EFFECT OF BLENDED NPSB FERTILIZER AND CATTLE MANURE RATES ON GROWTH, YIELD AND QUALITY OF POTATO (*Solanum tuberosum* L.) IN SEKA DISTRICT, JIMMA ZONE, SOUTHWEST ETHIOPIA

M.Sc. THESIS

BY

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DEDICATION

This Thesis is dedicated to my beloved family who always support me and are eager to see my success and also I dedicate to my dearest wife Amina, and my daughter Wofik for their continuous support and prayers to see my success.

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.

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BIOGRAPHICAL SKETCH

The author, Amirachu Shawul , was born in , Seka Chekorsa district, Jimma Zone of Oromia Regional National State in Ethiopia in 1985. He attended elementary and secondary school education at Seka and Jimma secondary Schools, respectively.In 2004, I joined Bako Agricultural College and graduated with Diploma in plant Science in July 2006 employed in Seka Chekorsa at Rural Development Office in September 2007 where I worked as a developmental agent coffee coverage keble. And I joined Jimma University in 2009 and graduated with the degree of Bachelor of Science in Horticulture in June 2011. After graduation I was served as vegetable and fruit expert at district level from 2011 to 2013.After graduation I was employed as he served as irrigation team leader at district level from 2014 to 2016.From 2016 to 2017 I served as vice coordinator of coffee authority office at district level.In 2018, From September 2017 to pursue the study in Horticulture.

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ABBREVIATIONS AND ACRONYMS

AGY	Adjusted Grain Yield
ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
BCR	Cost Benefit Ratio
BoARDO	Bore Agriculture and Rural Development Office
CEC	Cation Exchange Capacity
CIMMYT	International De Mesoramien to De Maiz Y Trigo (Spanish)
CIP	International Potato Center
CM	Cattle Manure
CSA	Central Statistical Agency
DAP	Di-ammonium Phosphate
DMC	Dray Matter Content
EARO	Ethiopian Agricultural Research Organization
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FAOSTAT	Statics Division for the Food and Agricultural Organization
EARO	Ethiopian Agricultural Research Organization
MB	Marginal Benefit
MRR	Marginal Rate of Return
MOA	Ministry of Agriculture
MSN	Main Stem Number
NR	Net Return
NPSB	Nitrogen, Phosphorous, Sulphur, Boron
RCBD	Randomized Complete Block Design
SIS	Soil Information System
SRDI	Soil Resources Development Institute
TC	Total Cost
TVC	Total Variable Cost

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ABSTRACT

Potato (Solanum tuberosum L.*) is one of the most important tuber crops which is being produced in Ethiopia. However, the production and productivity of the crop is far below the world average due to poor crop variety, soil fertility and water management practices. Therefore, a field experiment was conducted in Southwestern Ethiopia 'Seka district, under irrigation during the 2018/2019 off-season. Treatments consisted of four levels of NPSB (0, 61, 122 and 183 kg ha^{-1}) and four levels of cattle manure (0, 10, 15 and 20kg ha^{-1}) laid out in Randomized Complete Block Design (RCBD) in a 4x4 factorial with three replications. Data were collected on growth and yield parameters. The combined application of NPSB blended fertilizer and cattle manure significantly ($P<0.005$) 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 NPSB blended fertilizer and cattle manure. Unmarketable tuber number and yield was also not affected by the main effects of NPSB blended fertilizer and cattle manure and as well as their interaction. The highest total tuber yield (40.08 t ha^{-1}) was obtained by applying 183 kg ha^{-1} NPSB bended fertilizers+20 t ha^{-1} cattle manure. The combined application of 183 kg NPSB ha^{-1} bended fertilizers+20tha^{-1} cattle manure gave the maximum net return of Birr 193365.5ha^{-1} with an acceptable marginal rate of return (1726 %). The total nitrogen, available phosphorus and organic carbon content of the experimental soil were also increased due to the interaction of mineral NPSB blended fertilizers and cattle manure at their highest rates. The combined application of 122 kg ha^{-1}NPSB blended fertilizers and 10 t ha^{-1} CM is found economically feasible for farmer which un able to buy much input. In conclusion, the results revealed that combined application of 183 kg ha^{-1}NPSB fertilizers and cattle manure at 20 t ha^{-1} significantly increased total tuber yield (40.08tha^{-1}) of potato and restore of N, P and organic carbon of soil. And can be recommended for potato growers around Seka district.*

Keywords: Mineral fertilizer, jalenie, tuber quality, marketable tuber yield , total tuber yield

1. INTRODUCTION

Potato (*Solanum tuberosum* L.*)* is a crop of the world's major economic importance and number one non-grain food commodity (Rykaczewska, 2013). It is the third most important food crop in consumption in the world after rice and wheat (Hielke *et al*., 2011; Birch *et al*., 2012; Hancock *et al*., 2014), with a global cultivation exceeding 19.34 million hectare of land in more than 158 countries in the globe with an estimated annual production of 364 million tons (FAOSTAT, 2014). It is a starchy, tuberous crop of the Solanaceae family (van den Berg and Jacobs, 2007).

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 introduced to Ethiopia in 1858 by a German Botanist called Schimper (Pankhurst, 1964; Horton, 1987). 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).

In Ethiopia, potato ranks the first among the major tuber crops 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 69,610.81 ha per season with an annual production of 9.6 M. tone (CSA, 2018). In Ethiopia, the total area cropped by potato increased from 40,000 hectares in 1996 to 160,000 in 2006 (Gildemacher *et al*., 2009). The total area cropped by potato increased from 40,000 hectares in 1996 to 69,610.81 in 2017 (CSA, 2017/218). Ethiopia, approximately 1,127,467 million farmers grew the crop in mid and highlands of the country where the crop covered more than 0.45% of the area under all crops and contributed 2.24% to the total crop production in the country (CSA, 2017/18).

This can be accounted for the development of high yielding varieties, wider adoption by farmers and use of potato blight (Phytophthora blight), variety together with improved agronomic practices. However, potato soil nutrient requirements, for example in terms of

Nitrogen and Phosphorus, application rates were given less attention under irrigated conditions (CSA, 2008). Evaluation of the impact of improved practices, such as optimum fertilizer application on productivity, nutrient recovery and water productivity were not also focus areas of research in Ethiopia. Compared to the huge potential and yield gaps, the claimed increase in yield indicated above is very low (Endale *et al*., 2005).

According to FAOSTAT (2008) about 70% of cultivated agricultural land of Ethiopia is suitable for potato production due to the availability of diverse climate and soil conditions. In relation to climate, for example, there are long frost free periods, which allow production during both the rainy and off seasons. More than 3.5 billion m3 water resources of the county is also potential resource which can offer opportunities for off-rainy season potato production. Generally, these are good opportunities that worth exploring to increase the current low productivity and low crop quality level. Some of the main contributing factors for the low production and utilization of potato are, pests and diseases, lack of appropriate agronomic practices such as balanced and optimum nutrition and water inputs, lack of good quality seed etc. The research support in terms of provision of improved agronomic practices is weak (Burton, 2008).

Application of Nitrogen and phosphorus fertilizers has shown good yield responses for different crops across different locations, indicating low nitrogen and phosphorus status of the soils (Berga *et al*., 1994a). In addition to that lack of optimum nitrogen and phosphorus application rates, there are a number of production problems accounting for low yields of potato in Ethiopia. These constraints include limited supply of high quality seed tubers of potato (Gildemacher *et al*., 2009), which become more critical in potato production in view of the fact that the crop is one of the heavy feeders of soil nutrients (Powon, 2005).

According to Ababiya (2018), 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 at Seka District.

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 NPSB blended fertilizer having proportion of (N19:,P38:,S6.95:,B0.1), substituting DAP for adoption by farmers. This blanket application can lead to excessiveness or deficiency in relation to plant nutrient requirement. When excessive nitrogen is applied, it may adversely affect crop yield; increase the cost of production and the environment can be polluted, especially soil and ground water can be highly affected due to nitrate leaching (Madramootoo *et al*., 1992). Use of under dose of nitrogen may also bring about significant yield reductions. This gives an insight to conduct trials for different varieties to develop optimum rate of fertilizer application, to enhancing economic return and maintain environmental health. Blanket national recommendation of 165 kg urea and 195 kg DAP ha^{-1} is used without considering the fertility status of the soil, the type of variety and season of production in different areas of Ethiopia (Taye,1998).

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 (Najm, 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, 1998).Therefore, this study was undertaken to investigate the influence of combined application of mineral NPSB and cattle manure to enhance growth and yields of potato under southwest Ethiopia condition.

1.1. Objective

To determine the effect of different rates of blended NPSB fertilizer and cattle manure, and their interaction on growth, yield, yield components and tuber quality of potato in Seka Chekorsa District.

2. LITERATURE REVIEW

2.1. Environmental and Agronomic Requirements of Potato Crop

Potato prefers a cool climate for growth and development. Best suited altitudes ranged between 1500-2800 m.a.s.l. However, for healthy tuber production, particularly for planting purpose, it should strictly cultivate in high altitude areas. For high yields, the total crop water requirements about 500 to 700 mm (MOA, 2011). Potatoes can be grown on all soil types, except heavy water-logged clays, but for optimum yields need a well-drained loam or sandy loam, relatively free from stones. Better tuber yields have been obtained from potatoes grown at soil reaction ranging from pH 5.0 to 7.0 (AGRISNET, 2010).

A temperature ranged between 15-25^{o}C is ideal for potato tuber development (Mondal and Chatterjee, 2001).At higher temperatures the plant fails to initiate tuber formation and at low temperatures vegetative growth is restricted by frost (Horton, 1987). The number of tubers produced per plant is higher at lower than at higher temperature. The seed tubers produced at higher temperatures (34 ^{0}C) are low yielding compared to seed tubers produced at cooler temperatures (7.7^{0}C) (Mondal and Chatterjee, 2001).

Very shallow planting of seed tubers may result in inadequate soil moisture around the seed piece and in production of tubers so close to the soil surface that greening caused by exposure to light is a problem. On the other hand, planting too deep will slow tubers to emerge and may be more subject to attack by various diseases. As a result planting ought to be deeper on lighter soils than on heavy soils (Alexander *et al*., 2001). A good rule of thumb is never to have more than 10 cm of soil above the tip of the developing sprout (Ngungi, 1982).

In Seka district 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.

2.2. Potato Production and its Major Growing Areas in Ethiopia

Ethiopia is endowed with suitable climatic and edaphic conditions for quality potato production. About 70% of the available agricultural land are located at an altitude of above 1500 meters above sea level and receives an annual rainfall of more than 600 mm, which is suitable for potato production (Tekalign, 2005). The national average yield is 13.69 tons ha^{-1} (CSA, 2014/15), which is lower than the world's average of 19.4 t ha^{-1} (FAOSTAT, 2014). Adoption of the crop by Ethiopian farmers occurred very gradually for several decades (Kidane-Mariam, 1980). Cultivation was limited to potato growing voluntarily in fields in the cold highlands until wider adoption of the potato occurred at the end of the nineteenth century in response to a prolonged famine (Gebremedihin *et al*., 2009). Potato production in Ethiopia has increased considerably through the twentieth century. In 1975, the area of potato cultivation was estimated at 30,000 hectares, with an average yield of approximately five tons per hectare (Gebremedihin *et al*., 2009). But that by 2001, Ethiopia's potato area grew to 160,000 hectares, with average yields around eight tons per hectare. An upward trend in potato production might be due partly to the continuing increase in population and subsequent decline in the average size of farm holdings, hence the pressure for agriculture to become more labor intensive (Gebremedihin *et al*., 2009).

In Ethiopia, potato is grown in four major areas: the central, the eastern, the north-western and the southern regions. Together, they cover approximately 83% of the potato farmers (CSA, 2008/2009). Regional distribution of potato depicted that Oromia, Amhara and SNNPR constitutes 56.79, 26.30 and 15.92% respectively (CSA, 2015). Oromia is the major potato producing region due to the ecological suitability of areas. The growing importance of potato as a food crop is prefaced on rising food insecurity in the country to help ease the food security challenges of the country.

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, appropriate mineral fertilizer application, especially nitrogen and phosphorus are required to correct the nutrient imbalance in infertile soils (Peter *et al*., 2015).

Those with a more limited root system, a characteristic usually associated with earlier maturing cultivars, have a reduced capacity to explore the soil profile for nutrients. While adequate nutrient levels are necessary to maintain an active canopy for an extended period, the amounts required may vary between cultivars as a consequence of essential variation in their capacity to generate leaf area. Consequently, the response to applied phosphorous fertilizer may vary if the principal effect of this nutrient is to influence canopy cover (Assefa, 2005). According to Bansal and Trehan (2011), there is significant yield variability in relation to variety which makes it consistent with present experiment as variety, affected highly significantly yield and yield component of the potato product. Response of potato to NPK varies with variety, soil characteristics and environmental condition (Naz *et al*., 2011). Although the improved varieties have been reported to be high yielding and resistant to late blight, their adoption by farmers has been low in most areas where the new varieties have been disseminated (Tesfaye *et al*., 2013; Gebremedhin, 2015).

2.4. Effect of Blended NPSB Fertilizer on Yield and Yield Components of Potato

The main reason contributing to low yields of potato in most parts of the world is low soil fertility. This is attributed by continuous cultivation without adequate replenishment of the mined nutrients (Naz *et al*., 2011). The formulation blending fertilizers based on actual need is determined by the combination of crop requirement and soil test level. The formulation blending fertilizers based on actual need is determined by the combination of crop requirement and soil test level. The recent completed research and soil tests through the Ethiopian Soil Information System Project revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and Urea (ATA, 2013).

The main advantages of blended fertilizers to the farmers are: nutrients are supplied in ratios to suit the needs of particular soils and crops; the cost per unit of plant nutrient is generally low; the cost of transportation and spreading is low because of the high analysis of bulk blends (Roy *et al*., 2006). Moreover, blends have the advantage of allowing a very wide range of fertilizer grades that makes it possible to match a fertilizer exactly to a soil test recommendation (Oldham, 2000). Lack of appropriate fertilizer blends micronutrients in fertilizer blends is a national problem constituting a major constraint to crop productivity (Bekabil *et al*., 2011). Applying fertilizers increases not only yield, but also mineral concentrations in potato tubers there by affecting the nutritional, processing and storage qualities of the crop (Allison *et al*., 2001). Accordingly, it should be possible to increase tuber yield and mineral concentrations of the crop with appropriate fertilization strategies (White *et al*., 2009).

2.4.1. Effect of Nitrogen Fertilizer on Yield and Yield Components of Potato

Nitrogen is a fundamental component of many compounds, including chlorophyll and enzymes, essential for plant growth processes. Among the macro-nutrients nitrogen has been identified as being the most limiting nutrient in plant growth. Nitrogen supply plays an important role in the balance between vegetative and reproductive growth for potato (Alva, 2004). Plants are require nitrogen in relatively larger amounts than other elements (Marschner, 1995).Plants uptake nitrogen both in the cationic (NH_4^+) and/or the anionic (NO_3^-) form.

Nitrogen fertilizer increases the nitrogen uptake and this increase has a positive effect on chlorophyll concentration, plant height, and photosynthetic rate, total number of leaves and dry matter accumulation (Israel *et al*., 2012).Potato leaf area index at various growth stages dissimilar with different nitrogen sources and time of application. Nitrogen in the presence of adequate phosphorus and potassium stimulates canopy growth, leaves and branches. This is through production of extra leaves and branches, extension of leaf area duration and expansion of leaf area (Muthoni and Kabira, 2011).

Getu (1998) reported that a significant difference in mean stem number of potato per hill due to nitrogen application. However, many previous studies have shown that nitrogen fertilizer applications can increase total and/or marketable tuber yield (Zebarth *et al*., 2004; Zelalem *et al*., 2009). Sommerfeld and Knutson (1965) noticed that an increase in nitrogen application increased tuber number. Similarly, Yibekal (1998) reported that increasing application of nitrogen from 0 to 150 kg N ha^{-1} significantly increased total tuber number per hill.

The average tuber weight has been reported that the most important yield component of potato after stem and tuber number, contributing to the total tuber yield (De la Morena *et al.*, 1994). Harris (1992) showed that the potato yield component most affected by nitrogen and potassium application was the mean tuber weight. Similarly, Sharma and Arora (1987) indicated that the increase in the weight of tubers with the supply of fertilizer nutrients could be due to more comfortable growth, more foliage and leaf area and higher supply of photosynthates that helped in producing bigger tubers resulting in higher yields. Moreover, many authors had been reported that total tuber yield and size of potato tubers increase with increasing nitrogen. For example, Sanderson *et al*.(1987); Zelalem *et al*. (2009) reported that total tuber yield found to be strongly associated with average tuber weight and total tuber number signifying both the increase in tuber number as well as size have substantially contributed to tuber yield increase in response to the fertilization of nitrogen treatments.

The yield reduction due to high rates of nitrogen may be due to the fact that high amount of this nutrient stimulates shoot growth more than tuber, which may result in deterioration of canopy structure and physiological conditions (Sommerfeld and Knutson, 1965). When nitrogen is applied in large amount, excess vegetative growth occurs, decreases the quality and the plants fall over with the slightest wind. Crop maturity is delayed, and the plants are more susceptible to disease and insect pests. On the other hand, shortage of nitrogen restricts the growth of all plant organs such as roots, stems, leaves, flowers, fruits and finally gives stunted plant architecture with yellow leaf appearance (Barker and Bryson, 2007). Shortage of nitrogen also restricts tuber size due to reduced leaf area and early defoliation (Goffart *et al*., 2008). The deficiency symptoms of nitrogen in plants generally include stunted plant growth, and thin appearance of plants, reduced growth of leaves, chlorosis and premature senescence of older leaves and restricted root growth and branching (Tisdale *et al*., 1995). The leaves are small and thin, have high fall colour, and drop early, shoots are short and smaller in diameter than usual. Shoots may be reddish or reddish brown, flowers bloom heavily, but may be delayed (Barbara, 2007).

Moreover, application of nitrogen fertilizer rates has been advised as optimal for potato production. For instance, Ruža, *et al*. (2013) recommended a fertilization rate of 140 kg N ha^{-1} as optimum for tuber yield above 30 t ha^{-1}. The recommended nitrogen fertilization rates vary from 70 to 330 kg ha^{-1}, and the most economically efficient rates from 147 to 201 kg N ha^{-1} (Fontes *et al.*, 2010). Generally, potato is a crop that is highly responsive to nitrogen fertilizer (Sincik *et al.*, 2008). Furthermore, Zelalem *et al*. (2009); Israel *et al*. (2012); Shunka *et al*. (2016); Belachew, (2016) recommended that application of nitrogen fertilizer from 110 to 165 kg N ha^{-1} is required for optimum potato production to obtain reasonable economic yield.

2.4.2. Effect of Phosphorus Fertilizer on Yield and Yield Components of Potato

Phosphorus is believed to be the second most often limiting plant nutrient (Tisdale *et al*., 1995). Phosphorus is a nutrient that should be available in adequate quantities from the early growth stages (Hue *et al*., 2010) to maintain a high photosynthetic rate during tuber bulking. It is known to be involved in many physiological and biological processes of plants.

Plants uptake phosphorous in the forms of $H_2PO_4^-$ and HPO_4^{2-} (Tisdale *et al*., 1995). Plants provided with adequate amount of phosphorus had been reported to form good root system, strong stem, mature early and give high yield. The rate, at which the phosphorus concentration in the soil solution is renewed, therefore becomes the principal item, particularly because plant roots do not absorb phosphorus uniformly from the entire soil mass (Dimenstein *et al*., 1997).

Potato is highly responsive to soil applied nutrients, especially to phosphorus, due to its short cycle and high yield potential (Fernandes and Soratto, 2012). The phosphorous requirement for potato is frequently higher than the requirement for other field crops due to the high nutrient demand of potato and its relatively shallow root system (Robert, 2006). Ali and Anjum (2004) noted that above ground growth and dry matter production of potato in relation to phosphorous application at 0, 50, 100, 200 and 400 kg P_2O_5 ha^{-1}. Similarly, Balemi (2012) reported that in a controlled growth chamber on the effect of phosphorous supply on morphological and physiological plant parameters of three potato genotypes grown under two phosphorous levels, such as 100 mg P kg^{-1} soil (low phosphorous) and 700 mg P kg^{-1} of soil (high phosphorous) obtained that low phosphorous supply reduced shoot dry matter yield, relative growth rate, and leaf number, total leaf area per plant, plant height and net assimilation rate of phosphorous inefficient genotype more than that of the phosphorous efficient genotypes.

Yibekal (1998) also reported that increasing application of phosphorous from 0 to 60 kg P_2O_5 ha^{-1} significantly increased total tuber number per hill. In the same way, Sommerfeld and Knutson (1965) noted that the application of phosphorous increased the number of tubers set per unit area, while Sharma and Arora (1987) observed the absence of strong association between tuber number and increased application rates of applied phosphorous.

Potato tuber yield is also known to be influenced by phosphorous fertilizers through its effect on the number of tubers produced, the size of the tubers and the time at which maximum yield is obtained (Sommerfeld and Knutson, 1965; Sharma and Arora, 1987). Biochemically, phosphorus deficiency causes changes in functions of the plant including accumulation of sucrose and reducing sugars and sometimes of starch (Rending and Taylor, 1989). Israel *et al*. (2012) indicated that the highest total tuber yield (37. 6 t ha^{-1}) was obtained at phosphorous application of 60 kg ha^{-1}, but the lowest yield (27.1 t ha^{-1}) was obtained at no pho1sphorous application. On other hand, Desalegn *et al.* (2016) indicated that the shortest plant height of 45.65 cm was recorded at 0 Kg ha^{-1} application of phosphorous and the longest height of 64.11 cm was recorded at 90 Kg P ha^{-1} rate application. Moreover, Zelalem *et al.* (2009); Israel *et al*. (2012) reported that application of phosphorous fertilizer from 46 to 60 kg P_2O_5 ha^{-1} is required for optimum potato production to obtain reasonable economic yield.

2.4.3. Effect of Sulphur Fertilizer on Yield and Yield Components of Potato

Sulphur has a beneficial effect on soil properties as it may reduce soil pH which improves the availability of microelements such as Fe, Zn, Mn and Cu as well as crop yield and related characteristics (Tantawy *et al*., 2009). Sulphur is rated as fourth major nutrients after N, P and K and its importance is being recognized in view of its role in improving crop quality and balance of anions in agricultural crops including potato (Tandon, 1991). Sulphur increases the resistance of this species to environmental stresses and plays an important role in protecting the plants from pests and diseases (Walker and Booth, 1994).

Singh *et al*. (1995) reported that fertilization increases the sulphur content of dry matter in tubers and also affects the increase in tubers, calcium, magnesium, sulphur, copper and iron. Klikocka (2011) indicated that the highest tuber yield was found when 25 kg ha^{-1} of sulphur was applied in sulphate form and 50 kg S ha^{-1} applied potassium sulphate. On other side, Singh and Srivastava (1995) reported that sulphur fertilizer (20 kg S ha^{-1}) increased stem and tuber, Fe contents and plant Fe uptake, but tuber Fe concentration declined during growth from the dilution effect.

Intensive cropping and use of high grade fertilizers have caused to reduce the number of sulphur in soils. Sulphur deficient plants had low utilization of nitrogen, phosphorous and potash and a significant reduction of catalase activities at all growth stages (Nasreen *et al*., 2003). Its deficit decreases crop yield and often leads to deterioration of the yield and quality, which is determined by the content of minerals and their ratios (McGrath and Blake-Kalff, 2003).

2.4.4. Effect of Boron Fertilizer on Yield and Yield Components of Potato

Micronutrients are essential elements for plant growth and development which are utilized in very small amounts by plants. Among micronutrients, boron play several important physiological roles in plants such as, in cell elongation, nucleic acid synthesis, hormone responses and membrane function (Jafar-Jood *et al*., 2013).

Bari *et al*.(2001) showed that application of 1.1 kg B ha^{-1} from borax increased potato fresh haulm weight per hill, number of tubers per hill, dry matter content of tubers and yield of tuber per hectare, but decreased plant height. Because boron tends to accumulate in reproductive tissues, flower buds may fail to form or are not have a natural shape and pollination and seed viability is usually poor in boron deficient plants (Jacobsen and Jasper, 1991). Affected plants grow slowly and appear stunted as a result of shortened internodes. In addition to chlorosis, leaves may develop dark brown, irregular lesions that will progress to leaf necrosis in severe cases of deficiency of boron. Furthermore, Rashid *et al*. (2002) also reported the severity of boron deficiency with the advancement of time and confirmed its necessity for plant fertilization. Hopkins *et al*. (2007) had studied the role of boron on tuberization and yield in potato and reported a non-significant increase due to soil or foliar application of boron. Boron does not have direct influence on yield or related attributes; however it plays supplementary role when applied with sulphur (Bari *et al*. 2001). The advantage of cattle manure application depends on application methods, which increase the value, reduce cost and effectiveness (Erkossa *et al*., 2004).

2.5. Effect of Organic Manure in Crop Production

Organic fertilizer has beneficial effects including the increases of hydraulic conductivity, raises the water holding capacity, changes the soil pH where increases or decreases in the pH, depending on the soil type and characteristics of organic fertilizer, elevates the soil aggregation and water infiltration and reduces the frequency of plant diseases (Olson and Papworth, 2006).Using of animal manure such as cattle manure has positively beneficial effects on vegetative growth, yield and tuber quality (Najm *et al*., 2013).

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 and Qian, 2002). Cattle manure is the main source of nutrients for the maintenance of soil fertility in settled agriculture until the advent of mineral fertilizers (Ofori and Santana, 1990). 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). 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. Olaoye *et al.* (2013) report at that 10t 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.

2.6. Effect of Combined Use of Cattle Manure and Inorganic Nitrogen and Phosphorus on Yield Components Yield and Economics of Potato

Inadequate agronomic management practices specifically, inadequate and inappropriate application of fertilizers, low nutrient reserves in arable soils, a negative nutrient balance on crop and by potato growers are factors contributing to the low yield of potato in study areas. Potato is one of the heavy feeders requiring relatively large quantities of fertilizers. However, scarcity use of only chemical fertilizers without supplementing with organic sources due to the high cost of chemical fertilizers and limited availability for the smallholder farmers accompanied with a high amount of rainfall that might have caused leaching of macro- and micro-nutrients significantly reduced soil fertility and crop productivity in the study area. In addition to the high cost, use of mineral fertilizers constantly leads to decline soil chemical and physical properties, biological activities and thus, overall, the total soil health (Tadesse *et al*., 20013). Due to this, nutrients supplied exclusively through chemical sources, though enhance yield initially, and lead to unsustainable productivity over the years (Mahajan, *et al.*, 2008).

Thus, the undesirable impacts of chemical fertilizers, coupled with their high prices, have prompted the interest in the use of organic fertilizers as a source of nutrients. The combined use of Organic together with mineral fertilizer application has been reported to improve crop growth by supplying plant nutrients including micronutrients as well as improving soil physical, chemical, and biological properties there by provide a better environment for root growth by improving the soil structure (Mengistu and Mekonnen,2012) .Many research findings have shown that neither mineral fertilizers nor organic sources alone can result in sustainable productivity (Satyanarayana *et al*.,2002).Furthermore, the price of mineral fertilizers is increasing and becoming unaffordable for resource-poor smallholder farmers. The best remedy for soil fertility management is, therefore, a combination of both mineral and organic fertilizers, where the mineral fertilizer provides readily available nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil (Godara *et al.,* 2012*).*

The combined application of mineral and organic fertilizers, usually termed as integrated nutrient management, is widely recognized as a way of increasing yield and or improving the productivity of the soil sustainably (Mahajan *et al*., 2008). Several researchers have verified the beneficial effect of integrated nutrient management in moderating the deficiency of several macros- and micro-nutrients. In view of this fact, identifying the optimum dose of integrated nutrients application is crucial and is required for maintaining sufficient amount of nutrients for increased yield of the crop (Mahajan *et al., 2008*). Cattle manure is a decayed mixture of the dung and urine of cattle or other livestock with the straw and litter used as bedding and residues from the fodder fed to them. Whatever is collected for manuring is usually heaped on the ground surface with residues from fodder and other house sweepings. The nitrogen in the manure is subject to volatilization and leaching losses and the material that finally will be spread on the field may have low nitrogen content. The application of well-decomposed manure is more desirable than using fresh materials (Zhu *et al*., 2012). Daniel and Niguse(2008) reported high tuber yield of potato was obtained when CM (cattle manure) at the rate of 1t ha^{-1} was combined with mineral nitrogen at 111 kg N ha^{-1} and phosphorous at 90 kg P_2O_5 ha^{-1} on Nitosol, of Bako Ethiopia. Shiferaw, 2014 reported that the highest potato tuber yield was attained by combined Application of 15 t ha^{-1} CM with the application of 100% recommended rate NPK (100:100:100 kg ha^{-1}) and NP (100/100 kg ha^{-1}) increased tuber yield over control by 567.9 and 393.9%, respectively as compared to the application of organic or mineral fertilizers in isolation.(Pervez *et al*., 2000 as citied in Biruk ., 2015) the application of 30 t ha^{-1} cattle manure along with nitrogen at 120 kg N ha^{-1} and phosphorous at 92 kg P_2O_5 ha^{-1} gave yield advantage of 8.4 t ha^{-1} in North-Eastern Ethiopia.

However, the use of organic manure alone may not be enough to maintain the present level of crop production and enhancing soil fertility because of its limited availability, relatively low nutrient content and high labour requirements (Palm *et al*., 1997). Therefore, the integrated use of both manure and chemical inorganic fertilizers is the best alternative to provide balanced and efficient use of plant nutrients and increase productivity of soil (Menon, 1992). Although potato is major crop produced in Jimma zone, its productivity is less than its potential due to poor fertility of the soil, leaching of major nutrients which enhance production of the crops, fixation of P, shortage of cattle manure to cover the outfield and high cost of chemical fertilizers to apply at the required rate. Generally, there is little information on balanced use of organic and inorganic fertilizer on potato production in Jimma zone. Hence, conducting systematic investigation in this line is vital to come up with conclusive recommendations that would help to increase the yield of the crop in the study area.

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

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 (Tesfaye, 2013). 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. Maximum tuber yield (36.8 t ha^{-1}) was obtained by the utilization of 150 kg N + 20 t cattle manure ha^{-1} Najm (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(Ababiya, 2018) obtained optimum tuber yield was obtained from combined application of 150 kg ha-1 NPS blended fertilizer and 20- 30t ha-1 CM.

According to Baniuniene and Zekaite (2008) 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 t ha^{-1}) was obtained by combined application of cattle manure and N fertilizer at the concentrations of 20 t ha^{-1} and 150 kg N ha^{-1}respectively. Yenagi *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) the presence of nutrients in manure and balanced supplement of nitrogen and phosphorus through mineral fertilizers 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 cattle manure 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. 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 Erkossa *et al.* (2004) reported that high tuber yield was observed with a combination of 2 t cattle manure 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 t ha^{-1}CM.(Suh *et al*.(2015), as citied in Ababiya,(2018) 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.

2.7.1. Tuber number

Yibekal (1998) has found that increasing application of N from 0 to 150 kg N ha^{-1} and P from 0 to 60 kg P_2O_5 ha^{-1} significantly increased total tuber number per hill. Contradicting results have also been reported by different investigators regarding the effect of mineral nutrition on the number of tubers set per plant. For instance, Sharma and Arora (1987) 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

Different investigators have reported contradicting results regarding the effect of mineral nutrition on the number of tubers set per plant. For instance, Sharma and Arora (1987); Lynch and Row berry (1997) and Sharif (2005) reported significant difference in tuber number due to nitrogen fertilization. Jenkins and Mahamood (2003) also observed that the number of tubers varied considerably as a result of N fertilization, and doubled when N level was increased to higher levels. Zamil *et al*. (2010) have found that the high dose of nitrogen (254 kg N ha^{-1}) resulted in significantly higher total tuber number in Potato tubers. Similarly, Freeman *et al*. (1998); Maier *et al*.(2002a) and Sanderson *et al*. (2003) noted that the application of P increased the number of tubers set per unit area. In addition, Zelalem *et al.* (2009) have found that application of 207 kg N/ha and 60 kg p /ha increased marketable tuber number by 95.6% and 43.5% respectively, as compared to the control. Mulubrhan (2004) also reported that the application of Nitrogen and Phosphorus increased the tubers number of potato per unit area.

2.7.2. Stem number per hill

The potato plant commonly consists of various stems, each stem forming roots, stolen and tuber behaving like an independent plant. Tubers show a wide range of variation and possess a variable number of growing points (buds) arranged in groups (eyes) over their surface (Otroshy, 2006). According to Margaret *et al*., (2007), the plant has two kinds of stems, the above ground stem that bears the leaves and flowers and the underground one whose terminal portion swells to form the tubers as it accumulates starch and sugars from photosynthesis in leaves. The number of eyes per tuber was reported to be dependent on the size of tubers. Varietals difference was also reported to influence eye number per tuber. Many investigators reported the absence of close relationship between mineral nutrition and the number of stems per plant. Lynch and Tai (1989) and van den Berg *et al.* (1991) from their studies on yield development of potato as influenced by N fertilizer, observed that the yield difference due to N treatment was not attributed to its effect on stem density as the number of stems was not significantly influenced by N nutrition. Similarly, Lugt *et al*. (1964) observed non-significant difference in plant establishment as a result of increased application of N, P and K fertilizers.

2.7.3. Tuber number per hill

The number of tubers set per potato plant (hill) largely governs the total tuber yield as well as the size categories of potato tubers showed that the number of tubers set by plants was determined by stem density, spatial arrangement, variety, season and crop management. 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. (Powon *et al*., 2006) reported that tuber number increased with increasing application of phosphorus and farmyard manure. Sharma and Arora (1987) 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.

2.8. Tuber Quality Parameters

2.8.1. Dry matter content

Dry matter content in potato tubers depends on the environmental condition and their changes. However, the highest possible amount of dry matter is limited by genetic characteristics of the potato variety (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). Singh *et al*. (1995) found significant increase in dry matter content in potato tuber with sulphur application. The maximum dry matter content of tubers (25.30%) was recorded at the integrated use of 5 t ha^{1} farm yard manure with mineral NP each at 130 kg ha^{-1} (Pervez *et al*., 2000 as cited in Biruk ., 2015). Desta (2018) report that sulphur fertilization increased yield of potato tubers and improved tuber quality increased (content of protein, starch, carotene, vitamin C, macro and microelements).

2.8.2. Specific gravity and starch content

Specific gravity is the measure of choice for estimating dry matter and starch content and ultimately for determining the processing quality of potato varieties (Tesfaye *et al*., 2013). Consequently, potato varieties with a dry matter content of 20% or higher, a starch content of 13% and above and/or a specific gravity of 1.08 or higher is the most preferred for processing products (Kirkman, 2007). Like any other quality attribute, genotype has a decisive effect in determining the specific gravity of potato varieties (Rivero *et al*., 2009). Specific gravity is a value as measure of quality in potato tuber which is related to the dry matter contents in the tubers. According to Lujan and Smith (1964), specific gravity has been found to be an accurate index of meal content in potatoes. It is useful in predicting suitability of potatoes for cooking, canning or dehydrating in addition to its use to predict the yield of potato chips. Kabira and Berga (2003) noted 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. Specific gravity is positively correlated with starch content, texture, pulp pH, and soluble solids, and negatively correlated with reducing sugars (Feltran *et al.,* 2004, as cited in Nebiya, 2016). High, uniform specific gravity in potato tubers is important to the grower and the processor. Kleinkopf *et al*. (1981) showed that the specific gravity of tubers decreased with increasing rates of nitrogen. This appears to be a reflection of the delay in maturity due to high nitrogen treatment. Similarly, Zelalem *et al*. (2009);Firew (2014) indicated that nitrogen fertilization significantly reduced both tuber specific gravity and dry matter content which may be associated with the influence of nitrogen on gibberellins biosynthesis and other phyto hormonal activities which have direct influence on plant growth and dry matter accumulation. However, Robert and Cheng (1988) reported that non-significant difference in specific gravity of tubers due to nitrogen treatment. Conflicting results have also been reported regarding the effect of phosphorus on the specific gravity of potato tubers. For instance, Firew (2014) reported that phosphorous can increase the size and percentage of dry matter indicated by specific gravity of the tubers. However, Desta (2018) indicated that non-significant effects on specific gravity of tuber due to fertilizer application. Significant influence of environment and genotypes on specific gravity was similarly reported (Elfnesh *et al*., 2011; Tesfaye *et al*., 2013).

3. MATERIALS AND METHODS

3.1. Description of the Study Site

The study was conducted on a farmer's field in Seka Chekorsa district in Jimma Zone the Oromia Regional national state of Ethiopia. Seka Chekorsa is bordered on the south by the Gojeb River which separates it from the Southern Nations, Nationalities and Peoples Region, on the west by Gera, on the northwest by Gomma, on the north by Mana, on the northeast by Kersa, and on the east by Dedo. (Figure 1)

The altitude of this district ranges from 1580 to 2560 meters above sea level. Research site is 7.670'N latitude and 36.830'E longitude having an altitude of 1780 meters above sea level (from GPS reading, 2019). 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, re1spectively. 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 data)

Based on figures published by the Central Statistical Agency in 2005, this district has an estimated total population of 336,277, of whom 168,863 were males and 167,414 were females; 14,574 or 4.33% of its population are urban dwellers, which is less than the Zone average of 12.3%. With an estimated area of 1,607.66 square kilometers, Seka Chekorsa has an estimated population density of 209.2 people per square kilometer, which is greater than the Zone average of 150.6 (CSA, 2015).

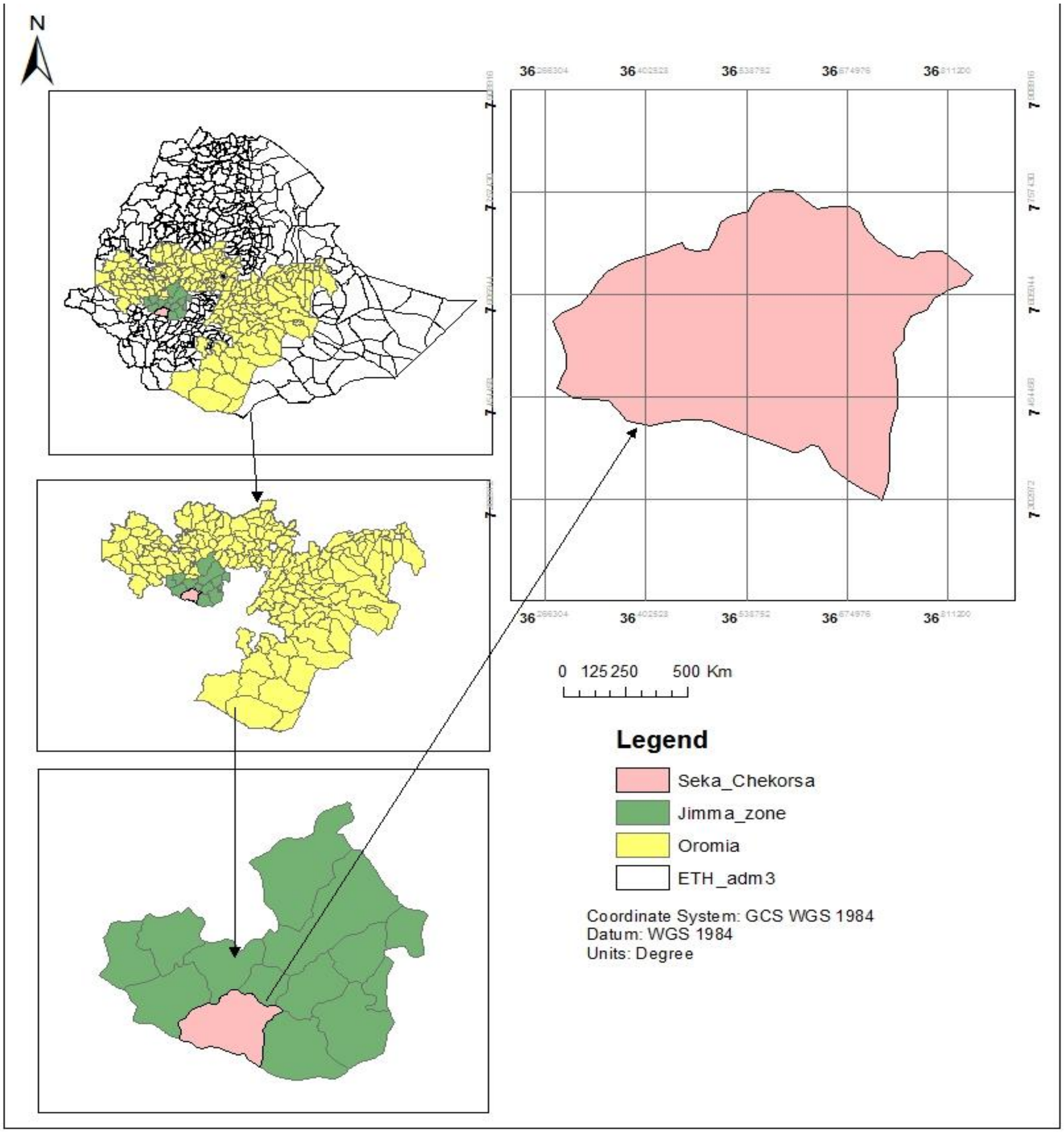

Figure 1: Map of the Study Area

3.2. Experimental Materials

Potato cultivar "Jalane" which was obtained from Jaldu farmer’s cooperative union via Holetta Agricultural Research center was used for the study in 2006. Jalane 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 experiment was laid out in randomized complete block design (RCBD) under factorial arrangement with three replications (Table 1). Four levels of cattle manure (0, 10t/ha, 15t/ha, 20t/ha,) and four level of inorganic fertilizers (NPSB= 19: 37.7: 6.95:0.1) 0, 61kg/ha, 122 kg/ha 183kg/ha). The inorganic fertilizer rates have been set based on P_2O_5 and N_2 recommended rates. A total of sixteen treatment combinations were evaluated.

Table 1: Treatment combinations

Treatments	Description
T1	Control
T2	61 kg ha^{-1} blended NPSB fertilizer
T3	122 kg ha^{-1} blended NPSB fertilizer
T4	183 kg ha^{-1} blended NPSB fertilizer
T5	10 t ha^{-1} Cattle Manure
T6	61 kg ha^{-1} blended NPSB fertilizer + 10 t ha^{-1} Cattle Manure
T7	122 kg ha^{-1} blended NPSB fertilizer + 10 t ha^{-1} Cattle Manure
T8	183 kg ha^{-1} blended NPSB fertilizer + 10 t ha^{-1} Cattle Manure
T9	15 t ha^{-1} Cattle Manure
T10	61 kg ha^{-1} blended NPSB fertilizer + 15 t ha^{-1} Cattle Manure
T11	122 kg ha^{-1} blended NPSB fertilizer + 15 t ha^{-1} Cattle Manure
T12	183 kg ha^{-1} blended NPSB fertilizer + 15 t ha^{-1} Cattle Manure
T13	20 t ha^{-1} Cattle Manure
T14	61 kg ha^{-1} blended NPSB fertilizer + 20 t ha^{-1} Cattle Manure
T15	122 kg ha^{-1} blended NPSB fertilizer + 20 t ha^{-1} Cattle Manure
T16	183 kg ha^{-1} blended NPSB fertilizer + 20 t ha^{-1} Cattle Manure

3.4. Experimental Procedure and Crop Management

The experimental field was ploughed using oxen and plots were leveled manually. Sowing was done on November, 22, 2019 at Seka district Buyoo Kechama 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. NPSB 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, Soil samples were collected from 0-20 cm depth by using an auger from 15 spots of the experimental field in a zig-zag pattern before planting. The samples were mixed thoroughly to produce 1.0 kg of a representative composite sample. The composite sample was put in polythene bag and submitted to the soil laboratories for the analysis.

The soil analysis included determination of total nitrogen, available phosphorus, textural analysis (sand, silt and clay), soil pH, Cation exchange 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

No	Parameter	Soil		
		Values	Rating	Reference
1	PH	6.031	Slightly acid	Hazelton and Murphy(2007)
2	OC%	2.75	Medium	Hazelton and Murphy(2007)
3	TN%	0.1098	Medium	Bruce and Rayment (1982)
4	av.P(ppm)	28.52	Very high	Cottenie (1980)
5	CEC(cmol)	19.376	Medium	Landon,(1991)
6	%OM	2.18517	Low	EthioSIS, (2014)
7	EC	96.20	None saline	
8	Soil Texture	-		
	Sand	30		
	Clay	30		
	Silt	40		
	Textural classes	Silt		

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..

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 Carbon and/or organic matter is high, implying that this organic fertilizer can be a good source of plant nutrients. Therefore, application of inorganic NPSB 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,B after harvest (Appendix Table 3) 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 buildup 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 .This explains why plots that received CM or NPSB+CM had higher N and P contents after harvesting.

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. Growth parameters

Plant height: Plant height was measured from the ground level to the top of the plant was measured in 70 days after planting and was expressed in centimeters.

Stem number: The average number of stems per plant was recorded at 10 weeks after emergence or five plants per unit area was counted at 50% flowering and it was also a parameter used to measure the growth rate.

3.6.2.. Phonological and Growth variables

Days to 50% flowering: The numbers of days from the date of planting to the date at which 50% of the plants produced flowers was recorded by counting.

Days to maturity: Number of days from emergence to maturity was recorded when 95% of the plants of different treatments were ready for harvest as indicated by the senescence of the haulms.

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 has been obtained by counting and adding up the number of marketable and unmarketable tubers (Zelalem *et al*., 2009).

Marketable Tuber Yield : 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: 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: 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).

Total dry biomass yield: Total dry biomass yield (leaves, stem, roots, stolen and tubers) was been recorded by selecting five hills randomly from each plot at physiological maturity before senescence. Samples were air dried for 72 hours and then oven dried at 70 °C for 48 hours.

Leaf area: Leaf area was measured on graph paper that has one centimetre square grid lines and the numbers of grid squares that are inside of the leaf on the paper were the area of the leaf. Based on this, five leaves were taken randomly from five plants from the bottom to the top part of plants recorded at flowering stage and converted into leaf area per plant and then to leaf area index.

Harvest index: - Harvest index is used in agriculture to quantify the yield of a crop species versus the total amount of biomass that has been produced by the plant. The commercial yield which is the economic yield can be the grain, the tuber or the fruit. Therefore, harvest index is the ratio of yield to total plant biomass (shoots plus roots).

Harvest Index (%) = Dry weight of tubers/Total dry weigh

3.6.4. Quality parameter

Quality: Tuber dry matter content and specific gravity were been also is determined as quality parameters from randomly selected tubers by using appropriate procedures

Dry matter content of tuber (%): was obtained by taken from five fresh tubers randomly selected in each plot and weighed. Tubers were sliced and dried in an oven at 70°C until constant weight. Dry weight were been recorded and dry matter percent were calculated according to William MA, Woodbury GW (1968).

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

Specific gravity of tubers: To determine the specific gravity, tubers of all size categories weighing about two kilograms were randomly taken from each plot, washed with water. The first sample weighed in air and then re-weighed suspended in water. Specific gravity was determined by using the following formula (Kleinkopf *et al*, 1987).

$$\text{Specific gravity} = \frac{\text{Weight of tubers in air}}{\text{Weight of tubers in air} - \text{Weight of tubers under water}} \times 100$$

Starch content determination: Starch content and DM of a sample of tubers per treatment were determined at harvest on the principle of a linear relationship between specific gravity with starch content. Specific gravity is a measurement of density and in tubers it is the weight of the tuber compared to the weight of the same volume of water. This was computed by

using the equation of Simmonds (1977) since specific gravity is an indirect way of obtaining dry matter and starch content of sweet potato. Starch content was, therefore, computed as:
Starch content = -2.86 + 47.1U. Where, U= (5G – 5) / G, G = Specific gravity.

3.7. Economic Analysis

The partial budget analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Birr. The concepts used in the partial budget analysis were the mean marketable tuber yield of each treatment, the gross benefit (GB) ha-1 and the field price of inputs (the costs of blended NPSB fertilizer, cattle manure ; labor and potato varieties). 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 100% with the highest net benefit was taken to be economically profitable.

When the new technology surpassed the conventional practice, it is said to be un-dominated (CIMMYT, 1988). It becomes unnecessary when the new technology costs less than the farmers' present technology. When the new technology yields lower benefit, then the technology is said to be dominated. MRR is calculated by dividing the marginal increase in net benefit with the marginal increase in variable cost and multiplying the result by 100.

Partial budget averaged over the 16 treatments is presented in Table 6. From the final experimental data, the gross yield for all treatments was collected. Then the recommended level of 10% was adjusted to obtain net yield. Net yield was multiplied by the market price to obtain gross field benefit. Costs and benefits were calculated for each treatment. All variable costs were calculated based on the current market price especially for fertilizers and cattle manure. Purchasing costs for fertilizers, NPSB with transportation and cattle manure were taken as Birr 1,650birr/Qt and 500birr/Qt respectively. Variable costs for decomposing, transporting and spreading cattle manure were taken. The selling price of potato at the local market at the harvest time was taken as Birr 5.50/kg. Since farmers are using family labour to perform most of the activities, other costs like ploughing, weeding, harvesting, etc., were not added in the variable costs. Variable costs were summed up and subtracted from gross benefits this was taken as the net benefit.

Gross average marketable tuber yield (kg ha-1) (AvY): AvY was an average yield of each treatment.

Adjusted yield (AjY): AjY was the average yield adjusted downward by a 10% to reflect the difference between experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988).

Adjustable marketable tuber yield = Average yield - (Average yield -0.1)

Gross field benefit (GFB): GFB was computed by multiplying field/farm gate price that farmers receive for the potato when they sale it as adjusted marketable tuber yield.

Gross field benefit (GFB) = Adjustable marketable tuber yield*field/farm gate price for potato.

Total variable cost (TVC): Total cost was the cost of fertilizers and application cost of fertilizers as differ dosage for the experiment. The costs of other inputs and production practices such as labor cost, land preparation, planting, Earthingup, weeding, top killing, and harvesting were considered the same or are insignificant among treatments.

Net Income (NI) or Net Benefit (NB): - was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR). NB = TR – TVC

Marginal rate return (MRR): was the measure of increasing in return by increasing input.

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in total variable cost.

Dominance Analysis (identification and elimination of inferior treatments): is also used to eliminate those treatments which involve higher cost but do not generate higher benefits.

Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefit) is dominated treatment (marked as "D"). Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%).

3.8. 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.

4. RESULTS AND DISCUSSION

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

This probably due to the released from organic manure (Cattle Manure).Nitrogen and phosphorus availability recorded after harvesting revealed that the highest Nitrogen (0.305%) was found 122kg NPSB+15t CM ha^{-1} and the lowest was 0.208% observed in the control. Similarly, the amount of available phosphorus ranged from 10.05ppm in the control to 18.5ppm in 122kg NPSB ha^{-1}+15t cattle manure ha^{-1}.

Soil analysis results after harvesting showed that the soil is Silty in texture and it was found to be slightly acid with a pH of 6.31 Sole application of CM led to a slight decrease in pH level after harvesting from 6.8 to 6.81 which was not different from the initial soil. The reduction was more pronounced with plots that received inorganic fertilizer particularly NPSB. It is therefore advisable to apply chemical fertilizer to the experimental site to reduce the pH level.

Organic carbon after harvesting, it ranged from 2.018 to 3.545% having highest value in 122kg NPSBha^{-1}+20t ha^{-1} CM ha^{-1}followed by 3.45% in 183kg ha^{-1} NPSB+15t ha^{-1} CM and by 3.33% in 122kg ha^{-1}NPS+15t ha^{-1}CM. After harvesting, the soil organic carbon was reduced to 0.732 % in the control. However, the organic carbon was in the range 2.018 to 3.54% in the NPSB+ 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 cattle manure in combination with N fertilizer helped in increased the original organic matter status of the soil. According to Landon (1991), the cation exchange capacity (CEC) of the soil before planting is medium 19.376 cmol $^{(+)}$ kg^{-1} of soil.After harvesting organic matter it ranged from 3.168 to 5.915 having highest value in 183kg NPSBha^{-1}+20tha^{-1}CM ha^{-1}.

4.2. Effect of Blended NPSB Fertilizer and Cattle Manure on Growth and Phonological Parameters of Potato

4.2.1. Plant height

The main effects of NPSB blended fertilizer and cattle manure rates and their interaction effects have showed highly significant (P<0.01) difference on plant height (Appendix Table 1 and Table 3).The highest plant height (72.33 cm) was recorded with treatment combination of 183kg NPSB ha^{-1}+ 20t CM ha^{-1} which increased 1. 64times compared with the control which is 44 cm (0 kgha^{-1} NPSB + 0tha^{-1}CM). Increasing the different rates of NPSB blended fertilizers from zero to 183kg ha^{-1} increased mean plant height (Table 4). The increased plant height in response to the application of the fertilizers may be attributed to the influence of the nutrients contained on enhancing plant growth owing to their contribution to enhanced cell division, stem elongation, promotes leaf expansion and vegetative growth of plants (Marschner, 1995; Tisdale *et al*., 1995). Similarly, increasing the different rates of CM from zero to 20 t ha-1also enhanced the plant height. The finding is in agreement with that of Ababiya (2018). Increasing the different rates of NPS blended fertilizers from zero to 150kg ha^{-1} increased mean plant height. In a like manner increasing the different rates of CM from zero to 30 t ha^{-1}also enhanced the plant height. 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 Gonzcalez *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, Bwembaya and Yerokun (2001) reported that plants applied with N and P fertilizer and CM were significantly taller than those in the control plots.

Table 3: Interaction effect of NPSB blended fertilizer and Cattle manure on growth and phonological variable of plant height, steam number, Days to 50 % flowering (DF), Leaf area and Maturity day.

Blended fertilizers NPSB (kg ha^{-1})	Cattle manure (t ha^{-1})	Steam number	Days to 50 % flowering	Plant height	Leaf area	Maturity day
0	0	2.97^{i}	47.00^{j}	44.00^{j}	13.11^{j}	87.33^{i}
	10	3.03^{i}	50.33^{ih}	45.33^{ij}	13.80^{j}	88.00^{hi}
	15	3.13^{hi}	51.33^{ih}	45.67^{ij}	14.23^{ij}	89.33^{ghi}
	20	3.20^{hi}	51.66^{ih}	48.80^{ih}	14.70^{ij}	91.00^{gef}
61	0	3.53^{hg}	52.33^{gh}	47.40^{ij}	15.37^{ihj}	89.67^{fhg}
	10	3.10^{i}	53.33^{gf}	54.56^{gf}	16.83^{ihg}	92.33^{de}
	15	3.87^{g}	53.67^{gf}	57.33^{ef}	17.80^{fhg}	94.00^{dc}
	20	4.73^{f}	54.00^{ef}	66.00^{cb}	19.28^{feg}	95.33^{bc}
122	0	4.87^{fe}	51.66^{ih}	52.67^{gh}	20.07^{fe}	92.67^{de}
	10	5.13^{e}	56.00^{d}	61.07^{ed}	21.99^{e}	91.00^{fe}
	15	5.20^{e}	58.00^{c}	62.67^{cd}	26.55^{d}	95.33^{bc}
	20	5.67^{d}	51.66^{ih}	67.67^{b}	34.95^{b}	96.00^{bc}
183	0	4.96^{fe}	53.33^{ed}	58.00^{ef}	20.45^{fe}	90.33^{feg}
	10	6.07^{c}	59.00^{c}	67.00^{b}	29.83^{c}	96.00^{bc}
	15	7.30^{b}	62.33^{b}	66.00^{cb}	35.20^{b}	97.33^{ba}
	20	7.87^{a}	65.33^{a}	72.33^{a}	38.05^{a}	99.33^{a}
LSD(5%)		0.397	2.28	3.94	2.83	1.71
CV (%)		5.06	1.63	4.25	7.90	1.37

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. Number of Main Stem per Hill

Highly significantly ($p<0.01$), difference was observed between blended fertilizers, cattle manure and their interaction effects for number of stems per hill (Appendix Table 1 and Table 3) . Thus, the highest stem number (7.9 hill^{-1}) was attained at the rate of 183 kg NPSB ha. The lowest number of main stems (2.97 hill^{-1}) was obtained from the control treatment [Figure 2(A)].This result was consistent with 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 NPSB blended fertilizer, highest main stem number of 7.9 was recorded with rate of 20 t CM ha^{-1}, [Figure 2(B)]. 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 20 t ha^{-1}. This work is similar with the result obtained by Jayramaiah , *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%.

CV (%)=5.06 & LSD (0.05)=0.40 CV(%)=5.09 & LSD (0.05)=0.40

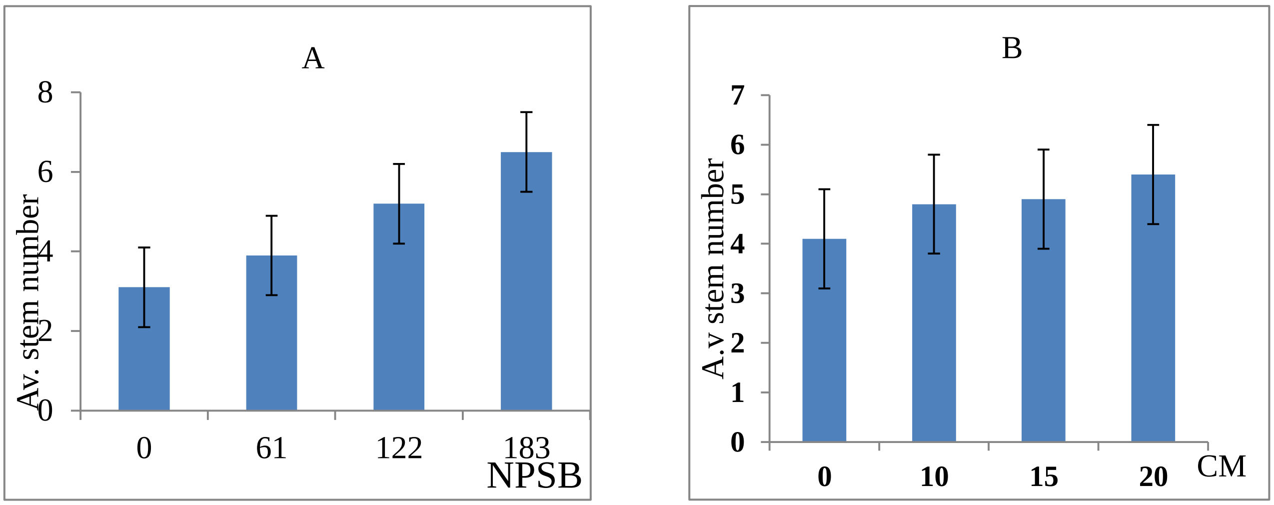

Figure 2: Main effects of NPSB blended fertilizer and CM on main stem number of potatoes (A= NPSB blended fertilizer and B= Cattle Manure (CM).

This result consistent with 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%. This might be due to the supply of adequate nutrients under blended NPSB fertilizer condition may have facilitated the production of main stem number and secondary branches which may contribute the production of higher tuber yield. In agreement with the present finding, Hassanpanah *et al.* (2009) ; Alam *et al*. (2007) have reported that the lowest stem number of potato was obtained from unfertilized control.

Similar with 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 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%.

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 NPSB blended fertilizers and cattle manure (CM) and their interaction effects (Appendix Table 1 and Table 3) The earliest days to 50% flowering (47.33 days) was recorded with a treatment combination of zero NPSB and zero CM. Thus, increasing the different rates of CM from zero to 20 t ha^{-1} extended the number of days to 50% flowering. Similarly, combined application of 183 kg NPSB blended fertilizer ha^{-1} +20 t CM ha^{-1} delayed days to 50% flowering (65.33) by 18 days compared to 0/0 NPSB/CM (Appendix Table 1 and Table 3).

The results is in agreement with Yourtchi *et al*. (2013) who reported 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 reserve 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).

This is due to the fact that increased level of nitrogen increased the leaf area which in turn increased the amount of solar radiation intercepted and consequently, increases vegetative growth phase which increases days to physiological maturity. Therefore, a crop with more nitrogen will mature later in the season than a crop with less nitrogen, because later growth is related to excessive haulm development whereas early tuber growth to less abundant haulm growth (Mulubrhan, 2004; Barbara, 2007; Israel *et al.*, 2012).

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.The main effect of NPSB and CM highly significant (P <0.01) and their interaction effects significant (P <0.05) for days to75% physiological maturity of potato plants (Appendix Table 1 and Table 4).

Early physiological maturity date was recorded from the control treatment. Treatment combinations of 0/0,0/10, 0/15 and 61/0 kg NPSB 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 phyto hormones and may stimulate the plant growth and absorption of nutrients.

Indicate that due to the increased level of nitrogen increased the leaf area which in turn increased the amount of solar radiation intercepted and consequently, increases vegetative growth phase which increases days to physiological maturity. Therefore, a crop with more nitrogen will mature later in the season than a crop with less nitrogen, because later growth is related to excessive haulm development whereas early tuber growth to less abundant haulm growth (Mulubrhan, 2004; Barbara, 2007; Israel *et al.,* 2012). Plots that received 183kg ha^{-1} NPSB blended fertilizer +20t ha^{-1} cattle manure delayed maturity, which was statistically in parity with those plots fertilized with 183kgha^{-1} NPSB blended fertilizer +15t ha^{-1} cattle manure (Appendix Table 1 and Table 3).

The result is study are in agreement with 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.

4.2.5. Leaf Area

The main effect of blended NPSB fertilizer and CM rates and their interaction showed highly significant ($P<0.01$) differences on the Leaf area per plant.The highest leaf area of (38.05cm^2) was recorded with treatment combination of 183kg NPSB ha^{-1} + 20t CM ha^{-1} and the lowest from treatment combination of zero NPSB and zero CM. (13.11cm^2).Increasing the different rates of` NPSB blended fertilizers from zero to 183kg $ha^{-1}$and CM increased plant Leaf area (Appendix Table 1 and Table 3).

Due to the fact that increased level of nitrogen increased the leaf area which in turn increased the amount of solar radiation intercepted and consequently, increases vegetative growth phase which increases days to physiological maturity. Therefore, a crop with more nitrogen will mature later in the season than a crop with less nitrogen, because later growth is related to excessive haulm development whereas early tuber growth to less abundant haulm growth (Mulubrhan, 2004; Barbara, 2007; Israel *et al.*, 2012).

In agreement with study appropriate fertilization was reported to increase the average fresh tuber size , plant height, leaf number and tuber; weight per plant responded positively application and Leaf area was increased (Kandil *et al*., 2011). So, the use of animal manure has been reported as an important factor for better vegetative growth and increased tuber yield (Najm *et al.*, 2005).

Recently, Suh *et al.* (2015), as cited in Ababiya,(2018) in demonstrated that the highest values of plant height, stem diameter and leaf size were detected with plants which were fertilized with cow dung at the rate of 20tha^{1}. And NPK at the rate of (20: 10: 10) compared with sole application of cow dung or NPK mineral fertilizer Inorganic fertilizers reduce the soil pH, organic manure such as cow dung increased the organic carbon, organic matter and exchangeable cations in the soil.

4.3. Effect of Blended NPSB Fertilizer and Cattle Manure on Yield components.

4.3.1 .Total tubers number per plant

The total tuber number per plant was increased with combined application of organic and inorganic fertilizers compared to sole application of NPSB 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 blended NPSB 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 (16.33) was recorded with183 kg NPSB ha^{-1} + 20t CM ha^{-1}followed by 183kg NPSB ha^{-1} +15t CM ha^{-1}and 122 kg NPSB ha^{-1} +15t CM ha^{-1}with total tuber number of 15.0 and 14.35 respectively (Appendix Table 2 and Table 4).

Increasing rates of both NPSB and CM from zero to the maximum increased marketable tuber number per hill by 43.4% over the control. The increase in total tuber number with an increase in applied NPSB blended fertilizer and CM was associated with a decreased in the number of small sized tubers (un- marketable tuber) due to an increase in the weight of individual tubers. The result of is in conformity with 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.* (2011) 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}. In addition, Zelalem *et al*. (2009) have found that application of 207 kg N/ha and 60 kg p /ha increased marketable tuber number by 95.6% and 43.5% respectively, as compared to the control.

4.3.2. Marketable tuber number

The analysis of variance showed that the main effect of blended NPSB fertilizer and CM Highly significant ($p<0.001$) affect marketable, while interaction of both factors are significant on marketable tuber number (Appendix Table 2 and Table 4).

Increasing the application of blended NPSB fertilizer from 0 to 183 kg ha^{-1} and increasing the different rates of CM from zero to 20 t ha^{-1} significantly increased marketable tuber number per hill from 4.08 to 15.50, The highest marketable tuber number (15.50 $hill^{-1}$) was recorded from the application of 183 kg NPSB $ha^{-1}$and CM from zero to 20 t ha^{-1} fertilizer while, the lowest marketable tuber number (4.25$hill^{-1}$) was recorded from control (Table 4 and Appendix 2).

The highest marketable tuber number per hill at 183 kg NPSB $ha^{-1}$and 20 t ha^{-1}CM might be due to the fact that marketable tuber number increases at higher nitrogen rate because nitrogen can activate the vegetative growth development and also was associated with decrease in the number of small size tubers due to increase in the weight of individual tubers. 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, Increase in the number of marketable tubers might be due to application of boron and sulphur in soil increase the uptake of N and P which improves the N: S and IAA: ABA and cytokinin: ABA ratio, which induces the formation and growth of stolon mainly due to increase in gibberellin content of plant (Mohammad *et al*., 2013).

4.3.3. Un-marketable tuber number

The analysis of variance revealed that there was significant (P>0.001) difference due to interaction effect of NPSB blended fertilizer and Cattle manure rates on unmarketable tuber numbers of potato. Similarly, from the main effects of cattle manure rates remained highly-significant difference (Appendix Table 2 and Table 4).This might be due to nitrogen accelerate the growth of above ground part of plants, which often leads reduced tuber size and weight of the tubers become unmarketable. This result is in agreement with Firew (2014) who reported that increasing level of nitrogen increased Un-marketable tuber number.

However, Nebiya (2016) reported that the highest un marketable tuber numbers per hill were counted for control treatment (without phosphorus) (1.73) and the lowest un marketable tuber numbers per hill were harvested in response to the application of 138 Kg P_2O_5 ha^{-1} (0.907).

4.3.4. Marketable tuber yield t ha^{-1}

The main effect of blended NPSB fertilizer and CM Highly significant (p<0.001) effect marketable tuber, while interaction of both factors are significant at (p<0.05) on total tuber yield (table 4 and Appendix 2).Combined application of 183NPSB ha^{-1} and 20 ha^{-1} cattle manure the highest marketable tuber yield (39.58 t ha^{-1}) while the lowest marketable tuber yield (5.67t ha^{-1}) was recorded for the control plot (Table 4 and Appendix 2). 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 (Ababiya, 2018) .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} were obtained greater yield from 'gudane' in the same district this might be due to the varietal effect.

This might be due to the positive interaction and complementary effect between nitrogen, phosphorus, sulphur and boron in affecting and increasing the marketable tuber yield of potato. This increment of marketable yield in the response to increasing rate of blended NPSB fertilizer indicates that the importance of blended NPSB for growth and productivity of potato. This might be due to boron and sulphur contents of blended fertilizer fulfills the requirement of sulphur and boron in subsurface zone of soil which improves uptake of other macro and micronutrients resulting in enlarged potato tubers (Sud *et al.*, 1996).

4.3.5. Total Tuber yield

The main effect of blended NPSB fertilizer and CM and the interaction of both factors are highly significant ($p<0.001$) on total tuber yield, on total tuber yield (Appendix Table 2 and Table 4).The application of blended NPSB fertilizer and CM increased total tuber yield (ton ha^{-1}) in potato as compared to growing of without fertilizer application. Increasing blended NPSB fertilizer rates from 0 to 183 kg ha^{-1} increases total tuber yield from 8.95 to 40.08 (Table, 4).

Total tuber yield was significantly influenced by the cattle manure + NP fertilizers Tesfaye, (2013). Maximum tuber yield (36.8 t ha^{-1}) was obtained by the utilization of 150 kg N + 20 t cattle manure ha^{-1} Najm, (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) t FYM increased tuber yield by 35-82%, depending on inorganic fertilizer combination. Besides, Balemi (2012), 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.

The highest total tuber (38.47 t ha^{-1}) was harvested from the interaction of blended fertilizer rate of 183NPSB ha^{-1} and 20 ha^{-1} cattle manure and it was statistically at par 183 kg NPSB ha^{-1} and 15 ha^{-1} CM and statistically same with at the rate 122NPSB ha^{-1} and 20 ha^{-1} cattle manure (Table, 4).

According to 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 t ha^{-1}CM. (Suh *et al*. 2015., as citied in Ababiya A., 2018) 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.

4.3.6. Un -marketable tuber yield

The main effect of blended NPSB fertilizer and CM and the interaction of both factors are highly significant ($p<0.001$) on Un marketable tuber yield, (Appendix Table 2).The application of blended NPSB fertilizer and CM decrease Un marketable tuber yield (ton ha^{-1}) in potato as compared to growing of without fertilizer application. Increasing blended NPSB fertilizer rates from 0 to 183 kg ha^{-1} decrease Un -marketable tuber yield from 3.31 to 0.50 (Appendix Table 2 and Table 4). Unmarketable tuber yield was significantly affected by the main factor and interaction effects of NPSB blended fertilizer and cattle manure (Appendix 2). This finding suggests that unmarketable tubers may be controlled more importantly through manipulating other factors such as disease incidence, pest incidence, harvesting practice, and the like rather than mineral nutrition (Berga *et al*., 1994).

Table 4: Interaction effect of NPSB blended fertilizer and CM rates on marketable tuber yield (MTY), total tuber yields (TTY), marketable tuber number (MTN), total tuber number (TTN) of potato, Starch Content (STC) and Dry Matter Content (DMC).

NPSB (kg ha^{-1})	CM (t ha^{-1})	MTY	Un MTY	TTY	MTN	TTN	STC	DMC
0	0	5.67^{i}	3.31^{a}	8.95^{i}	4.25^{g}	7.08^{h}	8.43^{j}	18.37^{f}
	10	8.40^{i}	1.57^{b}	9.97^{ih}	5.42^{g}	7.42h^{g}	8.96^{ij}	20.61^{fe}
	15	11.50^{h}	1.00^{c}	12.50^{h}	6.83^{f}	5.58^{hg}	9.96^{ih}	20.47^{fe}
	20	15.17^{g}	0.70^{dc}	15.87^{g}	7.75^{ef}	8.50^{g}	10.29^{h}	20.84^{dfe}
61	0	16.27^{g}	1.90^{b}	17.83^{g}	7.33^{f}	8.08^{hg}	11.61^{g}	21.64^{de}
	10	23.57^{f}	0.73^{dc}	24.30^{f}	9.33^{d}	9.92^{f}	11.88^{gf}	22.48^{dce}
	15	27.13^{ed}	0.63^{dc}	27.77^{ed}	11.00^{c}	11.83^{ed}	12.41^{gf}	23.45^{dce}
	20	28.67^{d}	0.52^{dc}	29.18^{d}	11.75^{c}	12.08^{ed}	12.94^{ef}	23.88^{dc}
122	0	24.93^{ef}	0.68^{dc}	25.6^{ef}	8.83^{ed}	10.00^{f}	11.94^{gf}	20.45^{fe}
	10	32.17^{c}	0.75^{dc}	32.25^{c}	11.33^{c}	12.02^{ed}	13.60^{ed}	21.12^{dfe}
	15	35.87^{b}	0.32^{d}	36.18^{b}	14.00^{b}	14.35^{cb}	14.13^{cd}	26.75^{ba}
	20	37.43^{ab}	0.32^{d}	37.75^{ba}	13.25^{b}	13.67^{c}	14.80^{cb}	28.51^{a}
183	0	26.67^{ed}	0.83^{dc}	27.33^{ed}	9.50^{d}	10.83^{ef}	12.94^{ef}	22.27^{dce}
	10	35.92^{b}	0.32^{d}	36.23^{b}	11.50^{c}	12.27^{d}	15.27^{cb}	20.97^{dfe}
	15	37.92^{ba}	0.32^{d}	38.23^{ba}	14.17^{ba}	15.00^{b}	15.87^{b}	25.23^{bc}
	20	39.58^{a}	0.50^{dc}	40.08^{a}	15.50^{a}	16.33^{a}	17.32^{a}	28.51^{a}
LSD(0.05)		2.77	0.48	2.7544	1.39	1.32	0.373	2.59
CV (%)		5.84	32.23	5.59	7.07	6.12	4.66	7.09

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

4.4. Effect of Blended NPSB Fertilizer and Cattle Manure on Quality Variables

4.4.1. Effect of Blended NPSB Fertilizer and Cattle Manure on Dry Matter Content (%)

The main effect of blended NPSB fertilizer and CM and their interaction was highly significant at ($p<0.01$) (Appendix Table 3 and Table 5). Dry matter content of potato. 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 (Harris, 1992).

The highest dry matter content (28.5%) was obtained from the combination of blended NPSB fertilizer rate of 183kg ha^{-1} + 20 t ha^{-1} CM and the lowest dry matter content (18.37 %) were recorded from zero application, in addition Regarding of the jalane varieties' combined application of blended NPSB fertilizer and CM can significant evaluated were suitable for processing NPSB (122kg ha^{-1} + 10, 15 and20 t ha^{-1}) cattle manure and NPSB (183kg ha^{-1} + 10, 15 and20 t ha^{-1})cattle manure (Table 4 and Appendix 3). Dry matter content of 20% or higher, a starch content of 13% and above and/or a specific gravity of 1.08 or higher is the most preferred for processing products (Kirkman, 2007).

This might be due to the qualities of vegetables depend upon genetic, climatic, biotic, edaphic, chemical and other factors as well as combinations of these factors (Hamouz *et al*., 2005). 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*., 1995).

4.4.2. Effect of Blended NPSB Fertilizer and CM on Starch Content (%)

The main effect of blended NPSB fertilizer and CM at ($p<0.001$) and their interaction significant at ($p<0.05$) (table 4 and Appendix 3). total starch content (17.32g/100 g) from combined application of 183 kg NPSB blended fertilizer ha^{-1} +20 t CM ha-1 , and of 0/0 NPSB/CM (Appendix 3 Table 5). Potato tubers quality is often referred to as external and internal quality. The internal quality is determined by many traits of which the most important are dry matter content, type and amount of starch, sugar, and protein content (van den, 2007).

4.4.3. Effect of Blended NPSB Fertilizer and cattle manure on Harvest index.

The main effects of blended NPSB and CM highly significant ($P < 0.01$) on fresh harvest index. However, there was no any interaction between application of blended NPSB fertilizer and CM (Appendix 3).With the increasing combination of the blended NPSB fertilizer from 0 to 183kg ha^{-1}, and CM fertilizer from 0 to 20 kg ha^{-1}, harvest index decreased from 0.78 to 0.59 (Appendix Table 3 and Table 5).

Therefore, the yield advantage obtained through the use of increased N and P fertilizers might not be attributed to its effect on increment of harvest index; rather a parallel increase in both harvestable and non-harvestable parts was apparent. In general, although harvest index is commonly used as a key plant parameter it may not necessarily correlate with high yield (Gawronska *et al*., 1984).

Muluberhan (2004) reported that harvest index of potato was negatively affected in response to increased inorganic NP fertilizer application. On the other hand, applying manure increased the uptake of N, P, K, Ca, and Mg by plants, indicating that organic fertilizers are good enhancers of soil fertility (Adeniyan, 2003).

4.4.4. Effect of Blended NPSB Fertilizer and CM on Total dry biomass

The main effects of blended NPSB and cattle manure were significant ($P < 0.01$) on total dry biomass of potato. However, there was no any interaction between application of blended NPSB fertilizer and CM (Appendix Table 2 and Table 4).

The application of combination of blended NPSB fertilizer at the rate of 183kg ha^{-1} + 20 t ha^{-1} CM gave the highest dry total biomass which was significantly higher than the control. The increase in total dry biomass was 38 and 33% with the application of 183kg NPSB ha^{-1} in combination with 20kg CM ha^{-1} and 122kg NPSB ha^{-1} in combination with 15kg CM ha^{-1} respectively. The results in this study support with of Millard and Marshall (1986) who reported a significant increment in canopy dry matter yield of potato was reported as N application increased.

Similarly, total dry biomass of potato significantly increased with the increase in the manure rates from 0 to 5 and 10 t CM ha^{-1}.The additional increases in total dry biomass were 9.8 and

19.7% with the application of 5 t CM ha^{-1} and 10 t CM ha^{-1} over the control treatment respectively. This in consistent with observations of Gamal and Ragab (2003) who observed positive effects of organic fertilizer on vegetative growth parameters that could be attributed to their effects on supplying plants with the requirements of various nutrients for relatively long time, as well as their effect on lowering soil pH which could aid in facilitating the availability of soil nutrients and improving physical characters in favor of root development for higher water and nutrient uptake and dry matter accumulation.

4.4.5. Effect of Blended NPSB Fertilizer and Cattle Manure on Specific Gravity

Specific gravity is a value as measure of quality in potato tuber which is related to the dry matter contents in the tubers. According to Lujan and Smith (1964), specific gravity has been found to be an accurate index of meal ness in potatoes. It is useful in predicting suitability of potatoes for cooking, canning or dehydrating in addition to its use to predict the yield of potato chips. Kabira and Berga (2003) noted 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. Specific gravity is positively correlated with starch content, texture, pulp pH, and soluble solids, and negatively correlated with reducing sugars (Feltran *et al*., 2004, as cited in Nebiya, 2016).

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) High, uniform specific gravity in potato tubers is important to the grower and the processor. With starch content, texture, pulp pH, and soluble solids, and negatively correlated with reducing sugars (Feltran *et al*., 2004, as cited in Nebiya, 2016).

The main effect of blended NPSB fertilizer and cattle manure highly significant at ($p<0.001$) and their interaction non-significant at ($p<0.05$) (table 5and Appendix 3). The highest tuber specific gravity (1.098 g cm^{-3}) was obtained with the combination of blended NPSB fertilizer rate of 183kg ha^{-1} + 20 t ha^{-1} CM followed by a treatment combination of 183 kg NPSB ha^{-1} + 15 t CM ha^{-1} and the lowest tuber specific gravity (1.053 g cm^{-3}) was recorded from the control treatment which was also statistically in parity with the specific gravity (1.056gcm^{-3}) of potato tuber obtained with zero NPSB and 10 t CM ha^{-1}.

This explained that significant increase in specific gravity with the increase in the combined application of mineral NPSB and CM might be attributed to release of macro and micronutrients from CM. 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.

Table 5: Interaction effect of NPSB blended fertilizer and cattle manure rates on, Specific Gravity, Harvest Index and Total dry biomass of potato.

Treatment	HI	SG(gcm^{-3})	TDBM
NPSB (kg ha^{-1})			
0	0.76^{a}	1.058^{d}	302.00^{d}
61	0.72^{b}	1.073^{c}	321.50^{c}
122	0.69^{c}	1.079^{b}	378.75^{b}
183	0.64^{d}	1.089^{a}	419.17^{a}
LSD (5%)	0.016	0.004	15.30
CM (t ha^{-1})			
0	0.72^{a}	1.067^{c}	318.17^{c}
10	0.72^{a}	1.073^{b}	354.75^{b}
15	0.70^{b}	1.077^{b}	370.08^{a}
20	0.67^{c}	1.082^{a}	378.42^{a}
LSD (5%)	0.016	0.004	15.30
CV(%)	2.68	0.44	5.16

mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to fisher's protected test at 5% level of significance cv (%) =coefficient of variation, lsd (5%) = least significant difference at 5% probability.

4.5. The Effect of Blended NPSB Fertilizer and Cattle Manure on Economic Analysis

The highest net benefit was obtained from the combination of NPSB blended fertilizer rate of 183kg NPSB ha^{-1} + 20 t cattle manure ha^{-1} 40.08 t ha^{-1}. This combination generated Birr 193365.5ha^{-1} more compared to the control treatment. Based on the above information, the final step was to calculate Marginal Rate of Return (MRR) % for identifying the best one that is economically attractive (Table 6).

The MRR% (1726%) at the highest net benefit which was obtained from the treatment that received 183kg NPSB ha^{-1} + 20 t CM ha^{-1} 40.08 t ha^{-1} was acceptable. The computed MRR% gives an indication of what a producer can expect to receive by switching technologies. Hence, a 1726% MRR in switching from technology 1 to technology 2 (from farmers practice to improved new one) implies that for each Birr invested in the new technology, the producer can expect to recover the Birr one invested plus an additional return . Based on cost-benefit analysis, it is advisable to apply 183kg ha^{-1} NPSB+ 20 t ha^{-1} CM 40.08 t ha^{-1} to get optimum yield for the specific area of the experiment site. High yield and low cost evidently leads to high income.

The highest net benefit from the marketable tuber yield due to the combined application of mineral and organic fertilizers at the maximum rates might be due to the profitability and feasibility of using organic manure along with mineral fertilizers. Nutrients present in organic matter are not fully available to the crops in the season of its application (Ramamurthy and Shivashankar, 1996), they are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma and Mittra, 1991), supporting better root development, leading to higher crop yields. Residual effect of organic matter added to the soil by the manure refers to the carry-over benefit of the application on the succeeding crop.

The application of organic manure with mineral nutrients 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 (SOM) (Verma *et al*., 2005), improving water holding capacity and other physical propertie-s of soil like bulk density, penetration resistance and soil aggregation (Wells *et al*., 2000). There is also some 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 a variety of plants (Montemurro *et al*., 2006).

Table 6: Partial budget Averaged and Marginal Analysis from Treatments NPSB blended fertilizer and cattle manure (CM) Fertilizer trial (ha^{-1} basis).

NPSB (Birr ha^{-1})	CM (t ha^{-1})	AGY (t ha^{-1})	Adj.Y (t ha^{-1})	GFR (ETB ha^{-1})	TC (ETBha^{-1})	NR (ET ha^{-1})	MRR%	Dominance
0	10	9.97	8.97	49335	500	48835	901	
61	0	17.83	16.05	88275	1006.5	87268.5	1080	
0	15	12.50	11.25	61875	1500	60375	1154	
61	10	24.30	21.87	120285	1506.5	118778.5	6302	D
0	20	15.87	14.28	78540	2000	76540	3233	D
122	0	25.6	23.04	126720	2013	124707	1683	
61	15	27.77	24.99	137445	2506.5	134938.5	1616	
122	10	32.25	29.03	159665	2513	157152	6489	D
61	20	29.18	26.26	144430	3006.5	141423.5	1297	
183	0	27.33	24.60	135300	3019.5	132280.5	5027	D
122	15	36.18	32.56	179080	3513	175567	1842	D
183	10	36.23	32.61	179355	3519.5	175835.5	8711	D
122	20	37.75	33.98	186890	4013	182877	1462	
183	15	38.23	34.41	189255	4519.5	184735.5	890	
183	20	40.08	36.07	198385	5019.5	193365.5	1726	

Where, Adj.Y= Adjusted yield; Av.Y = Average yield; CM = Cattle manure; D = Dominated; ETB = Ethiopian Birr; GFB = Gross field benefit; NPSB = Fertilizer; NB = Net benefi; TC = Total cost

4.6. Correlation Analysis

The correlation analysis was performed to determine simple correlation coefficient between growth, yield and yield parameters as affected by NPSB and cattle manure application. The present finding has indicated that plant height was positively correlated with main stem number and days to 43 flowering (r = 0.91). Marketable tuber yield was significantly and positively correlated with number tuber (r = 0.94**), plant height(r = 0.93**). Many growth components and plant height contributed to marketable tuber yield increment because marketable tuber yield was found to be strongly and positively associated significantly with total tuber number (r = 0.90**)and days of flowering was positively correlated with Marketable tuber number (r = 0.88**), days to maturity (r = 0.88**), marketable tuber number (r = 0.89**) and total tuber yield (r = 0.89**). The present finding indicated that yield components and days to maturity contributed to total tuber yield increment because total tuber yield was highly and positively correlated with days to maturity (r = 0 .87**) ,and all growth parameter It is inversely (negatively correlated) related with unmarketable .(Table7).

Table 7.Correlation analysis on growth, yield, and yield components of potato

PAR	NPSB	CM	SN	DF	PH	MD	MTY	NMTY	TTY	MTN	TTN
NPSB	1										
CM	0	1									
SN			1								
DF			0.91**	1							
PH			0.85**	0.85**	1						
MD			0.80**	0.87**	0.88**	1					
MTY			0.86**	0.88**	0.93**	0.87**	1				
NMTY			-0.54**	-0.64**	-0.67**	-0.67**	-0.75**	1			
TTY			0.87**	0.89**	0.94**	0.87**	0.99**	-0.72**	1		
MTN			0.83**	0.89**	0.91**	0.88**	0.94**	-0.73**	0.94**	1	
TTN			0.87**	0.91**	0.90**	0.86**	0.93**	-0.64**	0.93**	0.98**	1

*SN=number of main stem, PH=plant height, MD=days to maturity, MTN= marketable number of tuber, MTY=marketable tuber yield, NMTY =unmarketable tuber, TTY=total tuber yield, MTY=marketable yield, *, **and*** indicate significant difference at probability level of 5 %, 1% and 0.1% respectively*

5. SUMMARY AND RECOMMENDATIONS

Yield and productivity of potato is low due to several factors; poor crop management practice and low soil fertility are observed in most farmers' field in this study. Sustaining soil fertility for higher yields and better quality of crops could be achieved through optimum levels of fertilizer application and fertilizer management. Thus, information on fertility status of soils and crop response to different soil fertility management is very important to come up with profitable and sustainable crop production. Fertilizer is suggested as an important input to obtain high yields, qualities and to overcome the low productivity of potato in Ethiopia. However, there is insufficient site specific based experimental information on how much fertilizer to apply on different soil type with patch of high and low fertility of soil. Therefore, this experiment was carried out with the objective of studying the effect of NPSB blended fertilizer and cattle manure application on yield and yield related traits of potato (*Solanum tuberosum* L.) at Jimma South Western Ethiopia. The treatment consists of the combinations of four levels of NPSB (0, 61, 122 and 183kg/ha) and four levels of cattle manure (0, 10t/ha, 15 and 20t/ha^{1}). The interaction effects of NPSB and cattle manure cattle manure as well as their main effect had considerable influence on growth, yield component and quality parameters of Jalane potato variety.

The main effects of NPSB and cattle manure as well as their interactions were considerable influence on phenology and growth parameters. Increasing the rates of NPSB increased the number of days to 50% flowering, plant height, steam number and days to maturity across all the increased rates of CM. Thus, due to the interaction effect of NPSB 183kg ha^{-1} and 20 t ha^{-1} CM, flowering and maturity were delayed by 21 days and 12 respectively.

Yield and yield components of potato were affected with application of NPSB blended fertilizer and cattle manure at different levels. Combined application of NPSB and CM at the rate NPSB 183kg ha^{-1} and 20 t ha^{-1} cattle manure gave the highest marketable tuber yield (39.58 t ha^{-1}) and the lowest marketable tuber yield (5.67 t ha^{-1}) was recorded from the control. Increasing the rate of NPSB and cattle manure application was strongly increased total tuber yield from 8.95 to 40.08 t ha^{-1}.

Almost all parameters yield had the highest values when the highest application rate of NPSB blended fertilizers, cattle manure and their interaction., It there is a positive and significant association among response variables such as marketable tuber yield, total tuber yield, marketable and total tuber number, dry matter content, total dry biomass, harvest index, leaf area and specific gravity.

In conclusion, potato responded well to the application of NPSB and CM in terms of growth and yield in the study area. Therefore, smallholder farmers in the area could be advised to use combined application of 183 kg NPSB ha^{-1} and 20 t CM ha^{-1} to optimize potato tuber yields. The highest net benefit was obtained from the combination of NPSB blended fertilizer rate of 183kg ha^{-1} + 20 t ha^{-1} CM 40.08 t ha^{-1}. This combination generated Birr 211,400.5ha^{-1} more compared to the control treatment. Based on the above information, the final step was to calculate Marginal Rate of Return (MRR) % for identifying the best one is economically attractive. In economic point of view, combined application of 122 kg NPSB ha-^{1} fertilizers and 10 t ha^{-1} cattle manure is found economically feasible alternative for poor grower. in addition combined application of blended NPSB fertilizer and CM can significant evaluated were suitable for processing NPSB (122kg ha^{-1} + 10, 15 and20 t ha^{-1} cattle manure and NPSB (183kg ha^{-1} + 10, 15 and20 t ha^{-1}) cattle manure.

However, this study was conducted using one variety at one location and in one season. This implies that it is not easy to give a conclusive recommendation. Therefore, similar studies will have to be done under various agro-climatic and soil condition to make a conclusive recommendation. Further, combined experiments with other fertilizers and manure rate in different location, soil types and variety. May reflect the sustainability of this practice and investigation of economic threshold points.

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8. APPENDICES

Appendix Tables 1 Analysis variance showing mean squares for Germination number at 25th day ;50% of flowering days, 75% of maturity days, plant height at 70 days after emergence , main stem numbers after 10 weeks of emergence, leaf area and maturity day from emergence to

Sourceof variation	DF	PH	SN	DF	LA	MD
REP	2	0.65^{ns}	0.07^{ns}	1.52^{ns}	1.00^{ns}	3.06ns
NPSB	3	865.42**	28.37**	235.03**	722.30**	98.74**
CM	3	349.73**	3.94**	80.91**	196.42**	75.74**
NPSB*CM	9	20.44**	0.97**	7.86**	41.56**	3.69*
ERROR	30	0.65**	0.06	0.81	3.02	1.618
CV (%)		4.25	5.06	1.63	7.90	1.37

*Where; DF = degrees of freedom, DF= days to 50% flowering, DM= days to 95% maturity, PH=plant height, SN=main stem number, LA= leaf area and NS, * and ** implies non-significant, significant and highly significance differences at 5% level of probability, respectively.*

Appendix Tables 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 NPSB and cattle manure

Source of variation	DF	Mean squares Tuber yield(t/h)					
		MTY	UnMTY	TTY	MTN	UnMTN	TTN
REP	2	11.40*	0.052^{ns}	11.55*	3.47**	0.012^{ns}	3.16**
NPSB	3	1512.68**	3.48**	1361.30**	104.11**	2.82**	82.34**
CM	3	319.41**	3.52**	264.30**	52.70**	1.97**	33.88**
NPSB*CM	9	5.03*	0.72**	8.16**	1.197*	0.48**	2.61**
ERROR	30	2.21	0.084	2.15	0.51	0.15	0.46
CV (%)		5.84	32.23	5.59	7.07	40.10	6.12

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

Appendix Tables 3. Analysis of variances showing that mean square of specific gravity (gcm-3); dry matter content (%);Harvest index ; Total dry biomass yield and Starch content

Source of variation	DF	SG(gcm^{-3})	DMC (%)	HI	TDBMY	STC
REP	2	0.0000ns	3.40ns	0.00076ns	1191.02ns	0.76ns
NPSB	3	0.002**	35.73**	0.027**	34448.68**	75.68**
CM	3	0.00047**	33.50**	0.0050**	8528.40**	14.69**
CM*NPSB	9	0.000037ns	10.79**	0.00071ns	612.33ns	1.017*
ERROR	30	0. 000022	2.53	0.00035	336.88	0.35
CV (%)		0.44	7.09	2.68	5.16	4.66

*Where; SG = specific gravity, DMC= dry matter content (%), HI= Harvest index, TDBY= Total dry biomass yield, STC=m Starch content, TSDWR= Tuber to shoot dry weight ratio and NS, * and ** implies non-significant, significant and highly significance differences at 5% level of probability, respectively*

Appendix Tables 4: Selected physic-chemical properties of soil after harvesting

Cm t ha^{-1}	NPSB kg ha^{-1} Fertilizer	pH-H_2O	EC(dS/m)	%OC	%OM	%TN	av.P(ppm)
0	0	6.43	20.34	2.018	3.168	0.208	10.05
	61	6.78	23.04	3.048	3.170	0.288	10.01
	122	6.56	21.56	2.976	4.130	0.256	10.10
	183	6.56	23.78	3.273	5.640	0.282	11.30
10	0	6.30	20.62	2.790	3.809	0.240	14.20
	61	6.69	22.33	3.199	4.515	0.276	11.58
	122	6.47	21.68	2.604	4.489	0.224	11.45
	183	6.63	21.90	3.162	5.450	0.272	12.10
15	0	6.81	23.67	2.985	4.636	0.292	14.40
	61	6.60	24.21	3.310	4.707	0.285	13.94
	122	6.88	24.38	3.334	5.092	0.305	18.50
	183	6.64	24.26	3.446	5.579	0.279	16.93
20	0	6.80	24.80	3.422	4.900	0.295	15.18
	61	6.48	20.62	2.790	4.809	0.262	16.20
	122	6.74	22.77	3.545	5.887	0.269	17.10
	183	6.72	22.80	3.199	5.915	0.2757	17.06

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

APPENDIX 5: Different pictures captured during the research process