf{Weight of tubers in air} - \textbf{Weight of tubers in water}}$$

3.7. Statistical analyses

Data were subjected to analysis of variance (ANOVA) using SAS version 9.3 (SAS Institute Inc., 2012). The difference between treatments means were compared using Least Significant Difference (LSD) at 5% level of significance. Pearson correlation analysis was done between major growth and yield component of potato.

3.8. Economic analysis

The economic analysis was done using the partial budget analysis described by CIMMYT (1988).Net return (Birr $\mathrm{ha^{-1}}$) and cost benefit ratio were calculated by considering the sale prices of potato and cost of fertilizers and labour for all field activities done. Thus, the economic gains of the different treatments were calculated to estimate the net returns and the cost of cultivation, after considering the cost of fertilizer NPS, cattle manure , labour and the income from total potato tubers for economic analysis. Hence, following the CIMMYT partial budget analysis methodology, total variable costs (TC), gross benefits(GB) and net benefits (NB) were calculated (CIMMYT, 1988). For each pair of treatments, marginal rate of return [MRR (%)] was calculated as the ratio of the difference in higher net benefit to lower benefit over the difference in higher total costs that vary to lower costs and expressed in percent. Thus, the treatment which was non-dominated and having a MRR of greater or equal to 50% with the highest net benefit was taken to be economically profitable.

4.RESULTS AND DISCUSSION

4.1. Selected Physico-chemical Properties of the Soil of the Experimental Site

Soil sample was taken after harvesting from each treatments of the experimental site and soil chemical properties were determined. The soil samples were analyzed for selected chemical properties mainly for soil pH, total nitrogen, available phosphorus and organic carbon using the appropriate laboratory procedures. The cattle manure (CM) analysis results showed that the organic C and/or organic matter is high, implying that this organic fertilizer can be a good source of plant nutrients. Therefore, application of inorganic NPS fertilizers along with well decomposed cattle manure with very high nutrient content is justified to produce good yield of potato at the study site.

The change in total N,P,S after harvest (Appendix table 4) relative that incorporation of cattle manure and mineral N,P,S fertilizers could improve the fertility status of the soil. Improvement in the soil nutrient contents with application of cattle manure might be a result of build up in the organic carbon (Saviozzi and Cardelli, 2013), solublization of different organic nitrogenous compounds into simple and available form, conversion of unavailable P into available form at the time of decomposition of manure (Eichler- Löbermann *et al*., 2007). The application of organic or inorganic fertilizers is widely known to ameliorate soil N or P status (Ngome *et al*., 2011; Tittonell *et al*., 2010). This explains why plots that received CM or NPS+CM had higher N and P contents after harvesting.

This probably due to the released from organic manure (Cattle Manure). Nitrogen and phosphorus availability recorded after harvesting revealed that the highest Nitrogen (0.299%) was found in 100kg NPS+30t CM ha^{-1} and the lowest was 0.103% observed in the control. Similarly, the amount of available phosphorus ranged from 10.227ppm in the control to 12.922ppm in 150kgha^{-1}NPS+30tCMha^{-1}.

Soil analysis results before planting showed that the soil is Silty clay in texture and it was found to be moderately acid with a pH of 6.5. Sole application of CM led to a slight decrease in pH level after harvesting from 6.75 to 6.68 which was not different from the initial soil sample pH (7.5). These trends of results were in agreement with those obtained by Monirul (2013) and Camberato and Mitchell (2011). Furthermore, Kingery *et al.* (1993) reported that the application of organic manure over many years had an average surface soil pH of 6.3 compared to fields receiving only chemical fertilizers (pH 5.8).The pH of the soil is moderately acidic (Herrera, 2005) with values ranging between of 5.69 – 6.98, which facilitated nutrient uptake by the plants (Warren, 2004). This pH value indicates that there is no toxicity of aluminum, manganese and hydrogen; rather cations such as K, Ca and Mg are abundant (Fall, 1998). Meanwhile, soil pH was observed to reduce with the application of organic or inorganic fertilizer compared to the initial soil condition before planting (Table 2). The reduction was more pronounced with plots that received inorganic fertilizer particularly NPS. It is therefore advisable to apply chemical fertilizer to the experimental site to reduce the pH level.

Table 3: Selected physic-chemical properties of soil after harvesting

Treatment	NPS kg ha-^{1} Fertilizer	Cm t ha^{-1}	pH-H_2O	EC(dS/m)	%OC	%OM	%TN	av.P(ppm)
1	0	0	5.69	0.078	1.51	2.051	0.103	10.227
2	50	0	5.53	0.099	2.18	3.144	0.157	11.341
3	100	0	5.61	0.147	2.15	3.752	0.188	11.508
4	150	0	5.52	0.109	2.09	3.446	0.272	11.551
5	0	10	6.75	0.098	2.63	4.538	0.227	11.389
6	50	10	5.79	0.106	2.11	3.631	0.282	12.051
7	100	10	5.65	0.186	2.16	5.446	0.292	12.518
8	150	10	5.52	0.104	1.93	3.328	0.256	12.696
9	0	20	6.78	0.12	2.67	4.899	0.123	12.647
10	50	20	5.78	0.214	2.15	3.631	0.182	12.066
11	100	20	5.71	0.114	2.81	4.641	0.242	12.364
12	150	20	5.43	0.132	2.63	4.238	0.297	12.784
13	0	30	6.98	0.099	2.46	4.936	0.212	12.073
14	50	30	5.78	0.107	2.18	4.562	0.248	12.862
15	100	30	5.69	0.109	3.77	4.278	0.299	12.885
16	150	30	5.69	0.105	2.95	4.273	0.294	12.922

Where; CM=cattle manure,TN=Total nitrogen,Av.p= Available phosphors,PH= hydrogen power,OC=organic carbon,EC=electric conductivity and OM=organic matters

Organic carbon before planting was 2.5% (Table 2). After harvesting, it ranged from 1.51 to 3.77% having highest value in 100kgNPSha^{-1}+30tha^{-1}CM ha^{-1}followed by 2.95% in 150kg NPS+30tha^{-1} CM and by 2.81% in 100kgha^{-1}NPS+20tha^{-1}Cm. After harvesting, the soil organic carbon was reduced to 1.51 % in the control. However, the organic carbon was in the range 2.11 to 3.77% in the NPS + CM treated plots. The total organic carbon results were in similar trends with those obtained by (Monirul, 2013). Singh *et al.*, 1999 reported a drastic reduction in organic carbon concentration on continuous application of chemical fertilizer, whereas addition of 5t/ha Farm Yard manure in combination with N fertilizer helped in maintaining the original organic matter status of the soil. According to Landon (1991), the cation exchange capacity (CEC) of the soil before planting is medium 19.26 cmol (+) kg^{-1} of soil.

4.2. Effect of NPS Blended Fertilizer and Cattle Manure on Growth and Phenological Parameters of Potatoes

4.2.1. Plant height

The main effects of NPS blended fertilizer and cattle manure (CM) rates and their interaction effects have showed highly significant ($P<0.01$) difference on plant height (Appendix 1 table 3).The highest plant height of (86.7 cm) was recorded with treatment combination of 150 kg NPS ha^{-1} + 30t CM ha^{-1} which increased 1.86 times the control (0kgha^{-1} NPS + 0tha^{-1}CM) which was also statistically in parity with the plant height obtained with 150 kg NPS ha^{-1}+ 20 t CM ha^{-1}, 150 kg NPS ha^{-1} + 10t CM ha^{-1}, 100kg ha^{-1}NPS +30 tha^{-1}CM and 100kg ha^{-1}NPS blended fertilizer +20t ha^{-1} CM. Increasing the different rates of NPS blended fertilizers from zero to 150kg ha^{-1} increased mean plant height (Table 3). In a like manner increasing the different rates of CM from zero to 30 t ha^{-1}also enhanced the plant height.

The finding is in agreement with Suh *et al.* (2015) who demonstrated that the highest values of plant height, stem diameter and leaf size were high for plots fertilized with cow dung at the rate of 20tha^{-1}and NPK (20: 10: 10) kgha^{-1} compared with sole application of cow dung or NPK mineral fertilizer. Application of CM in combination with NP fertilizers might be attributed to provision of sufficient micro and macro nutrients, which most likely have helped in enhancing the metabolic activity in the early growth phase which in turn probably have encouraged the overall growth (Najm *et al*., 2013).The findings are also in conformity with the work of Gonzalez *et al*. (2001) who reported that organic manure and inorganic fertilizer supplied most of the essential nutrients during growth stage resulting in increase of growth variables including plant height. Similar to our result, Bwembya and Yerokun (2001) reported that plants applied with N and P fertilizer and CM were significantly taller than those in the control plots.

Table 4: Interaction effect of NPS blended fertilizer and Cattle manure on growth and phenological variables

Treatments		Growth	Phenological variables	
NPS blended fertilizer (kgha^{-1})	Cattle Manure (t ha^{-1})	Plant height(cm)	Days to 50% flowering	Days to Physiological Maturity
0	0	46.5^{g}	48.7^{j}	89.0^{i}
	10	56.7^{f}	51.0^{hi}	90.0^{hi}
	20	68.2^{cd}	53.7^{f}	90.7^{hg}
	30	68.6^{cd}	55.3^{e}	91.0^{fgh}
50	0	47.8^{g}	50.7^{i}	89.7^{hi}
	10	57.6^{f}	51.7^{h}	91.0^{fgh}
	20	72.7^{c}	55.7^{e}	92.0^{efg}
	30	78.6^{b}	57.00^{d}	94.0^{cd}
100	0	61.2^{ef}	51.3^{hi}	92.3^{ef}
	10	83.9^{ab}	57.3^{d}	94.3^{cd}
	20	85.5^{a}	59.3^{c}	97.0^{b}
	30	85.8^{a}	60.3^{b}	98.7^{a}
150	0	63.8^{ed}	52.7^{g}	93.0^{de}
	10	84.1^{a}	57.3^{d}	94.7^{cd}
	20	85.6^{a}	61.0^{ab}	98.3^{ab}
	30	86.7^{a}	61.7^{a}	99.7^{a}
LSD(0.05)		5.33	0.86	1.51
CV (%)		4.51	2.11	1.16

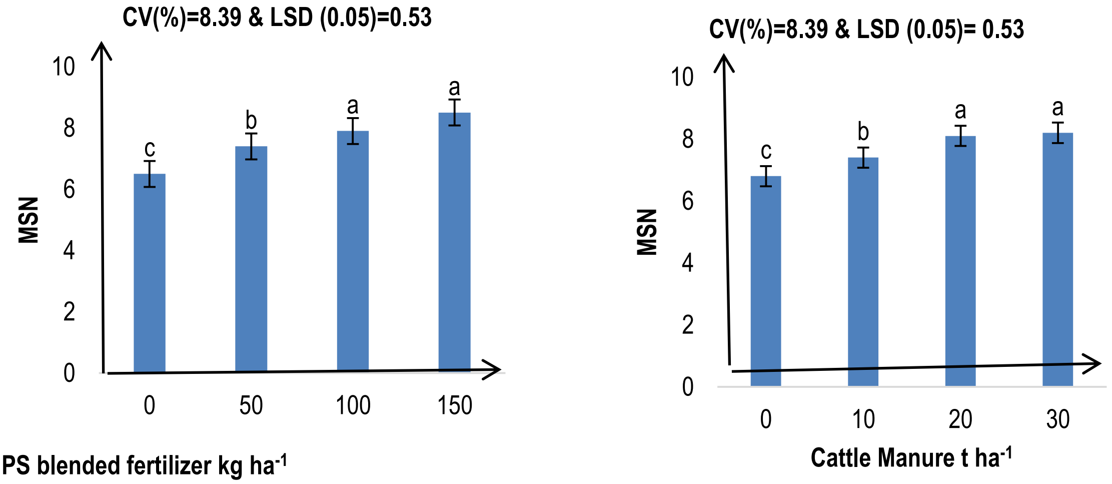
LSD = least significant difference; CV = coefficient of variation.Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$)

4.2.2. Main stem numbers

Understanding on the number of main stems per hill or plant provides an insight on the morphology and physiology of the potato plant. Each stems produces a single eye can be regarded as an independent production unit. Therefore, a sufficient number of stems should develop per seed tuber (Shayano wako *et al.*, 2015) since each single main stem is regarded as a production unit, tuber yield is most likely to vary with increase in tuber number (Hammes, 1985). The analysis of variance showed highly significant differences in main stem number due to the main effects of NPS blended fertilizer and CM ($P<0.05$) but not for the interaction effect (Appendix table 1).Potato grown with the highest rate of NPS blended fertilizer (150 kg ha^{-1}) recorded higher main stem number of 8.5, which is statistically in parity with 100kg ha^{-1} NPS blended fertilizer (7.9).On the other hand, the lowest main stem number (6.5) was obtained from the control treatment [Figure 3(A)].This result was consistent with that of Manochehr Shiri *et al*., (2009) who reported that increasing NP level from nil up to 80 kg N ha^{-1} led to significantly increased potato stem numbers by about 99%.

Similar with NPS blended fertilizer, highest main stem number of 8.2 was recorded with rate of 30 t CM ha^{-1}, which is also statistically at par with 20t CM ha^{-1}with the result of (8.1) [Figure 3(B)]. Conversely, the lowest main stem number of 6.8was recorded with the control treatment. The results revealed that increasing the rate of CM increased the number of main stems produced per plant. However, the increase in the number of stem in response to increasing CM did show significant difference among rates from 0 to 30 t ha^{-1}. This work is similar with the result obtained by Jayrpamaiah *et al*. (2005) who reported that the rate of application of CM was increased from 0 to 30 t ha^{-1} the number of main stems increased significantly by 23%.

Contradicting to our findings other researchers reported that stem number is not influenced by mineral fertilizers but by other factors such as physiological age of the seed tuber (Asiedu *et al*., 2003), storage condition of tubers, number of viable sprouts at planting, sprout damage at the time of planting and growing conditions (Firman and Allen, 2007), variety and tuber size (Park *et al*., 2009).



(A) **(B)**

Figure 2: Main effects of NPS blended fertilizer and CM on main stem number of potatoes (A= NPS blended fertilizer and B= Cattle Manure (CM). Means followed by the same letter within a treatment is not significantly different at 5% significant.

4.2.3. Days to 50 % flowering

Highly significant ($P < 0.001$) differences in days to 50% flowering was due to the main effect of NPS blended fertilizers and cattle manure (CM) as well as their interaction effects (Appendix table 1). The earliest days to 50% flowering (48.7days) was recorded with a treatment combination of zero NPS and zero CM. Application of 50/0, 0/10, 100/0 and 50/10 kgha^{-1} NPS/t ha^{-1}CM recorded days to 50% flowering by 50.7, 51.0, 51.3 and 51.7 in the same order whereas, application of 150/20 and 150/30 kgha^{-1} NPS/t ha^{-1}CM delayed days to 50% flowering by12.3 and 13.0 respectively compared to the check (Table 3). Increasing the different rates of NPS blended fertilizers from zero to 150kg ha^{-1}delayed mean days to 50% flowering from 52.7 to 58.2 (Same Table 3). Increasing the different rates of CM from zero to 30 t ha^{-1} extended the number of days to 50% flowering. Similarly, combined application of 150 kg NPS blended fertilizer ha^{-1} +30 t CM ha^{-1} delayed days to 50% flowering (61.67) by 13 days compared to 0/0 NPS/CM (Table 3).

The results of this study in agreement with the finding of Yourtchi *et al.* (2013) who reported that the earliness in flowering due to combinations of lower rates of inorganic NP and CM as well as the control treatments could be attributed to the enhancement of vegetative growth and storing of sufficient reserved food materials for differentiation of buds into flower buds. On the other hand, the delayed flowering in response to the interaction effect of maximum amount of mineral and organic fertilizer could be due to extended vegetative phase of the plant owing to the availability of nutrients in cattle manure (Najm *et al.*, 2010) and could also be due to enhanced soil moisture holding capacity as a result of integrated mineral fertilizer and organic manure application (Srivastava *et al.*, 2012).The number of days required to flowering is one of the important parameter for potato farmers due to the fact that it enables the grower to forecast its harvesting scheme as well as the marketing plan (Khalafalla, 2001).

4.2.4. Days to physiological maturity

Days to physiological maturity for potato defined as number of days from emergence to maturity when 75% of the plants of different treatments were reached to harvest accompanied with senescence of the haulms. Highly significant ($P < 0.05$) difference for the interaction effect of NPS blended fertilizer and CM was recorded for days to physiological maturity (Appendix table 1).Early physiological maturity date was recorded from the control treatment. Treatment combinations of 50/0, 0/10 and 100/0 kgha^{-1} NPS/t ha^{-1}CM recorded earlier days to physiological maturity which is statistically at par with the check (Table 3), because of probably cattle manure activates many species of living organisms, which release phytohormones and may stimulate the plant growth and absorption of nutrients.

This may be a plausible reason that use of organic manure with inorganic fertilizer leads to increase the leaf area which increases the amount of solar radiation intercepted thereby increasing days to flowering, physiological maturity, plant height and dry matter accumulation (Ouda and Mahadeen, 2008). Plots that received 150kg ha^{-1}NPS blended fertilizer +30t ha^{-1}cattle manure delayed maturity, which was statistically in parity with those plots fertilized with 150kgha^{-1}NPS blended fertilizer +20t ha^{-1} cattle manure and 100kgha^{-1}NPS blended fertilizer + 30t ha^{-1}cattle manure (Table 3).

The findings of this study are in agreement with the work of Zelalem *et al.* (2009) who reported that the application of N and P fertilizers delayed flowering and prolonged days required to attain physiological maturity of potato. Moreover, Nebret (2012) reported that the application of N resulted in significantly delayed physiological maturity. EARO (2004) also stated that days to maturity of potato varieties varied from 90 to 120 days and the variation is accounted for by variety, growing environment and cultural practices. The presence of N in excess promotes development of the above ground organs, Synthesis of proteins and formation of new tissues are stimulated, resulting in vigorous vegetative growth. This increases the days of physiological maturity (Lincoln and Edvardo, 2006).

4.3. Effect of NPS Blended Fertilizer and Cattle Manure on Yield Variables

4.3.1 .Total tubers number per plant

The total tuber number per plant^{-1} was increased with combined application of organic and inorganic fertilizers compared to sole application of NPS blended fertilizers or CM. This might be due to its higher nutrient composition and capacity to increase availability of native soil nutrient through higher biological activity .The main effect of NPS blended fertilizer and CM rates and their interaction showed highly significant ($P<0.01$) differences on the total number per plant (Appendix table 2).Maximum total tuber number per plant (17.32) was recorded with100 kg NPS ha^{-1} + 30t CM ha^{-1}followed by 100 kg NPS ha^{-1} +20t CM ha^{-1}and 150 kg NPS ha^{-1} +20 t CM ha^{-1}with total tuber number of 15.44 and 13.43 respectively (Table 4).

The lowest total tuber number per plant (6.59) was recorded with the control which was statically in parity with total tuber number per plant obtained with treatment combinations of 50 kg NPS ha^{-1} + 10 t CM ha^{-1}, zero NPS and 10t CM ha^{-1}and 50kg NPS + zero t CM ha^{-1}respectively with 7.56, 7.61 and 7.79 per plant in the same order. The result of this study is in conformity with finding of (Annad and Krishinapp, 1989) who stated that the increase in total tuber number per plant is in response to the increased application of the combined NP fertilizers and CM might be due to the increased photosynthetic activity and translocation of photosynthetic to the root, which is probably helped in the initiation of more stolon in potato. Taheri *et al*. (2010) also found the highest ratio (13.07%) of number of large tubers as a result of application of 20 t compost ha^{-1}of combined with 225 kg P ha^{-1} and 50 kg zinc ha^{-1}.

Sparrow *et al.* (1992) and Lynch and Rowberry (1997) reported a significant tuber number per plant increment in response to increasing N rates. At any given level of P the total tuber number plant^{-1}, increased with increase in cattle manure application. Thus, tuber number increased with increase in P and FYM application (Powon *et al*., 2006). In contrary of our result, tuber number is also determined by the number of stems produced which in turn depends up on the tuber size and variety as reported by Ebwongu *et al*. (2001).

Table 5: Interaction effect of NPS blended fertilizer and CM rates on marketable tuber yield (MTY), total tuber yields (TTY), marketable tuber number (MTN) and total tuber number (TTN) of potato.

Treatment		Tuber yield(t ha^{-1})		Tuber number		
NPS blended fertilizers (kg ha^{-1})	CM (t ha^{-1})	MTY	TTY	MTN	TTN	SG(gcm^{-3})
0	0	9.59^{k}	11.12^{k}	3.94^{i}	6.59^{g}	1.056^{j}
	10	12.22^{j}	13.25^{j}	6.42^{h}	7.61^{fg}	1.059^{ij}
	20	21.69^{h}	22.66^{h}	7.15^{fgh}	8.26^{f}	1.062^{hi}
	30	21.79^{h}	23.04^{h}	7.47^{fgh}	8.57^{ef}	1.063^{h}
50	0	15.01^{i}	16.41^{i}	6.17^{h}	7.79^{fg}	1.075^{g}
	10	26.97^{g}	28.48^{f}	7.13^{fgh}	7.56^{fg}	1.080^{ef}
	20	30.62^{f}	31.79^{e}	7.67^{efg}	8.24^{f}	1.082^{de}
	30	32.08^{ef}	33.09^{de}	7.87^{ef}	8.33^{f}	1.084^{d}
100	0	25.10^{g}	25.97^{g}	8.46^{ef}	8.58^{ef}	1.075^{g}
	10	33.73^{ed}	34.19^{d}	8.01^{ef}	9.58^{ed}	1.090^{c}
	20	37.08^{bc}	37.91^{bc}	14.25^{b}	15.44^{b}	1.092^{c}
	30	37.95^{ab}	38.90^{ab}	16.07^{a}	17.32^{a}	1.096^{ab}
150	0	26.02^{g}	26.56^{g}	8.83^{de}	10.17^{d}	1.078^{fg}
	10	35.67^{cd}	36.94^{c}	9.85^{d}	10.24^{d}	1.090^{c}
	20	37.96^{ab}	39.30^{ab}	13.03^{bc}	13.43^{c}	1.093^{bc}
	30	39.79^{a}	40.23^{a}	12.36^{c}	12.89^{c}	1.098^{a}
LSD(0.05)		2.04	1.95	1.26	1.05	0.003
CV (%)		4.35	4.0	8.92	7.63	0.53

Means sharing the same letter are not significantly different at $P \leq 0.05$ CV= Coefficient of variance, LSD= Least significant different.

4.3.2. Marketable tuber number

The marketable tuber number plant^{-1}increased with increasing CM application rate because the CM applied to soil resulted in an increase in carbon mineralization in the soil due to available carbon for microbial respiration and provision of nitrogen. The main effects of NPS blended fertilizer and CM rates and their interaction revealed highly significant difference ($P<0.01$) on marketable tuber number plant^{-1}(Appendix Table 2). Higher marketable tuber number plant^{-1}(16.07) recorded with100kg NPS ha^{-1} + 30t CM ha^{-1}followed by 100 kg NPS ha^{-1} +20 t CM ha^{-1} and 150 kg NPS ha^{-1} +20 t CM ha^{-1}with marketable tuber number of 14.25 and 13.03 respectively (Table 4). However, the lowest marketable tubers number plant^{-1} (3.94) obtained with the control plots.

The possible reasons for the maximum marketable number of tuber per hill observed from the higher combined application of NPS blended fertilizer and cattle manure could be due to the presence of adequate amount of nitrogen which resulted in better vegetative growth, greater photo assimilate for the production of marketable tuber numbers. The high total and marketable tuber yields obtained due to combined use of mineral and organic fertilizers could be attributed to the synergetic effect of mineral NP and Cattle Manure (Palm *et al.*, 1997). Similarly, number of marketable tuber increased significantly as the rate of sulfur increased, probably due to Sulfur's role in synthesis of sulfur containing amino acids, proteins, energy transformation, activation of enzymes which in turn enhances carbohydrate metabolism and photosynthetic activity of plant with increased chlorophyll synthesis (Juszczuk and Ostaszewska, 2011).This was important for photosynthesis and net assimilation processes and no re-absorption evidently took place from the tubers, leading to increased tuber size and weight so the tuber could be marketable (Boral and Milthorpe, 1962).

4.3.3. Un marketable tuber number

The analysis of variance revealed that there was no significant difference ($P>0.05$) due to interaction effect of NPS blended fertilizer and Cattle manure rates on unmarketable tuber numbers of potato. Similarly, the main effects of NPS blended fertilizer and cattle manure rates remained non-significant difference (Appendix Table 2).

4.3.4. Total tuber yield

Variation in the rate of application of organic manure and inorganic fertilizers could influence the yield of potato (Monirul *et al.,* 2013). The main effects of NPS blended fertilizer and CM rates and their interaction had highly significant ($P<0.001$) effect on total tuber yield (t ha^{-1}) of potato (Appendix Table 2). The total tuber yield ha^{-1} increased with combined application of NPS blended fertilizer and CM compared to sole application of either NPS blended fertilizer or CM. The highest total tuber yield (40.23 t ha^{-1}) obtained with combined application of 150 kg NPS blended fertilizer ha^{-1} + 30 t CM ha^{-1} followed by 150 kg NPS blended fertilizer ha^{-1} + 20 t CM ha^{-1}and 100 kg NPS blended fertilizer ha^{-1} + 30 t CM ha^{-1}with total tuber yield of 39.30 and 38.90t ha^{-1}respectively, which were also statistically in parity with this optimal total tuber yield (Table 4).On the other hand the lowest total tuber yield (11.12 t ha^{-1}) was obtained from the control treatment. The combined application of 150 kg NPS blended fertilizer ha^{-1} + 30 t CM ha^{-1} increased total tuber yield by 38.31% over the control treatment. In the present study it was observed that total tuber yield had highly significant and positive Correlated with total tuber number (r= 0.734**), marketable tuber number (r=0.811**), plant height (r=0.944**) and main stem number (r=0.781).The possible reasons for the existence of this relation among the parameters are as the plant height increased the plants produce higher photosynthesis and as a result the total tuber yield was higher. This result is consistent with that of (Hammes, 1985) who reported that increase in stem numbers markedly increased tuber numbers and total tuber yield per unit area of land and also plant height and total tuber yield indicating the existence of positive association between the two parameters which corroborated the findings of Yibekal (1998).

Mohammadi *et al*. (2013) reported that the presence of nutrients in manure and balanced supplement of nitrogen and phosphorus through mineral fertilizers might have contributed to increased cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters. Probably because CM supply and promote uptake of nitrogen, the tuberous root bulking might have enhanced due to the catalytic role CM plays in enhancing dissolution and uptake of other nutrients from the soil. Similarly in onion, the application of compost and combinations of N, P, and S to soils somehow increased the bulb diameter (Gebrekiros A. (2013). Our finding is also similar to the works of Balemi, (2012)who reported that application of 20 or 30 t ha^{-1} FYM + 66.6% of the recommended inorganic NP fertilizers significantly increased total tubers yield. Nasreen *et al*. (2007) obtained the highest onion yield in response to the combined application of 120 kg N + 40 kg S ha^{-1} with a blanket dose of 40 kg P, 75 kg K, 5 kg Zn ha^{-1} and 5 t ha^{-1} of cow dung. Darzi *et al*., (2012) maximum tuber yield (36.8 t ha^{-1}) was obtained by using 150 kg N ha^{-1} + 20 t CM ha^{-1}. Suh *et al.* (2015) observed also that tuber yield was increased by the combined use of cow dung and NPK (20: 10: 10) compared to sole application of cow dung or NPK.

4.3.5. Marketable tuber yield

The main effect of NPS blended fertilizer and CM rates and their interaction showed significant ($P< 0.001$) effect on marketable tuber yield of potato (Table 4 and Appendix Table 2).The highest marketable tuber yield (39.79 t ha^{-1}) was recorded with application of 150 kg NPS blended fertilizer ha^{-1} + 30 t CM ha^{-1}followed by 150 kg NPS blended fertilizer ha^{-1} + 20 t CM ha^{-1} and 100 kg NPS blended fertilizer ha^{-1} + 30 t ha^{-1} CM with marketable tuber yield of 37.98 and 37.95 t ha^{-1}respectively, which are also statistically at par with this highest marketable tuber yield (Table 4). However, the lowest marketable tuber yield (9.59 t ha^{-1}) was recorded with the control treatment, which is less by 33.82% compared with highest value obtained with150 kg NPS blended fertilizer ha^{-1} + 30 t CM ha^{-1}. The control plot produced the lowest values for marketable tuber yield of potato, due to the absence of adequate nutrient level needed for proper growth, development and yield. Combining mineral fertilizers with cattle manure prolonged the release and added more macro and micro nutrient thereby promoting better crop growth and marketable tuber yield of potato (Yeng *et al*., 2012).

The possible reasons for the maximum marketable tuber yield per ha observed with the higher combined application of NPS blended fertilizer and CM could be due to a function of total biomass production, the percentage of biomass that is partitioned to the tubers, the moisture content of the tubers and the proportion of tubers that are acceptable to the market, in terms of size and lack of defects; and great opportunities exist to increase potato yield and quality by improving nutrient management (Ewing, 1997). (Abay and Tesfaye, 2011) reported that supplementation of 10 t ha^{-1} compost with 73.4 kg N and 59.5 kg P_2O_5 ha^{-1} gave yield advantage of 8.4 t ha^{-1} in southern Ethiopia. Marketable tuber yield was positively and significantly ($P < 0.01$) correlated with total tuber yield ($r = 0.998^{**}$) and total tuber number ($r=0.739^{**}$).This indicates that factors leading to increased marketable tuber yield would also increase total tuber yields and tuber numbers significantly.

4.3.6. Unmarketable tuber yield

The analysis of variance revealed that there were no statistically significant difference ($P>0.05$) due to treatments interaction effect of NPS blended fertilizer and Cattle manure rates on unmarketable tuber yield of potato. Similarly, the main effects of NPS blended fertilizer and cattle manure rates remained non-significant difference (Appendix Table 2).

4.4. Effect of NPS Blended Fertilizer and Cattle manure (CM) on specific gravity (g cm^3)

The specific gravity may give an insight about estimation of starch content of potato tuber because it is the major component of the dry matter, usually comprising 65-75 per cent of the total soluble solids (Storey and Davies, 1992). The analysis of variance revealed that there was significant difference between treatments due to the main effect of NPS blended fertilizer and CM and their interaction (Table 4 and Appendix Table 3). In the present study, application of NPS blended fertilizer and CM highly significantly ($p< 0.001$) increased tuber specific gravity (Table 4). The highest tuber specific gravity (1.098 g cm^{-3}) was obtained with the combination of NPS blended fertilizer rate of 150 kg ha^{-1} + 30 t ha^{-1} CM followed by a treatment combination of 100 kg NPS ha^{-1} + 30 t CM $ha^{-1.}$ Application of NPS blended fertilizer rate of 150 kg ha^{-1} + 30 t ha^{-1} CM registered higher specific gravity which is at par value with the treatment combination of100 kg NPS ha^{-1} + 30 t CM ha^{-1}(Table 4).The lowest tuber specific gravity (1.056 g cm^{-3}) was recorded from the control treatment which was also statistically in parity with the specific gravity (1.059 gcm^{-3}) of potato tuber obtained with zero NPS and 10 t CM ha^{-1}. This explained that significant increase in specific gravity with the increase in the combined application of mineral NPS and CM might be attributed to release of macro and micronutrients from CM.

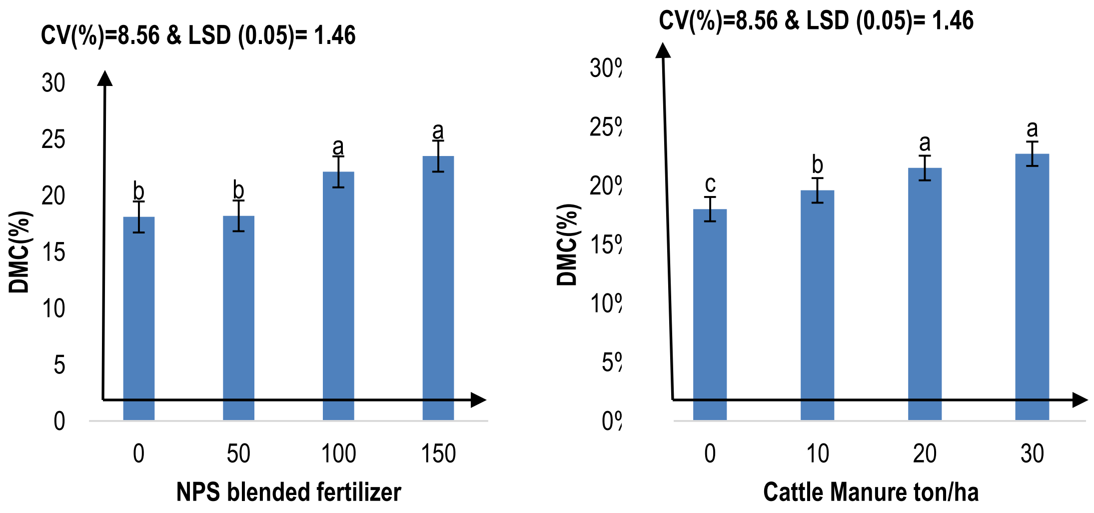
Increasing CM rate from zero to 30 t ha^{-1} increased specific gravity (Table 4) However, an increase in tuber specific gravity by increasing N rates, cattle and chicken manure was also reported by (Abou-Hussein *et al*., 2003), and combined application of chicken manure and NPK (Soliman *et al*.,2008).In this study integrating100 to 150 kg NPS blended fertilizer with 20 to 30 t CMha^{-1} seemed to improve tubers specific gravity (Table 4) similar to Ahmed *et al.* (2009) works who reported that potato growth and quality were affected by combination of both sources of fertilizers.

Pervez *et al*, (2000) reported that combined application of 5 t FYM ha^{-1}along with 200 kg K_2O ha^{-1}recorded higher specific gravity (1.091) compared to sole K fertilizer and control. In a similar manner, Kandil *et al*. (2011) found the improved specific gravity (1.064 g cm^{3}) with 60% mineral N (238 kg N ha^{-1}) combined with 40% organic chicken manure (158 kg N ha^{-1}). N'Dayegamiye *et al,* (2013) reported also that specific gravity of tubers ranged from 1.070 to 1.073 and was significantly increased with organic amendment and mineral fertilizer application.

4.5. Effect of NPS Blended Fertilizer and CM on Dry matter content (%)

Dry matter content is affected by various factors, among which the most significant are the following ones: tuber maturity, growth character, plant nutrient and water uptake (Haris, 1992).In the present study, dry matter content was determined based on the formula described by Bonierbale *et al.* (2006). Highly significant ($p<0.05$) differences was noted for dry matter content due to the main effect of NPS blended fertilizer and CM but not for their interaction (Appendix Table 3).Potato grown with 150 kg ha^{-1} NPS blended fertilizer recorded 23.5% which is statistically at par 100 kg ha^{-1} NPS blended fertilizer (Figure 3A), however, the lowest dry matter content was obtained with the control treatment, which was also statistically in parity with the value obtained with intermediate level (50 kg) NPS blended fertilizer ha^{-1}. This probably is associated with the influence of N on gibberellins biosynthesis and other phyto-hormonal activities which have direct influence on plant growth and dry matter accumulation.This might be attributed to high NPS dose which results in high NPS use efficiency and dry matter accumulation in tuber (Gawronska *et al.*, 1984).

Dry matter content was positively and significantly ($P < 0.05$) correlated with Specific gravity ($r = 0.74^{**}$) (Table 7). This indicated that dry matter (total solid) of tubers is a true indicator of the amount of specific gravity of tubers which is similar with the report of Tekalign and Hammes (2005).Similarly, dry matter content has been used as a criterion of potato quality due to its positive correlation with the specific gravity of tubers and the rapidity with which it can be determined (Lulai and Orr, 1979). In a like manner highly significant ($p<0.05$) difference was recorded for dry matter content with CM. Maximum value of dry matter content was observed with 30 t ha^{-1}which is statistically at par with 20 t CM ha^{-1}, whereas the lowest dry matter content was recorded with the control treatment (Figure 3B).The addition of such organic sources might create the favorable condition in rhizosphere, increase the uptake of nutrients, the secretion of certain enzymes and auxins and other growth promoting substances which ultimately improve the quality of potato (Singh *et al.*,2007).



(A) **(B)**

Figure 3: Mains effects of NPS blended fertilizer and Cattle Manure on dry matter content of potato tuber (A = NPS blended fertilizer and B = Cattle Manure). Means followed by the same letter within a treatment is not significantly different at 5% significant.

This work contradicts with Baniumiene and zekaite (2008) findings who reported that higher values of starch and dry matter content with potato tubers grown without FYM. The highest dry matter and starch content were accumulated in potatoes tubers fertilized with mineral not organic fertilizers (Stimumar *et al*.,1990).Other study indicated that increase in NP fertilizer might have enhanced growth components by promoting the dry matter accumulation Najm *et al*. (2010). The increase in plant height with the increased application of S might be due to its role in the growth and physiological functioning of plants, thus improving its quality by increasing the dry matter contents of the tubers (Barker and Pilbeam, 2007). The dry matter content of potato tubers determines suitability for chip processing purposes by influencing the chip yield, texture flavor, final oil content and process efficiency (Kumlay *et al*., 2002; Kaber *et al*., 2001).

4.6. Economic benefit

The results of the partial budget analyses revealed that the highest net returns of Birr 139,893 was recorded in the treatment that received 20 t ha^{-1} cattle manure in combination with 150kg ha^{-1} of NPS fertilizer followed by 30t/ha cattle manure along with 100kgNPS ha^{-1}.However, the lowest net returns of Birr 5472 was received 0-0 NPS kgha^{-1}and CM t ha^{-1}.The same treatments which give highest net return also recorded highest benefit: cost ratio of 3.29 and 3.47 respectively (Table 5).Dominance analysis is thus carried out by first listing the treatments in order of increasing costs that vary. Any treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary was consider dominated (CIMMYT, 1988).High net return from the foregoing treatments could be attributed to high yield and the low net return was attributed to low yield. However, the maximum marginal rate of return was recorded in the treatment receiving 100 kg NPS kg ha^{-1} +30 t ha^{-1} CM and the minimum marginal rate of return was recorded from the treatments that received 150 kg NPS kg ha^{-1} + 20 t ha^{-1} CM.

Table 6: Results of the economic analysis for combination of NPS and CM in potato grown at Dabo Gibe Kebele in Seka wereda

NPS kg ha^{-1}	CM t ha^{-1}	TC (Birr ha^{-1})	MC (Birr ha^{-1})	AGY(t ha^{-1})	GR(Birr ha^{-1})	NR (Birr h^{-1})	MB	MRR (%)	BCR
0	0	50128		11.12	55600	5472	-	-	1.11
50	0	51625	1497	16.41	82050	30425	24953	16.67	1.58
100	0	52898	1273	25.97	129850	76952	46527	36.55	2.45
150	0	54165	1267	26.56	132800	68635	-8317	-	2.41
100	20	55892	1727	37.91	189550	133658	65023	37.65	3.39
100	30	55987	95	38.9	194500	138513	4855	51.1	3.47
150	20	59607	3620	39.3	196500	139893	1380	0.38	3.29
150	30	69757	110150	40.23	201150	131393	-8500	-	2.88

Where: Purchasing costs for fertilizers NPS (Nitrogen, phosphorus, sulfur) were estimated at Birr 16 kg $^{-1}$. The cattle manure were estimated at Birr 25/quintals .The selling price of potato at the local market at the harvest time was estimated at Birr 500/quintal . Purchasing costs for potato seed Birr 9/kg.MC=marginal total cost, MRR = marginal rate of return TC=total production cost per ha, marginal cost, AGY= Adjusted yield, GR=gross return, NR= net return, MB = marginal benefit, BCR= cost benefit ratio.

From the economic point of view all the treatment which have marginal rate of return are advantages; however it was apparent from the results that treatments receiving 100 NPS kg ha^{-1} + 20 t ha^{-1} CM and 30tha^{-1}CM were more profitable than the rest of treatment combinations.

5. SUMMARY AND CONCLUSIONS

Field experiment was conducted on NPS blended fertilizer rate and cattle manure on potato at Seka wereda Dabo Gibe Kebele farmers' site in 2016. The results of this study showed that growth, yield and quality parameters of potato such as days to 50% flowering, days to 75% of physiological maturity, marketable tuber yield, marketable tuber number per plant, total tuber yield, total tuber number per plant, plant height, main stem number, dry matter content and specific gravity of potato increased as a result of the application of NPS blended fertilizer and cattle manure rates.

Results indicated that the main effects of NPS blended fertilizer and cattle manure and their interaction significantly influenced plant height, days to 50% flowering, days to 75% of physiological maturity, total tuber yield, marketable tuber yield, total tuber number per plant, marketable tuber number per plant and specific gravity.

The interaction effect of NPS blended fertilizer and cattle manure significantly influenced plant height, days to 50% flowering, days to 75% of physiological maturity, total tuber yield, marketable tuber yield, total tuber number per plant, marketable tuber number per plant and specific gravity (1.098) were recorded at application of 150kg ha^{-1}NPS blended fertilizer + 30t ha^{-1}cattle manure followed by 150/20,100/30,100/20kg/t ha^{-1}. In general, the highest mean number of plant height, days to 50% flowering, days to 75% of physiological maturity, total tuber yield t ha^{-1}, marketable tuber yield, total tuber number per plant, marketable tuber number per plant and specific gravity (86.7cm, 61.7, 99.7, 40.23 t ha^{-1}, 39.79 t ha$^{-1,}$ 12.89, 12.36 and1.098 gcm^{-3}) were observed when 150kg ha^{-1} NPS blended fertilizer + 30t ha^{-1} cattle manure were applied respectively followed by150/20,100/30 and100/20kg/tha^{-1}. The main effect of NPS blended fertilizers and cattle manure significantly influenced main stem number and dry matter content of tuber. The highest main stem number obtained by application of 150kgha^{-1} NPS (8.5) and 100kgha^{-1} NPS (7.9) and the lowest from control. In the same manner highest main stem number obtained by application of 30tha^{-1} (8.2) and 20tha^{-1}(8.1) cattle manure. The highest dry matter content obtained by application of 150kgha^{-1} NPS (23.5%) and 100kgha^{-1} NPS (22.1%) and the lowest from control. In the same manner highest dry matter content obtained by application of 30tha^{-1} (22.7%) and 20tha^{-1}(21.5%) cattle manure the lowest from control.Almost all parameters except unmarketable tuber number and yield had the highest values when the highest application rate of NPS blended fertilizers, cattle manure and their interaction.In this study, it is found that there is a positive and significant association among response variables such as marketable tuber yield, total tuber yield, marketable and total tuber number, plant height, main stem number, dry matter content and specific gravity.

Generally, the present study indicated that the combined application of NPS blended fertilizer and CM improved growth, yield and quality of potato. Accordingly, optimum tuber yield was obtained from combined application of 150 kg ha^{-1} NPS blended fertilizer and 20- 30t ha^{-1} CM. In terms of economic point of view, combined application of 100 kg NPS kg ha^{-1} blended fertilizers and 20-30 t ha^{-1}CM found high net benefit with high marginal rate of return and economically feasible and recommended for potato growing areas of Dabo Gibe kebele in Seka wereda. However, sound recommendation cannot be drawn from this study since the research work was conducted only for one season in a single location. Therefore, we suggest that NPS blended fertilizer levels combined with CM study be carried out in more than one seasons with multi-locations having diverse ecologies, for optimum potato productivity which would help to draw sound conclusions and recommendations.

6. REFERENCE

Abebe, T., Wongchaochant, S., Taychasinpitak, T. (2013). Evaluation of specific gravity of potato varieties in Ethiopia as a criterion for determining processing quality. *Kasetsart Journal of Natural Science* **47**: 30-41.

Abera Girma. 2001. Influence of Variety and Nitrogen and Phosphorus Nutrition on Yield, Yield components and Tuber Quality of Potato (*Solanum tuberosum* L.) on Nitosols of Bako Area. MSc. Thesis. Haramaya University.102pp.

Abou-Hussein S.D, Abou-Hadid A.F, El-Shorbagy T, El-Behariy U. 2003 a. Effect of Cattle and Chicken Manure With or Without Mineral Fertilizers on Vegetative Growth, Chemical Composition and Yield of Potato Crops. *Acta Hort* (ISHS) **608**: 73-79.

Adamu Molla and Asnakech Tekalign. 2010. Potato based intercropping with sorghum in the hot to warm moist valleys of North Shewa, Ethiopia. *World Journal of AgriculturalScience*, **6(5)**: 485-488.

Ahmed, M.S., Quadri, S.M.K. 2009. Decision support systems: concepts, progress and issues, a review. In: Lichtfouse, E. (Ed.), Climate change, intercropping pest control and beneficial microorganisms, Sustainable agriculture review 2. Springer Science + Business Media B.V. Dordrecht, Netherlands. 373: 399.

Alam, M.N., Jahan, M.S., Ali, M.K., Ashraf, M.A. and Islam, M.K. 2007.Effect of vermicompost and chemical fertilizers on growth, yield and yield components of potato in Barind soils of Bangladesh. *Journal of Applied Sciences Research*, **3**(12): 1879-1888.

Alemayehu Yibekal. 1998. The effect of nitrogen and phosphorus on yield and yield components, and some quality traits of potato (*Solanum tuberosum L.)* grown on soils of Wendo Genet area. An M. sc. Thesis presented to the school of graduate studies of Haramaya University, 84pp.

Ali, H. and Anjum, M.A. 2004. Aerial growth and dry matter production of potato (Solanum. tuberosum L.) Desiree in relation to phosphorus application. *International Journal ofAgriculture and Biology*, **3**: 458-461.

Ali, R., M.J. Khan and R.A. Khattak. 2008. Response of rice to different sources of Sulfur (S) at various levels and its residual effect on wheat in rice-wheat cropping system. Soil Environment **27**(1): 131-137.

Alva, A. 2004. Potato nitrogen management. *J. Veg. Crop Prod.*, **10**: 97-130.

Amin, M.R., Hasan, M.K., Naher, Q., Hossain, M.A. Noor, Z.U. (2007). Response of Onion to NPKS Fertilizers in Low Ganges River Flood Plain Soil. *International Journalof Sustainable Crop Production* **2(1)**: 11-14.

Annad, S, and Krishinapp, K.S., 1989. Dry matter accumulation and nutrient uptake by potato cv. Kufri badshah affected by different level of N and K in sandy loam soil. *Mysor J. Agricultural Science.* **23**: 65-70.

Arisha, H. M. E., Gad, A. A. and Younes, S. E. 2003. Response of some pepper cultivars to organic and mineral nitrogen fertilizer under sandy soil conditions. *Zagazig J. Agric. Res*. **30**: 1875–99.

Arshad, M., Khalid, A., Mahmood, M.H. and Zahir, Z.A. 2004. Potential of nitrogen and L-tryptophan enriched compost for improving growth and yield of hybrid maize. *Journal of Agricultural Science.* **41**: 16-24.

Asiedu, S.K., Astatkie, T. and Yiridoe, E.K. 2003. The Effect of seed-tuber physiological age and cultivar on early potato production. *Journal of Agronomy and Crop Science*, **189**:176-184.

Assefa, Nuru. 2005. Response of two improved potato (*Solanum tuberosum* L.) varieties to nitrogen and phosphorus application. An MSc thesis presented to the School of Graduate Studies of Harmaya University, Ethiopia. 101p.

Atiyeh R.M., Subler S, Edwards C.A., Bachman G, Metzger JD, Shuster W. 2000. Effects ofvermicomposts and compost on plant growth in horticultural container media and soil. Pedobiologia. **44**: 579–590.

Balemi, T. 2012. Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato in Ethiopia. *Journal of Soil Science and Plant Nutrition*, **12 (2**): 253-261.

Baniuniene A. and Zekaite, V. 2008. The effect of mineral and organic fertilizers on potato tuber yield and quality. Lithuanian institute of agriculture’s Perloja Experimental Station, Agronomijas Vēstis (*Latvian Journal of Agronomy*) **11**:202-206.

Baritelle, A.L. and Hyde, G.M. 2003. Specific gravity and cultivar effects on potato tuber impact Sensitivity. *Postharvest Biology and Technology*, **29** 279-286.

Barker, A.V., Pilbeam, D.J. 2007. Handbook of Plant Nutrition. Taylor and Francis, Boca Raton London New York, Pp 21-183.

Bayu, W., Rethman, N.F.G., Hammes, P.S. and Alemu, G. 2006. Effects of Farmyard Manure and Inorganic Fertilizers on Sorghum Growth, Yield, and Nitrogen Use in a Semi-Arid Area of Ethiopia. *Journal of Plant Nutrition*, **29**: 391-407.

Bekeko, Z., 2013. Improving and sustaining soil fertility by use of enriched farmyard manure and inorganic fertilizers for hybrid maize (BH-140) production at West Hararghe zone, Oromia, Eastern Ethiopia. *African Journal of Agricultural Research*, ***8*****(14)**:1218-1224.

Bekunda, B., Sanginga, N. and Woomer, P.L. 2010. Restoring soil fertility in sub-Sahara Africa. *Advances in Agronomy*, **108:** 184-236.

Berga, Lemaga., Gebremedhin Woldegiorgis,Teriessa Jalleta and Bereke-Tsehai Tuku. 1994. Horticulture Research and development in Ethiopia. pp. 101-119. In: Edward, H. and Lemma Desalgne (eds.), Proceedings of the 2nd National Horticulture Workshop of Ethiopia, 1-3 Dec. 1992.

Berihun, B. and Woldegiogis, G. 2012. Potato Research and Development in Ethiopia:Achievements and Trends pp35-44. In: Proceedings of the National Workshop on Seed Potato Tuber Production and Dissemination, 12-14 March 2012, Bahir Dar, Ethiopia.

Beukema, H.P. and Van der Zaag, D.E. 1990.Introduction to potato production. Pudoc Wageningen, Netherlands. 92-95.

Beyene Getu. 1998. Yield, quality and nitrogen uptake of potato (*Solanum tuberosum* L.) as influenced by rate and time of nitrogen application. M.Sc.Thesis, Alemaya University, Ethiopia.

Bonierbale, M., de Hann, S. and Forbes, A. 2006. Procedures for standard evaluation trials of advanced potato clones: An International Cooperators' Guide. International Potato Centre (CIP). 124pp.

Benson, N., Barnett, R. M. 1939. Leaching studies with various sources of nitrogen. *Agronomy J.*, **31**: 44 54.

Boral MN and FL Milthorpe. 1962. Growth of the potato as influenced by temperature. *Indian Journal Plant Physiology*. **5**:53-72.

Bucher, M. and Kossmann, J. 2007. Molecular physiology of the mineral nutrition of the potato. In Vreugdenhil, D. (ed.), Potato Biology and Biotechnology: Advances and Perspectives. Elsevier, New York, pp. 311–329.

Bwembaya, S and. Yevokun, O.A., 2001. Effects of Cassia spectabilis, cowdung and their combination on growth and grain yield of maize. *Seventh Easter and Southern Africa Regional Maize Conference,* 11th-15th February 2001.361-366.Cambridge. pp. 295-344

Catus, V. Botez, C. Chelu, M. Mirghis, R. Voican, V. and Bieche, B.I., 1994. The influence of organic and mineral fertilizers on tomato quality for processing. *ActaHorticulture*, **376**: 329-332.

Carla Bielli, *et. al.*,2001. Population Growth and Environment in Ethiopia. In-depth Studies from the 1994 population and Housing Census of Ethiopia. Italian Multi-Bi Research Project ETH/92/P01. Central Statistical Authority (CSA). Addis Ababa Ethiopia..

CIMMYT. 1988. from Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F.

Cottenie A 1980. Soil testing and plant testing as a basis of fertilizer recommendation. FAO Soils Bull. **38**:70-73.

CSA, (2013).Report on Area and production of major crops Thomas G Chastain Yield Components and Crop Yield.

Darzi *et al*., 2012. Effects of organic manure and nitrogen fixing bacteria on some essential oil components of coriander (coriandrum sativum). *International Journal of Agriculture and Crop Sciences* **4(12)**: 787-792.

Dolores, M., Torres, A., Parre˜no, W.C. 2009. Thermal Processing and Quality Optimization. 170p.In: Singh, J. and Kaur, L. (eds.), Advances in Potato Chemistry and Technology. Academic Press is an imprint of Elsevier.

EARO (Ethiopian Agricultural Research Organization). 2004. Directory of Released Crop Varieties and Their Recommended Cultural Practices. *Ethiopian Agricultural Research Organization*, Addis Ababa, 36p.

Ebwongu, M., E. Adipala, C.K. Ssekabembe, S.K. Yamanywa and A.S. Bhagsari, 2001. Effect of intercropping maize and Solanum potato on yield of the component crops in central Uganda. *Journal African Crop Science*. **9(1)**: 83-96.

Eichler-Löbermann, B., Köhne, S. and Köppen, D. 2007. Effect of organic, inorganic, and combined organic and inorganic P fertilization on plant P uptake and soil P pools. *Journal of Plant Nutrition and Soil Science*, **170**: 623-62.

EIAR (Ethiopian Institute of Agriculture Research). 2003. Potato production guide.(un published).

Emana B. and Gebremedhin H. 2007, Constraints and Opportunities of Horticulture Production and Marketing in Eastern Ethiopia, **46**. 29-30.

ErkossaT., Stahr, K. and Getachew Tabor. 2004. Integration of Organic and InorganicEthio SIS, 2014. Soil Fertility and Fertilizer tentative recommendation oromia Region. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA).

EthioSIS, 2014. Soil Fertility and Fertilizer tentative recommendation oromia Region. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA).

Ewing, E.E. 1997. The physiology of vegetable crops. Potato. In: H.C. Wien (ed.). UK,

Farooqi, A.H.A., Agarwal, K.K., Shabih, F., Ahmad, A., Sharma, S. and Kumar, S. 2001. Acyclic monoterpenes as anti-sprouting agents for potato tubers. European Patent Application PCT/IN00/00034.

Fernandes, A.M. and Soratto, R.P.2012. Nutrition, dry matter accumulation and partitioning and phosphorus use efficiency of potato grown at different phosphorus levels in nutrient solution. *R. Brassica oleraceae Solanum*, **36**: 1528-1537.Fertility in Sub-Sahara Africa. *Advances in Agronomy*, *108*.

Fontes, P.C.R. 1997. Preparo do solo, nutrição mineral e adubação da batateira. Viçosa, MG, Universidade Federal de Viçosa, 42p.

Frezgi Asgedom. 2007. Effect of planting density and nitrogen application on yield and yield components of potato (Solanum tuberosim L.) at Enderta, Southern Tigray, Ethiopia. An MSc. Thesis presented to the School of Graduate Studies of Haramaya University.

Gebre, E., Solomon, A., W/Giorgis, G. and Lemaga, B. 2005. Response of Solanum potato cultivars grown on vertisol to nitrogen and phosphorus fertilizers. *African Crop ScienceConference Proceedings*, **7**: 891-895.

Gebrekiros A., Solomon H. Mesgina, Yirga W. 2013. Response of Onion (*Allium Cepa L.*) Growth and Yield to Different Combinations of N, P, S, Zn Fertilizers and Compost in Northern Ethiopia. *International Journal of Science and Research*: 6.14- *4.438.*

Gebremariam F., Dechassa N. and Mohammed W. 2014. Response of Potato (*Solanum tuberosum* L.) to Nitrogen and Phosphorus Application. An MSc thesis presented to the School of Graduate Studies of Haramaya University, Ethiopia. 53p.

Gebremedhin, W.G., G. Endale and L. Berga (2008). Root and Tuber Crops. EIAR. Addis Ababa, Ethiopia.

Gedam, V.B., Rametke, J.R., Rudragouda, Power, M.S. 2008. Influence of organic manures on yield, nutrient uptake and change in physico-chemical properties of soil after harvest of groundnut. Crop Research, **36**, 111-114.

Gezehegn Wondimu, 2011.Response of potato (Solanum Tuberosum L.) to application of nitrogen phosphorus and farmyard manure at Deberk, North-Western Ethiopia. M.Sc. Thesis. Haramaya University, Ethiopia.

Gildemacher, Peter R. 2012. Innovation in Seed Potato Systems in Eastern Africa. Thesis, Wageningen University, Wageningen, the Nether Lands. ISBN 978-94-6173-310-8. 184pp.

Gonzalez, D.R., Avarez and Matheus, J., 2001. Comparison of three organic fertilizers for the production of sweet corn. Proceedings of the Inter American Society for Tropical Horticulture, **45**: 106-109.

Gunapala, N. and Scow, K.M. 1998. Dynamics of soil microbial biomass and activity in conventional and organic farming systems. *Soil Biology and Biochemistry*, **30**: 805-816.

Habtamu G, Wahassu M and Beneberu S (2016). Evaluation of Potato (*Solanumtuberosum* L.) Varieties for Yield and Yield Components in Eastern Ethiopia. Greener Journal of Plant Breeding and Crop Science, **4**(2): 014-026.

Hammes, P.S. 1985. The effect of stem population on tuber yield in a trial with single stem seed pieces. *Potato Research Journal* **28**: pp. 119 - 121.

HarnetAbrha, DerbewBelew, and GebremedhinWoldegiorgis, 2003. Studies on effect of inter and intra-row spacing on Seed tuber yield and yield components of potato (Solanumtuberosum L.) at Oflaworeda Northern Ethiopia. *African J. Plant Science*, **8**(6): 285-290.

Harris, P. M. 1992. Mineral nutrition. In: The Potato Crop. The scientific Basis for Improvement (ed.). Department of agriculture, University of Reading, Chapman and Hall. London. 162–209.

Hirpa, A., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Lansink, A.O., Tsegaye, A. and Struik, P.C. 2010. Analysis of seed potato systems in Ethiopia. *American Journal ofPotato Research*, **87**: 537-552.

Horton, D. and Sawyer, R.L. 1985.The potato as a world food crop, with special reference to developing areas, pp. 1-34. In: Paul, H.L.I. (ed.), Potato Physiology. Academic Press Inc. London, UK.

HU, Y.; YE, X.; SHI, L.; DUAN, H. & XU, F. 2010. Genotypic differences in root morphology and phosphorus uptake kinetics in Brassica napusunder low phosphorus supply. *Journal of Plant Nutrition*. **33**:889-901.

Hue, N.V. 1995. Sewage Sludge. pp. 193-239. In: Rechcigl, J.E. (ed.), Soil amendment and environmental quality. Lewis Publ., Boca Raton. FL.

Human, J.J. 1961. The effect of fertilizer levels on yield and specific gravity of potatoes. *Biological Abstracts*.**39**: 278

Israel Zewide, Ali Mohammed and Solomon Tulu. 2012. Effect of different rates of nitrogen and phosphorous on yield and yield components of potato (*Solanum tuberosum* L.) at Masha District, Southwestern Ethiopia. *International Journal of Soil Science*, **7(4)**: 146- 156.

Jayramaiah R, Thimme Gowda S, Chalapathi MV, Devakumar N,Rangaswamy BT, Basavarajappa HR, Phanikumar PR. 2005.Effect of Irrigation Regimes and Organic Manure Levels on Growth and Yield of Potato. *Karnataka Journal of Agriculture Science* **18(3**).134-136. *Journal of Potato Research*, **80**: 271-280.

Joy, P.P., Savithri, K.E., Mathew, S., Thomas, J., Kurien K. 2005. Effect of sole and combined application of FYM and fertilizer on growth, yield and quality of black musli (*Curculigo orchioides*).*Journal of Medicinal and Aromatic Plant Sciences***27**, 454-46.

Kabir, M.H., Alam, M.K., Hossain, M.A., Hossain, M.M., Hossain, M.J. 2004. Yield performance of whole-tuber and cut-piece planting of potato. *Tropical Science*, **44**: 16-19.

Kandil, A.A., Attia, A.N., Badawi, M.A., Sharief, A.E. and Abido, W.A.E. 2011. Influence of water stress and organic and inorganic fertilization on quality, storability and chemical analysis of potato (*Solanum tuberosum* L). *Journal of Applied Sciences Research*, **7**(3): 187-199.

Kefelegn, H., Chala, A., Kassa, B. and Tiwari, P.K. 2012. Evaluation of different potatovariety and fungicide combinations for the management of potato late blight (*Phytophthora infestans*) in Southern Ethiopia. *International Journal of Life Sciences*, **1**(1): 8-15.

Khajehpour, M., 2006. Production of industrial plants. Jehad-e-Daneshgahi Isfahan press. Isfahan. Iran. ISBN: **961**:6122-63-9.

Khalafalla, A. M. 2001. Effect of plant density and seed size on growth and yield of Solanum potato in Khartoum state, Sudan. *African Crop Science Journal*.

Kidane-Mariam, H.M. 1980. Project Proposal for the Development of an Ethiopian Potato Program. Addis Ababa. Manuscript.

Kleinkopf, G.E., Westerman, D.T and Dwelle, R.B. 1981. Dry matter production and nitrogen utilization by six potato varieties. *Agronomy Journal*, **73**: 799–802.

Kumar, P., S. K. Pandey, B. P. Singh, S. V. Singh, and D. Kumar. 2007. Effects of nitrogen rate on growth, yield, economics, and crisps quality of Indian potato processing cultivars. *Potato Research* **50**:143–155.

Landon, J.R., 1991. Booker tropical soil manual Longman Scientific and Technical. Li, S.X., Wang, Z.H. and Alton Stewart, B., 2011. Differences of Some Leguminous and Nonleguminous Crops in Utilization of Soil Phosphorus and Responses to Phosphate Fertilizers. *Advances in Agronomy*, *110*:125.

Levy, J.S. and Taylor, B.R. 2003. Effects of pulp mill solids and three composts on early growth of tomatoes. *Bioresource Technology*, **89**(3): 297-305.

Leytem, A.B., Westermann, D.T. 2005.Phosphorus availability to barley from manures and fertilizers on a calcareous soil. *Soil Science*, **170**(6):401-412.

Lincoln, T. and Z. Edvardo, 2006. Assimilation of Mineral nutrition. In: Plant physiology (4th ed.), Sinaur Associates, Inc. Pub. Sunderland. 705p.

Lung'aho, C., B. Lemaga, M. Nyongesa, P. Gildermacher, P. Kinyale, P. Demo and J. Kabira, 2007.Commercial seed potato production in eastern and central Africa. *Kenya Agricultural Institute*, 140p.

Lynch, D. R. and Rowberry, R. G. 1997. Population density studies with Russet Burbank potatoes. II. The effect of fertilization and plant density on growth, development, and yield. *American Potato Journal* **54**: 57-71.

Mahmood,S., 2005. A study of planting method and spacing of Potato using TPS. Asian Journal of Plant Science, 4(2): 102-105.

Makani, M.N., Sargent, S.A., Zotarelli, L. and Reyes-Cabrera, J. 2013. Postharvest quality of table stock potatoes in response to drip irrigation and harvest time. *Proc. Fla. State Hort. Soc.*, **126**: 184-186.

Makavaviciute, A., 2003.Effects of organic and mineral fertilizers on the yield and quality of deferent potato varieties. *Agronomy Research.* **1**(2): 197-209.

Manochehr Shiri, Ahmad Tobeh, Abazar Abbasi, Shahzad Jamaati-e-Somarin and Saeid Hokmalipour., 2009. Vegetative Growth of Potato (*Solanum tuberosum* L.) Cultivars, Under the Effects of Different Levels of Nitrogen Fertilizer. *Research Journal of Biological Sciences.* **7**:57-64.

Manochehr Shiri, Ahmad Tobeh, Abazar Abbasi, Shahzad Jamaati-e-Somarin and Saeid Hokmalipour., 2009. Vegetative Growth of Potato (*Solanum tuberosum* L.) Cultivars, Under the Effects of Different Levels of Nitrogen Fertilizer. *Research Journal of Biological Sciences.* 57-64.

Mauromicale G, Ierna A, Marchese M.2006. Chlorophyll fluorescence and chlorophyll content in field-grown potato as affected by nitrogen supply, genotype, and plant age. *Journal of Photosynthetica* **44**: 76-82.

McArthur, D.A.J. and Knowles, N.R. 1993. Influence of Species of Vesicular-Arbuscular Mycorrhizal Fungi and Phosphorus Nutrition on Growth, Development, and Mineral Nutrition of Potato (*Solanum tuberosum* L.). *Plant Physiology*, **102**: 771-782.

Mehdizadeh, M., Darbandi, E.I., Naseri-Rad, H. and Tobeh, A. 2013. Growth and yield of tomato (*Lycopersicon esculentum* Mill.) as influenced by different organic fertilizers. *International Journal of Agronomy and Plant Production*, **4**(4): 734-738.

Menzel C.M. 1985. The control of storage organ formation in potato and other species: Areview. Part. 1. Field Crop Abstratcts. **38**: 527-537.

Mikhailova, E. A., Cherney, J.H. and Cherney, D.J.R. 2003. Impact of Phosphorus from Dairy Manure and Commercial Fertilizer on Perennial Grass Forage Production. *J. Agronomy and Crop Science*, **189**: 367-375.

Mohammadi, G.R., Ajirloo, A.R., Ghobadi, M.E. and Najaphy, A. 2013. Effects of nonchemical and chemical fertilizers on potato (*Solanum tuberosum* L.) yield and quality. *Journal of Medicinal Plants Research*, **7**(1): 36-42.

Mohammadi, G.R., Ajirloo, A.R., Ghobadi, M.E. and Najaphy, A. 2013. Effects of nonchemical and chemical fertilizers on potato (*Solanum tuberosum* L.) yield and quality. *Journal of Medicinal Plants Research*, **7**(1): 36-42.

Mohr, R. and Tomasiewicz, D. 2008. Phosphorus management for irrigated potato production in Manitoba. *Better Crops*, **92**(1): 23-25.

Mondal, S. S. and Roy, B. (2001). Effect of potassium with and without farmyard manure on the yield and nutrient uptake by crops in potato (*Solanum tuberosum*)- jute (*Corchorus* spp.)-rice (*Oryza sativa*) sequence. *Indian J. Agric.Sci.*, **71**(2): 116-117.

Mugambi, S.M. 1979. Manure and fertilizer requirement of potatoes on acid soils. *East African Agricultural and Forestry Journal*, **44**(4): 278-284.

N'Dayegamiye, A., Nyiraneza, J., Giroux, M., Grenier, M. and Drapeau, A. 2013. Manure and paper mill sludge application effects on potato yield, nitrogen efficiency and disease incidence. *Agronomy*, **3**: 43-58.

Najm, A.A., Hadi, M.R.H.S., Fazeli, F., Taghi Darzi, M. and Shamorady, R. 2010. Effect of utilization of organic and inorganic nitrogen source on the potato shoots dry matter, leaf area index and plant height, during middle stage of growth. *International Journal of Agricultural and Biological Sciences*, **1**: 26-29.

Najm, A.A., Hadi, M.R.H.S., Taghi Darzi, M. and Fazeli, F. 2013. Influence of nitrogen fertilizer and cattle manure on the vegetative growth and tuber production of potato. *International Journal of Agriculture and Crop Sciences*, **5**(2): 147-154.

Nasreen, S., Hossain, A.K.M.(2004). Nutrient Uptake and Yield of Onion as Influenced by Chemical Fertilizer and Organic Manure. *Indian Journal of Agricultural Research***38**(3): 164-170.

Nebret Tadesse. 2011. The effect of Nitrogen and Sulphur on yield and yield component of common bean in Eastern Ethiopia. Unpublished M.Sc. Thesis presented to the school of graduate studies of Haramaya University. 25p.

Negassa, W., Negisho, K., Friesen, D.K., Ransom, J., Yadessa, A., 2001.Determination of Optimum Farmyard Manure and NP Fertilizers for Maize on Farmers Field. Seventh Eastern and Southern Africa Regional Maize Conference. 11th-15thFebruary. 387-393.

OlnagoT. M. 2008. Co-innovation for quality in agri-food chains (CoQA) kick-off workshop, November 3-4 Wageningen, the Netherlands p 7-12.

Olsen, S.R., 1954. Estimation of available phosphorus in soils by extraction with sodiumbicarbonate. United States Department of Agriculture; Washington.

Osono, T. and Takeda, H. 2005. Decomposition of organic chemical components in relation to nitrogen dynamics in leaf litter of 14 tree species in a cool temperate forest. *Ecol Res*., **20**: 41-49.

Ouda, B. A. and Mahadeen, A.Y. 2008. Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleracea*). *Int. J. Agri. Biol.* **10**: 627–32.

Palm C.A., Myers R.J.K., Nandwa S.M (1997). Combined use of organic and Inorganic Nutrient sources for Soil fertility Maintenance and Replenishment In: Replenishing Soil Fertility in Africa, eds. Buresh.

Pankhurst, R. 1964. Notes for a history of Ethiopian agriculture. *Ethiopian Observer* **7**: 210-240.

Pervez, M.A., Muhammad, F. and Ullah, E. 2000. Effects of organic and inorganic manures on physical characteristics of potato (*Solanum tuberosum* L.). *International Journal ofAgriculture and Biology*, **2**(1-2): 34-36.

Powon, M.P., Aguyoh, J.N. and Mwaj, A.V. 2006. Growth and tuber yield of potato (*Solanum tuberosum* L.) under different levels of phosphorus and farm yard manure. *Agricultura Tropica ET Subtropica*, **39**(3): 1-6.

Purakayastha, T. T and Bhatnagar, R. K., 1997. Vermicompost a promising source of plant nutrients. *Indian Farming*, **40**: 34-37.

Romero-Lima, M.R.A.,Santos, T.,Garcia-Espinosa R. and Ferrera-Cerrato, R. 2000. Yield of Potato and soil microbial biomass with organic and mineral fertilizers. Pbcado Com. ARTICULO *Agrociencia*, **34**: 261-269.

Roy, S.K., Sharma, R.C. and Trehan, S.P. 2001. Integrated nutrient management by using farmyard manure and fertilizers in potato-sunflower- paddy rice rotation in the Punjab. *Journal of Agricultural Science*, **137**: 271-278.

Sanderson JB, White RP (1987). Comparison of urea and Ammonium nitrate as nitrogen sources for potatoes. *American Potato J*. **64**(4): 165-176.

Saviozzi, A. and Cardelli, R. 2013. Organic matter characteristics, biochemical activity and antioxidant capacity of soil amended with different organic materials. *Archives of Agronomy and Soil Science*, http://dx.doi.org/10.1080/03650340.2013.767444.

Scott, G.J., Rosegrant M.W. and Ringler C. 2000. Global Projections for Root and Tuber Crops to the year 2020. Food Policy **25**: 561-597.

Shahzad,J.S., R. Zabihi, A. Mahmood and Y. Asgar, 2011. Yield and yield components of potato (*Solanum tuberosum* L.) tuber as affected by nitrogen fertilizer and plant density. *Australian Journal of Basic and Applied Sciences*, **4**(8): 3128-3131.

Shalini S, Kumar S, JainMC (1997) Methane emission from two Indian soils planted with different rice cultivars. Biol Fertil Soils **25**:285–289.

Sharma,V. C. and Arora, B. R. 1987. Effects of nitrogen, Phosphorus, and Potassium Application on the Yield of Potato Tubers (*Solanum tuberosum* L.). *Journal of Agricultural Sciences,* Cambridge **108**: 321-329.

Samuel Shaweno. 2017. Effect of Combined Application of Biochar and Inorganic Nutrients (N and P) on Yield and Yield Components of Potato (Solanum tuberosum L.) at Gecha, Andiracha District, South western Ethiopia. MSc thesis Submitted to School of Graduate studies, Jimma University, Jimma, Ethiopia.

ShayanowakoA., ManganiR., MtaitaT. and Mazarura U. 2015. Influence of Main Stem Density on Irish Potato Growth and Yield: A Review. Annual Research and Review in Biology: 2347-565.

Simanavičien O., Staugaitis G., Antanaitis A. (1996) Dirvožemio agrocheminių savybių įtaka bulvių irlauko daržovių derliui ir kokybei. *Žem÷s ūkio mokslai*, **2**:60-67.

Simret Burga, 2010. Influence of inorganic nitrogen and potassium fertilizers on seed tuber yield and size distribution of potato (*Solanum tuberosum* L.). An. M. Sc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia. 65p.

Singh, G., Kapoor, I.P.S. and Pandey, S.K. 1997. Studies on essential oils. Part 7. Natural sprout inhibitors for potatoes. *Pesticide Research Journal,* **9**: 121-4.

Sparrow, L. A., K. S. R. Chapman, D. Parsly, P. R. Hardman and B. Cullen, 1992. Response of potatoes (*Solanum tuberosum* L. and *Russet Burbank*) to band-placed and broadcast high cadmium phosphorus fertilizer on heavily cropped North-Western Tasmania. *Australian Journal of Agriculture*. **32**: 113-119.

SRDI (Soil Resources Development Institute). 1999. Map of the nutrient status of sulfur and upazila land soil resource utilization guide.

Srivastava, P.K., Gupta, M., Upadhyay, R.K., Sharma, S., Singh, N., Tewari, S.K. and Singh, B. 2012. Effects of combined application of vermicompost and mineral fertilizer on the growth of *Allium cepa* L. and soil fertility. *Journal of Plant Nutrition and Soil Science*, **175**: 101-107.

Storey, R.M.J. and H.V. Davies. 1992. Tuber quality. In: The potato crop. The Scientific Basis for Improvement (ed. Harris Paul). Second edition.742pp.

Strimumar T. S., Ockerman P. A. (1990) the effects of fertilization and manuring on the content of some nutrients in potato (var. Provita). *Food Chemistry*, **37**: 47-60.

Sud, K.C., Sharma, R.C. and Govinda, K.P.M. 1992. Influence of organic manure and nitrogen levels on nutrient status, translocation, and yield and tuber quality in four based cropping system. *Indian J. PotatoAssoc*.**19**:5-12.

Taheri, N., Sharif-Abad, H.H., Yousefi, K. and Mousavi, S.R. 2011. Effect of organic manure with phosphorus and zinc on yield of seed potato. *Australian Journal of Basic and Applied Sciences*, **5**(8): 775-780.

Tekalign, T. and Hamas, P.S. 2005. Growth and productivity of potato as influenced by cultivars and reproductive growth. I. Stomatal conductance, rate of transpiration, net photosynthesis, and dry matter production and allocation. *Scientia Horticulturae.**150**;* 13-27.

Tekalign, T., Abdissa, Y. and Pant, L.M. 2012. Growth, bulb yield and quality of onion (A*llium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol. II:Bulb quality and storability. *African Journal of Agricultural Research*, **7**(45): 5980-5985.

Tesfaye, G., Derbew, B. and Tulu, S., 2012. Yield and Growth Parameters of Potato (*Solanum tuberosum* L.) as Influenced by Intra Row Spacing and Time of Earthing Up: In

Boneya Degem District, Central Highlands of Ethiopia. *International Journal of Agricultural Research*, ***7**:255-265.*

.

Tibbitts, T.W.,Cao, W.and Bennett, S.M. 1992.Utilization of potatoes for life support in space. 5. Evaluation of cultivars in response to continuous light and high temperature. *American Potato Journal*, **69**: 229-237.

UN Estimate. 2017.Ethiopia population 2017 (Demographics, map, graphs). worldpopulationreview.com/countries/ethiopia-population

Van den Berg, R.G. and Jacobs, M.M.J. 2007. Molecular Taxonomy. Pp. 55-76. In: Vreugdenhil, D., Bradshaw, J., Gebhardt, C., Govers, F., MacKerron,D.K.L., M.A. Taylor, Ross, H.A. (eds.), Potato Niology and Biotechnology. Advances and Perspectives. Elsevier. BV.

Vos, J. 1995. The effects of nitrogen supply and stem density on leaf attributes and stem branching in potato (*Solanum tuberosum* L.). *Potato Research*, **38**: 271-279.

Walkley AC, Black TA (1935) Estimation of soil organic carbon by chromic acid titration method. Soil Sci **47:** 29-38.

Wells, A.T., Chan, K.Y. and Cornish, P.S. 2000. Comparison of conventional and alternative vegetable farming systems on the properties of a yellow earth in New South Wales. *AgrEcosyst Environ*., **80**: 47-60.

White, P.J., Wheatley, R.E., Hammond, J.P. and Zhang, K. 2007. Minerals, Soils and Roots. In: Vreugdenhil, D. (ed.), Potato Biology and Biotechnology. Advances and Perspectives. Elsevier, B.V.

Wijewardena, J.D.H. 1996. Response of potato and vegetable crops to phosphorus application in Ultiso. Regional Agricultural Research and Development Centre, Bombuwela, Kalitara.

Yourtchi, M.S., Hadi, M.H.S. and Darzi, M.T. 2013. Effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato (Agria CV.). *International Journal of Agriculture and Crop Sciences*, **5**(18): 2033-2040.

Zandstra, H.G., R. H. Anderson and W. K. Daley. 1969. Effects of fertilizer on the yield and quality of Norland Potatoes in North eastern Saskatchewan. *American Potato Journal*. **46**: 69-74.

Zelalem, A., Tekalign, T.and Nigussie, D. 2009.Response of potato (*Solanum tuberosum L.)* to different rates of nitrogen and phosphorus fertilization on vertisols at DebreBerhan, in the central highlands of Ethiopia. *Afr JPlant Sci*., **3**: 16-24.

Zelleke, G., Agegnehu, G., Abera, D. and Rashid, S. 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. International Food Policy Research Institute (IFPRI). http://www.ifpri.org/publication/fertilizer-and-soilfertility- potential-ethiopia.

Zinash, S. 2001. The role of livestock in crop-animal production system in Ethiopia. pp. 53-58. In: Paulos, D., Asgelil, D., Asfaw, Z., Gezahegn, A., Abebe, K. (eds.), Advances in Vertisols management in the Ethiopian highlands. Proceedings of the International Symposium on Vertisol Management, 28 Nov. to 1 Dec. 2000, Debre Zeit, Ethiopia

7. APPENDICES

7. APPENDICES

APPENDIX 1: Analysis variance showing mean squares for 50% of flowering days, 75% of maturity days, plant height at 60 days after emergence and main stem numbers at 50% of flowering days.

Source of variation	DF	DFR	DM	PH	MSN
REP	2	0.33	1.39	18.17**	0.18
CM	3	144.58**	54.75**	1562.91**	5.64**
NPS	3	94.47**	109.25**	1259.77**	9.07**
CM*NPS	9	3.12**	3.39**	49.58**	0.19ns
ERROR	30	0.27	0.82	10.22	0.41
CV(%)		2.11	1.16	4.51	8.39

Where; DF = degrees of freedom, DFR = days to 50% flowering, DM= days to 75% maturity, PH=plant height, main stem number and NS, * and ** implies non-significant, significant and highly significance differences at 5% level of probability, respectively.

APPENDIX 2: Analysis of variance showing mean squares for unmarketable tuber yield, unmarketable tuber number, marketable tuber yield, marketable tuber number, total tuber number, total tuber yield of potato, as affected by the application of NPS and cattle manure.

		Mean squares					
Source of Variables	df	Tuber yield(t/h			Average tuber number		
		MTY	unMTY	TTY	MTN	UnMTN	TTN
REP	2	0.68	0.0073	0.55	0.46	0.55	0.48
CM	3	461.72**	0.085ns	454.09**	47.35**	0.52ns	37.63**
NPS	3	847.72**	0.67ns	810.94**	90.32**	0.87ns	75.39**
CM*NPS	9	13.52**	0.36ns	14.91**	7.59**	0.54ns	10.05**
ERROR	30	1.49	0.32ns	1.36	0.65	0.36	6.2
CV(%)		4.35	54.77	4.00	8.46	50.88	7.63

MTY= marketable tuber yield, unMTY= unmarketable tuber yield, TTN= total tuber numbers, MTN= marketable tubers and unMTN= unmarketable tuber numbers, CM=cattle manure, NPS=Nitrogen, phosphorus and sulfur fertilizerandNS, * and ** implies non-significant, significant and highly significance differences at 5% level of probability, respectively.

APPENDIX 3: Analysis of variances showing that mean square of dry matter content (%) and specific gravity (gcm^{-3}).

Source of variation	DF	DMC (%)	SG(gcm^{-3})
REP	2	9.001	0.000007
CM	3	50.37**	0.00046**
NPS	3	89.13**	0.0022**
CM*NPS	9	3.28ns	0.000029**
ERROR	30	3.07	0.0000026
CV(%)		8.56	0.15

Where; DMC=dry matter contents, SG= specific gravity and NS, * and ** implies non-significant, significant and highly significance differences at 5% level of probability, respectively

APPENDIX 4: climate data on the research area during the growing period 2016/17

	Total rains fail (mm)	Mean temperature (^{0}C)		Mean Relative Humidity (%)	Mean soil temperature (0-30cm) (^{0}C)	Mean sun shine (hours)
		Minimum	Maximum			
Month	2016	2016/17	2016/17	2016/17	2016/17	2016/17
Jan	56.2	10.4	25.61	69.4	23.9	7.8
Feb	61.6	12.5	29	53	24.1	7.4
Mar	97.8	12.5	25.61	61.4	24.1	8.2
Apr	96.5	11.3	25.97	59.3	23.8	8
May	192.4	11.9	27	67	23.8	6.7
Jun	185.9	10.6	26.9	66	23.4	5.4
Jul	205.6	12	23.9	62.7	20.8	4.9
Aug	210.4	13.6	24.6	68	23.1	3.9
Sep	250.2	15.6	24.8	76	23.8	5.6
Oct	63.3	12.8	27	65	23.8	7.2
Nov	22.1	11.8	28.5	58	23.9	6.4
Dec	53.2	8.9	28.8	53	23.6	6.7
Total	1553	143.9	317.7	75.8	282.1	
Mean	124.6	12	26.5	63.2	23.5	6.5

Source: *Jimma Meteorological Station (2017).*

APPENDIX 6: Different pictures captured during the research process.