EFFECT OF NPSB BLENDED FERTILIZER ON GROWTH, YIELD AND QUALITY OF ORANGE FLESHED SWEET POTATO (*Ipomoea batatas* (L.) Lam) VARIETIES UNDER JIMMA CONDITION, SOUTH WEST ETHIOPIA.

M.Sc. THESIS

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In Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture

By

Getachew Etana Gemechu

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We, the undersigned, member of the Board of Examiners of the final open defense by **Getachew Etana Gemechu** have read and evaluated his/her thesis entitled **"Effect of NPSB Blending Fertilizer on Growth, Yield and Quality of Orange Fleshed Sweet Potato (*Ipomoea. batatas*) Varieties Under Jimma condition, - Southwest Ethiopia"** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Horticulture.**

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DEDICATION

This Thesis is dedicated to my beloved father Etana Gemechu and my beloved mother Shoge Etefa for nursing me with devotion and love.

STATEMENT OF AUTHOR

First, I declare that this Thesis is a genuine result of my own work and I have duly acknowledged all sources of materials that I used for writing it. This Thesis has been submitted in partial fulfillment of the requirements for the Degree of Master of Sciences at Jimma University and deposited it at the University's library to be made available to borrowers for reference under the rules and regulations of the library. I solemnly declare that this Thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born in a village called Amdin in Jimma Arjo wereda, East Wollega Zone, on 24th August 1986. He attended elementary education at Wayu worke primary School from 1991-1996 and secondary education at Jimma Arjo Mekonnenin Demessew Junior and senior Secondary School from 1997- 2002. After he took the Ethiopian School Leaving Certificate Examination (E.S.L.C.E.), he joined Bako ATVET College in 2003 and graduated with Diploma in Plant Sciences in August 5, 2005. He began his career as development agent at Ministry of Agriculture, Jimma Arjo Agricultural office. After serving for four years (September 2005-September 2009), he joined Jimma University to study B.Sc Degree in Horticulture. After completing his B.Sc study in 2011, he was reinstated at Jimma Arjo Agricultural office and served as Supervisor until April 8, 2012. In 2012, the author joined the Ethiopian Institute of Agricultural Research, Jimma Center (JARC) serving as technical Assistant. After serving the JARC for one year, he was reinstated on the position Assistant researcher. In 2016, he joined Jimma University to pursue his post graduate study leading to the Degree of Master of Science in Horticulture.

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ABBREVIATIONS AND ACRONYMS

HARC	Hawasa Agricultural Research Center
AGBFWT	Above Ground Biomass Fresh Weight
ATARC	Adami Tulu Agricultural Research Center
AVRDC	Asian Vegetable Research and Devotement Center
BARC	Bako Agricultural Research Center
CHI	Commercial Harvestable Index
CSA	Central Statistics Authority
DAP	Days After Planting
DRA	Daily Recommended Allowance
FAO	Food and Agricultural Organization
HI	Harvestable Index
MARC	Melkassa Agricultural Research Center
MoARD	Ministry of Agriculture and Rural Development
MRR	Marginal Rate of Return
MSRN	Marketable Storage Root Number
MSRWP	Marketable Storage Root Weight Per plant
MSRY	Marketable Storage Root Yield
OFSP	Orange Fleshed Sweet Potato
RAE	Retinol Activity Equivalent
SRDM	Storage Root Dry matter
SRG	Storage Root Girth
SRL	Storage Root Length
TSRN	Total Storage Root Number
TSRWP	Total Storage Root Weight Per plant
TSRY	Total Storage Root Yield
WAP	Weeks After Planting
WARC	Werer Agricultural Research Center
WFO	World Food Program
YFSP	Yellow Fleshed Sweet Potato

ABSTRACT

Sweet potato (Ipomoea batatas (L.) Lam) is economically important and a food security root crop in Ethiopia. In addition to this, orange fleshed Sweet potato (OFSP) is the cheapest source of β-carotene which is a precursor of Vitamin A whose deficiency (VAD) is a serious public health problem in Ethiopia. However, its productivity and quality is very low due to low soil fertility, lack of information on type and appropriate rate of fertilizers which have been recognized to be deficient in Ethiopian soil. Hence, a field experiment was conducted at Jimma Agricultural Research Center in 2017 cropping season to evaluate the effect of five different rates of NPSB fertilizer kg ha^{-1} (0,100 ,159, 214 and 239) on growth, yield and quality of three orange fleshed varieties (Kulfo, Tulla and Guntutie).The experiment was arranged in 3X 5 factorial RCBD with three replications. Data on growth, yield and quality were collected and subjected to various data analyses. Results revealed that, the interaction effect of varieties and NPSB rates were highly significant influenced the above ground biomass fresh weight, storage root girth, marketable storage root yield per hector, harvestable index, storage root dry matter content, β-carotene, ash ($P <0.01$) and Starch ($P<0.05$). Leaf area index and storage root length were resulted significantly highest difference due to the main effect of variety ($P<0.01$). Significantly the highest Storage root girth was obtained from Tulla with 159 kg ha^{-1} (79.35 mm). Guntutie with 159kg ha^{-1}, 214kg ha^{-1} and 239 kg ha^{-1} NPSB fertilizer resulted in significantly highest difference in marketable storage root yield in ton per hectare (63.33 ton ha^{-1}, 60.16 ton ha^{-1} and 63.44 ton ha^{-1}) respectively. Guntutie with 159 kg ha^{-1} resulted in significant highest difference in harvestable index (0.58). Tulla with 159 kg ha^{-1} resulted in significantly highest difference in storage root dry matter (35.4%) and Starch (28.21%). Significantly highest difference of β-carotene contents was scored in the variety Guntutie, that received 100 kg ha^{-1} NPSB fertilizer (1.4298mg/100g fwb). But the highest yield of β-carotene in terms RAE or RDA retinol μg ha^{-1}(g ha^{-1}) was obtained in Guntutie with 159 kg ha^{-1} NPSB fertilizer (46.4 g ha^{-1}) which was enough for 84.5 households (507 peoples) for 6 months. Marketable yield ton ha^{-1} was highly significant and positively correlated with LAI (r=0.614), SRL (r=0.711), β-carotene (r=0.495), MSRNP (r=0.555), MSRWP (1), HI (r=0.913).β-carotene content was highly significant positively correlated to SRL (0.521), MSRWP(r=0.495), MY ton ha^{-1} (r=0.495), LAI (r=0.315), HI (0.48). Storage root dry matter was high significant and positively correlate with SRG(r=0.768), HI(r=0.299), Starch (r=0.771). The highest marginal rate of return 805.19% were obtained in Guntutie with159 kg ha^{-1}. Use of selected orange fleshed sweet potato with NPSB blended fertilize to the optimum rate is important for yield improvement and qualities. Overall, 159 kg ha^{-1} NPSB should be recommended with Guntutie for highest significant yield and β-carotene; with Tulla for its higher significant storage root dry matter and starch content.

***Key words**: β-carotene, dry matter, NPSB, Starch, tuber yield*

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L.*)* Lam) is an herbaceous dicotyledonous plant with creeping, perennial vines and adventitious roots, and belongs to the family Convolvulaceae (morning glory) (Purseglove, 1972). It has a chromosome number of 2n = 90. Since the basic chromosome number for the genus *Ipomoea* is 15, sweet potato is considered to be a hexaploid. It is highly heterozygous cross pollinated crop in which many of the traits show continuous variations. It is originated in Central America of Mexico which is a centre of diversity (Martin and Jones, 1972; Nishiyama *et al.,* 1975). It is widely grown throughout the tropics and warm temperate regions of the world between latitudes of 40 ^{o}N and 40 ^{o}S of the equator, altitude from 0-2300 m.a.s.l (Jana, 1982), light, well-drained and aerated sandy loam or loamy sand soil with pH value of 4.5-6.5, Temperature 20 to 30 ^{o}C with an average 22^{o}C and optimum 25^{o}C. Average annual rainfall is between 700–900 mm (Kebede and Birru, 2011).

Globally sweet potato is the 7th most important food crop after wheat, rice, maize, potato, barley and cassava (FAO, 2014). More than 140 million tons had been produced globally per year (FAO, 2014). The world average storage root yield had been estimated to be 14.8t ha^{-1} (FAO, 2014). Asia is the world’s largest producing continent (129 M ton/annum) and China is the leading country (121 M ton/annum) which is 86% of world production. In Asia, it is primarily used for human consumption and animal feed. In Africa, sweet potato is the 2nd most important root crop after cassava and its production is concentrated in the East African and African great lake region countries (Ndole *et al.,* 2001; Dantata *et al.,* 2010). African farmers produce only about 9 million tons per annum which is mostly used for human consumption and to ensure food security (FAO, 2014; Sanginga and Mbabu, 2015).

In Ethiopia sweet potato is food security and economically important food crop. It is the 2nd most important root crop after Ensete. The crop is mostly used for human consumption either alone or blended with other crops (Kidane *et al.,* 2013). It is mainly grown by small scale and resource poor farmers in the South Western, Eastern and Southern parts of the country. It is a major subsistence crop in the periods of drought (Tofu *et al.,* 2007; Fite *et al.,* 2008). About 41,039.31 hectares of land were cultivated; in this it takes the 3rd position, next to Irish potato and Taro in root and tuber crops (CSA, 2016). It yields 33.4 ton ha^{-1} among all crops grown in Ethiopia, takes 2nd place next to sugar cane. Nearly 1.4M tons yield per annual were produced and ranked it 7th among all crops grown in Ethiopia. It accounts 79.56% next to enset (80%) at national level in house hold consumption (CSA, 2016). In Oromia, it was cultivated at about 17, 213.16 hectares and takes 2nd place next to Irish potato, among root and tuber crops grown in the region. About 851, 272.928 ton yields were produced per year, making it 1st among tuber and root crops with 49.455 ton ha^{-1}, ranking 1st among all crops yield in the region. In Jimma zone, about 683.84 hectares of land were cultivated, takes 1st place among root and tuber crops grown. A yield of 16,175.18 tons per year were produced next to taro with a yielded 23.65 ton ha^{-1} which is the highest of all crops in the zone (CSA, 2016).This indicated that, the yield is still below the genetic potential due to lack of appropriate agronomic practices.

Orange fleshed sweet potato (OFSP) varieties have high β-Carotene and can potentially reduce the effects of vitamin A deficiency. OFSP are currently at high demand in all developing nations. They have been popularized in Ethiopia through different approaches, hence, resulted in high demand for more OFSP cuttings (Tofu *et al.*, 2007). Through campaign of vitamin A for Africa (VITAA); in the year 2001 total of 20 OFSP clones were introduced from CIP-Nairobi to Ethiopia for evaluation. Also about 11 OFSP germplasm having high dry matter, high β-carotene content shipped to Ethiopia since 2003 for evaluation. Besides these, trials were done on the sensitization of farmers about OFSP and their nutritional advantages. Including these effort, for last 30 years, out of 25(White(13)+ Yellow(1) +Cream (5) + Pale orange(1) +Orange(5) released sweet potato varieties only five OFSP (Kulfo, Tulla, Kero, Guntutie and Birtukane) were registered as Pure orange fleshed variety which are very few (MoARD, 2009; Gurmu and Mekonnine, 2017)

Vitamin A deficiency (VAD) is a serious public health problem in Ethiopia (Demissie *et al.*, 2010; Kurabachew, 2015). It occurs mainly in children and women of child bearing age (Kassaye *et al.,* 2001; Tofu *et al.,* 2007). OFSP varieties are a solution for yield and nutritional quality to combat the malnutrition problems and mainly VAD; however, they have low dry matter content (Kidane *et al.,* 2013; Gurmu *et al.*, 2015b). These nationally released varieties have been not tested with fertilizers to improve their yield and nutritional quality mainly β-carotene and dry matter contents.

In Africa, the productivity of sweet potato is too low about 4 to 5 ton ha^{-1}, as compared to other growing region (Sanginga and Mbabu, 2015). Most varieties in sub-Saharan Africa are white-fleshed, low yielding and lacking β-carotene (Wariboko and Ogidi, 2014). In Ethiopia, the average national yield of sweet potato is about 8 ton ha^{-1} (Tesfaye *et al.,* 2011) which is low compared to the world's average production of about 14.8 ton ha^{-1}(FAO, 2014). Its yield at farmer's field is 6 to 8 ton ha^{-1} which is ten times lower than the potential sought and implies huge variation (Abdissa *et al.,* 2012; Markos and Loha, 2016). The major causes of the low yields are: the use of poor agronomic practices like scarcity of information on the appropriate rates of fertilizers recommendations, low soil fertility, shortage of improved varieties having high nutritional value, shortage of planting materials, pests and most varieties are white fleshed which lacks β-carotene (Kidane *et al.,* 2013). Fertilizer use in Ethiopia on sweet potato seems very limited. Out of 54,017 hectares, only 1073 hectares (1.986%) were treated with 239.1 tons of DAP and 156 tons of Urea fertilizer. In Oromia region, from 16,319 hectares sweet potato cultivated, only 4562 hectares were fertilized with 901.6 tons of combinations of all fertilizers. On 169 hectares of land about 73.6 tons of NPS + Urea were used and all planting materials were local. In Jimma zone, of 683.84 hectares of sweet potato production area, only 55 hectares were amended with Natural fertilizer (CSA, 2016) which is presumed to be one of the main reasons for low yield of the crop. Splitting of sweet potato tuberous root due to Boron (B) deficiency can reduce the quality of marketable storage tuber yields by 40–60% (Pillai *et al.*, 1986; O'Sullivan *et al.*, 1997; Swamy *et al.,* 2002). Inadequate sulfur supply will not only reduce yield and crop quality, but also, it will decrease N use efficiency and enhance the risk of N loss to the environment (Norton *et al.,* 2013).

The use of biofortified OFSP rich in β-carotenes are a proven cost effective strategy for providing vitamin A and cheep most accessible than other food items at high levels of bioavailability to vulnerable populations, particularly in young children, pregnant and lactating women (Low *et al.,* 2009; Kaguongo *et al.,* 2012; Kurabachew, 2015). It is a good source of energy, a number of vitamin B, vitamin C, K and other micronutrients (Ji *et al.*, 2015; Alam *et al.*, 2016). They are qualified to solve malnutrition problem (Ndunguru *et al.*, 2009; Emmanuel *et al.*, 2010). Therefore, enhancing awareness on the importance of OFSP as a source of β-carotene is very essential with an increase of its dry matter through targeted agronomic practice.

According to Workayehu *et al.* (2011), the potential yield of sweet potato reached up to 50 ton ha^{-1} on research station and 17.5-30.50 ton ha^{-1} on farms with improved agronomic practices. Abdissa *et al.* (2012) reported that, sweet potato yield under research field ranged from 30-35 ton ha^{-1} with improved cultivars. According to Teshome and Amenti (2010), average yield of 37.1 ton ha^{-1} was obtained from Bellala variety in Adami Tulu area with application of different fertilizers. Abdissa *et al. (*2011) reported that, sweet potato yields up to 64.4 ton ha^{-1} from Bellala variety using appropriate agronomic practices . Boron (B) prevents the splitting of sweet potato tubers and increases marketable tuber yield (Byju *et al.,* 2007). Adequate sulfur supply will increase yield, crop quality, N use efficiency and reduce the risk of N loss to the environment (Norton *et al.,* 2013). It has been estimated that, for every 15 parts of N in protein, there is approximately 1 part of S (15:1 ratio of N: S). It stimulates the uptake of micronutrients (Cu, Mn, Zn, Fe, and Ni) due to rhizospheres acidification as S oxidation occurs.

In the years past, MoANRD recommended 175 kg ha^{-1} DAP and 80 - 100 kg ha^{-1} Urea in blanket (Kebede and Birru, 2011). Currently, the ammonium fertilizer representatives, Sulfur and Boron containing fertilizers had been availed in Ethiopia. These are: NPS, NPSB and NPSBZn are being used all over Oromia region and in Jimma zone with 100 kg ha^{-1} NPSB in blanket recommendation to improve yield and quality of crop (EthioSIS, 2014; Bellete, 2016). Even though, a number of experiments had been conducted on variety evaluation of OFSP in different areas of Ethiopia mainly on yield improvement, less emphasis was given to quality aspect. A number of experiments were conducted to determine the response of sweet potato to NP, P, N, NPK and different organic fertilizer rates in different parts of the country. Yield responses vary from variety to variety and from place to place. To date, no research undertakings were reported on the effects of rate of inorganic fertilizers such as NPSB fertilizer on yield and quality of OFSP in Jimma area. To address these gaps, the present work was initiated with the following objectives:

General objective:-

- To assess the effect of NPSB blended fertilizer and variety on growth, yield and quality of orange fleshed sweet potato.

Specific objectives:-

- To assess a possible interaction effect of NPSB blended fertilizer and variety on growth and yield of orange fleshed Sweet potato,
- To assess interaction effect of NPSB blended fertilizer and variety on β-carotene and other qualities of orange fleshed Sweet potato.

2. LITERATURE REVIEW

2.1. Importance of Sweet potato

Orange fleshed sweet potato varieties are naturally biofortified crop and also known as a good source of vitamin A which is frequently lacking in diets of most African farming communities. The use of orange fleshed sweet potato(OFSP) rich in β-carotene introduced along with nutrition and education at the community level is a proven cost effective strategy for providing vitamin A at high levels of bioavailability to vulnerable populations, in particular young children, pregnant and lactating women(van Jaarsveld *et al*, 2005). It has great potential to be used in food based intervention programs to address VAD. Animal and plant source VA rich foods are only seasonally available, unpalatable to young children and often absent from the diets of low income households. OFSP is substantially better absorbed than others leave and vegetables while digestion. It is easy crop to grow and affordable to resource poor consumers (Jalal *et al*., 1998).

In Ethiopia, OFSP have been used in food based intervention due to its high β-carotene content. Bread enriched with 30% OFSP flour can contribute 83.3% and 74.2% of VA to 1- 3 and 4-6 years old children's daily requirement, respectively. A general trend of nutrient analysis showed that moisture, ash, fiber, β-carotene increased significantly as proportion of OFSP flour increased; while protein, fat, carbohydrate and energy content decreased. Therefore, OFSP flour enriched breads have been added advantages nutritionally, especially in β-carotene which is a base for policy makers and donors for more confidence to invest and work in OFSP for alleviation of VAD (Kidane *et al*., 2013).

OFSP varieties are recommended for household consumption as they have high pro-vitamin A which is essential for human health, specifically for regular growth, development, improved eyesight, metabolic functions and effective immune systems (Burri, 2011). It is most accessible than other food items which are unavailable or unaffordable to poor farmers (Low *et al.*, 2009; Kaguongo *et al.*, 2012).

Sweet potato traditionally processed into numerous products, including: bread, injera, flour and cookies, wot (stew), local beer, Starch, sugars and juice. These would reduce the post harvest losses of the crop related to its short shelf life and quality of the storage roots (Islam *et al.* 1997; Gurmu *et al*., 2015b). It serves as an energy food or a main source of carbohydrate, protein, vitamin A, B1, B2, C, minerals such as K, Na, P and Ca (Magagula *et al*., 2010). The young leaves are rich in protein, most vitamins and minerals (Onwueme and Sinha., 1991). Furthermore, the stem and leaves of sweet potato are excellent source for animal feed. They are well known as a source of carbohydrate 25% - 30 %, protein 1.6% - 2.0 %, fat 0.7 % and 1.0 % ash (FAO and WFP, 2005). Its fresh tuber contains 60-70 % water, 15-25 % Starch, 1-2% proteins and 1-2 % sugar (CIP, 2007). Therefore, enhancing farmers' awareness on the importance of OFSPs as a source of vitamin A is very essential while improving its dry matter content through targeted breeding and agronomic practice being different scholars indicate fertilizer can further improve the dry matter content of orange fleshed Sweet potato (Busha, 2006; El-Sayed *et al*., 2011; Teshome *et al*., 2011; Balcha., 2015).

2.2. Malnutrition and Sweet potato Production Constraints

According to Food and Agricultural Organization (FAO, 2014) estimates, there are 805 million chronically undernourished people on the planet. Almost two billons suffer from micronutrient deficiency particularly iron, vitamin A, zinc, iodine, and folic acid deficiencies. Globally, 163 million children under 5 years of age suffer from vitamin A deficiency (VAD) with the highest prevalence rates found in sub-Saharan Africa and South Asia. In many countries in these regions, the problem of under nutrition has actually been increasing (Sanginga and Mbabu, 2015).

Vitamin A deficiency is a serious public health problem in Ethiopia (Demissie *et al*., 2010). It occurs mainly in children and women of child bearing age (Kassaye *et al*., 2001). The prevalence of VAD appears to be highest among children between 2 - 6 years old (Tofu *et al*., 2007). Therefore, food based intervention has been proposed in the Ethiopia national VAD control framework as the long term option. It is important to shift from a subsidized periodic capsule distribution to a more sustainable food based interventions which could supply vitamin A in the diet of low income rural communities (Kidane *et al*., 2013).

Production of sweet potato is constrained by biotic, abiotic and socio-economic factors. The biotic stresses include diseases, insect pests and weeds; whereas abiotic factors are drought, heat and low soil fertility (Ndunguru *et al*., 2009). These factors have a direct effect on storage root yield. Constraints related to socio-economic and quality attributes are: lack of improved varieties, most sweet potato varieties are white-fleshed, low yielding and lacking β-carotene which is a precursor of vitamin A, lack of planting materials, low storage root yield, and low storage root dry matter of OFSP which are available currently (Ndunguru *et al.,* 2009; Balcha .,2015), however, consumers and industrialists prefer sweet potato varieties with high dry matter content (Mwanga *et al.*, 2009; Cervantes-Flores *et al.*, 2011).

The constraints also include inadequate supply improved varieties among the farmers, less adoption rate of improved agronomic practices and insect pest damage causes for low productivity of sweet potatoes (Tesfaye *et al.*, 2011; Gurmu *et al.*, 2015b; Markos and Loha, 2016). Splitting of sweet potato tuber is a very serious problem because of boron (B) deficiency (O'Sullivan *et al.,* 1997) and result in yield loss of 40–60% (Pillai *et al.,* 1986). The major post harvest constraints among farmers were: poor access to markets, poor prices, low yields, less dry matter content of storage roots of sweet potato, lack of knowledge about Sweet potato processing and preservation (Gurmu *et al*., 2015b).

2.3. Research Status of Sweet potato in Ethiopia

Since the establishment of agricultural research, a number of varieties have been release by Federal, regional and higher learning institute research system. Even though many of the varieties are WFSP which are low in vitamin A, some orange fleshed are released in Ethiopia. They were released under mandate of Hawasa, Sirinka, Bako, Werer and Haremaya University (Table 1).

Table 1. Released Sweet potato varieties in Ethiopia

No	Variety	Year release	Altitude	Maturity days	Flesh colour	Yield (qt/ha)	Center release
1	Kulfo (LO-323)	2005	1200-2200	150	Orange	270	Hawasa
2	Tulla (CIP 420027)	2005	1200-2200	150	Orange	285	Hawasa
3	Kero (TIS-8250)	2005	1200-2200	150	Orange	354	Hawasa
4	Kudade (TIS-1499)	1997	1200-2200	90-120	Cream	241	Hawasa
5	Falaha (TIS-3017(2)	1997	1200-2200	90-120	White	167	Hawasa
6	Dubo (I-444)	1997	1200-2200	90-120	White	217	Hawasa
7	Guntutie (AJAC-I)	1997	Mid-altitude	120-150	Orange	354	Hawasa
8	Bareda (375)	1997	1200-2200	120-150	White	296	Hawasa
9	Damota (Guralow)	1997	1200-2200	120-150	Cream	307	Hawasa
10	Awasa-83	1998	1200-2200	150-180	White	366	Hawasa
11	Koka-12	1987	1200-2200	120-150	Pale orange	177	Hawasa
12	Koka-6	1987	1200-2200	120-150	Cream	269	Hawasa
13	Belella (192040-I)	2002	1200-2200	90-120	Cream	183	Hawasa
14	Temesgen(192009-VIII)	2002	1200-2200	90-120	White	176	Hawasa
15	Ordollo (192009-IX)	2005	1200-2200	150	White	173	Hawasa
16	Jari (CN-2059-1)	2008	1650-1850	133	Yellow	192	Sirinka
17	Birtukane (saluboro)	2008	1650-1850	150	Orange	199	Sirinka
18	Berkume (TIS 8250-2)	2007	1650-2000	188-195	White	195	Har Uni.
19	Adu (Cuba-2)	2007	1650-2000	150-180	Cream	160	Har Uni.
20	Ballo (Koka-18)	2006	1400-1800	120	White	294	Bako
21	Beletech (192026-II)	2004	1200-2200	150	White	184	Hawasa
22	Dimtu	2005	1200-2200	120	White	-	Hawasa
23	Ogansegan	-	1200-2200		White	-	MoA
24	Mae	2010	300-980		White	-	Werer

Source: MoARD (2009)

2.4. Role of Variety on Yield, Yield Component and Quality of Sweet potato

In Ethiopia, there are white sweet potato varieties which are popular and known to be low yielding. In sub Saharan countries, yellow and orange fleshed sweet potato varieties have high nutrient value mainly β-carotene which is a precursor of vitamin A. They were tested and introduced to Ethiopia (Ndirigwe, 2006; Mukhtar *et al.,* 2010). It usually has higher protein content than other tubers such as cassava and yams which varies from 1 to 2.5%. The leaf is rich in carotene which is a precursor of vitamin A and calcium (Mukhtar *et al.*, 2010).

In North Ethiopia Orange flesh sweet potato (OFSP) were used in food based intervention. Bread enriched with 30% OFSP flour can contribute 83.3% and 74.2% of VA to 1- 3 and 4-6 years old children's daily requirement, respectively (Kidane *et al.*, 2013). It showed that moisture, ash, fiber, β-carotene increased significantly as proportion of OFSP flour increased; while protein, fat, carbohydrate and energy content decreased. Therefore, it gives direction and confidence for individuals, policymakers and donors to invest and work on OFSP for alleviation of VAD (Kidane *et al.*, 2013).

CIP (2007) noted that, the β-carotene content of sweet potato common to Africa ranged from 100 to 1,600 µg RAE/100g which agreeing with the β-carotene values obtained in some of the varieties of Ethiopia. Tumwegamire *et al.* (2011) reported that, selected East African (EA) white and orange fleshed sweet potato varieties were evaluated for storage root dry matter, nutrient content and obtained information on the potential contributions of the varieties to alleviate vitamin A and mineral deficiencies. It revealed that, farmer genotypes had higher dry matter, higher Starch and lower sucrose contents than the control clone introduced 'Resisto'. Also he reported that, nearly all light to deep OFSP farmer varieties clearly contain β-carotene. For the OFSP control (Resisto): β-carotene content of 271 ppm (27.1mg/100g drwb) was observed. Several OFSP farmer varieties namely: 'Carrot-C' (259 ppm or 25.9 mg/100g dwtb), 'Carrot Dar' (272 ppm or 27.2 mg/100g dwtb), 'Ejumula' (240 ppm or 24.mg/100g dwtb), 'Mayai' (264 ppm or 26.4 mg/100g dwtb), and 'Zambezi' (233 ppm or 23.3 mg/100g dwtb) were exhibited similar or slightly different β-carotene contents as the control.

Farmers accept varieties having dry matter content more than 25 % of the fresh weight of tubers while processing industries prefer varieties with dry matter content above 35 % (Shumbusha *et al.,* 2010). In Rwanda, analysis of selected OFSP and YFSP varieties was tested for nutritional qualities (Table 2) (Emmanuel *et al.,* 2010).

Table 2. Concentration of nutrients content in fresh, dried chips and processed flours from OFSP and YFSP in Rwanda

Nutrition	Fresh		Dried chips		Sweet potato flour	
	OFSP	YFSP	OFSP	YFSP	OFSP	YFSP
Carbohydrate%	7.65	8.7	64.8	73.6	64.8	73.6
Protein%	2.5	1.9	5.2	2.4	5.2	2.4
Fat%	1.15	0.6	2.1	0.7	2.1	0.7
Fiber%	3.4	5.3	4.12	6.09	4.0	5.0
Total ash%	4.7	3.5	4.0	3.0	4.0	3.0
Moisture content%	81.0	80.0	17.0	15.0	17.0	15.0
Total Reducing Sugar%	6.73	6.83	6.78	6.87	6.78	6.87
Vitamin C mg/100g	50.17	39.7	47.9	30.15	47.89	30.13
β- carotene mg/100g	8.75	0.045	8.04	0.040	8.04	0.040

Source: Emmanuel *et al.* (2010)

In Bangladesh, different orange fleshed sweet potato cultivar CIP 194513.15 resulted in the highest tuber root yields (31.59 ton ha^{-1}) and followed by CIP 440267.2 (30.97 ton ha^{-1}) and the lowest yield (13.34 ton ha^{-1}) were obtained by BARI SP 3 cultivar. The maximum dry matter (29.83%) was obtained by H6/07 while the minimum dry matter (17.61%) was obtained by CIP 441132. The highest Vitamin A (919.2 µg/100 g RAE, fwb) were recorded by CIP 440267.2 cultivar (Rahman *et al.*, 2013).

In china, different colour fleshed sweet potatoes in their dietary fiber content, anthocyanins, total phenolics content and their total antioxidant activity resulted in significance differences. Starch contents of Beijing-553 and Shangshu-19 were higher with fat contents. Protein content of Shangshu-19 was the highest followed by Jizi-01 and Xinong- 431 cultivar. Purple fleshed Sweet potato possessed much higher anthocyanins content than others up to 6.23 mg/g dry matter (Ji *et al.*, 2015).

2.5. Influence of Fertilizer on Average Vine length, Above ground biomass weight and Days to maturity.

Growth parameters are the main important yield determining factors in sweet potato and they are highly influenced by soil fertility and soil amendments (Collins *et al.,* 1995). According to Sanwal *et al*. (2007) report, nitrogen, phosphorus and potassium influence vegetative and reproductive phase of plant growth. Because it readily produces adventitious roots and has trailing vines.

The vegetative growth of “Beaure Gard” cultivar of sweet potato plants were significantly increased with increasing P rate from 35.71 kg ha^{-1} P_2O_5 up to 107.14 kg ha^{-1} P_2O_5. Plants which received the later rate had showed significant increases in main stem length, canopy dry weight, leaf area, total chlorophyll, carotenoids, marketable yield, total yield, dry matter percentage of tuber root, tuber root weight and diameter compared to the other rates (El-Sayed *et al.,* 2011). Vine length was highly influenced by the interaction effect of FYM with P. As application of 0 ton FYM ha^{-1} + 0 P_2O_5 increased to 15 ton FYM+90 kg ha^{-1} P_2O_5, average vine length increased by about 51.86% (Abdissa *et al.,* 2012). Applications of N and P (46 N kg ha^{-1}, 23P kg ha^{-1}) significantly increased tuber number and vine length (Ambecha, 2001).

On most soils, tuber yield is increased by the application of nitrogen fertilizer. However, an excess of nitrogen can stimulate increased foliage production at the expense of tubers and may also lead to tuber cracking (Kebede and Birru, 2011). Ambecha (2011) stated that the use fertilizer varies from region to region and the experience of some African country may apply in our country and indicate that use of Nitrogen beyond 45N kg ha^{-1} enhance vegetative growth rather than root growth. Ambecha (2001) who reported that increasing the amount of N application significantly promoted shoot growth at the expense of tuber growth on ridge seed bed. Adequate supply of N and P promotes higher photosynthetic activity and vigorous vegetative growth and promotes the chance for emergence of new vines. Busha (2006) stated that, increasing N levels from 0 to 45N kg ha^{-1} significantly increased the internodes length of Sweet potato. Commonly adequate supply of N is associated with high photosynthetic activity and vigorous vegetative growth thereby increasing internodes lengths. Abdissa *et al.* (2012) stated that, even though shoot fresh weight Sweet potato (Bellala) of is benefited at the highest level of farmyard manure, shoot dry weight was increased as the proportion of farmyard manure to phosphorus decreased. Days to maturity obtained at 15 ton FYM ha^{-1} + 180 kg ha^{-1} P_2O_5 was 22.76 % earlier than the one obtained at combined application of 10t FYM ha^{-1}+ 90kg FYM ha^{-1} (Abdissa *et al.,* 2012). Applications of N and P (46 kg ha^{-1}N, 23 kg ha^{-1} P) significantly influenced days to maturity (Ambecha, 2001).

2.6. Influence of Fertilizer on Average Storage root length and diameter

Applications of N and P (46 kg ha^{-1} N, 23 kg ha^{-1} P) significantly increase tuber length (Ambecha, 2001). The highest tuberous root diameter was obtained when 5 ton ha^{-1} FYM and 90 kg ha^{-1} P_2O_5 were applied in combination. This value was in statistically parity with the combined applications of 5 ton FYM ha^{-1} and 180 kg ha^{-1} P_2O_5. It resulted in 18.31% root diameter advantage. This indicates that minerals supplied from both P had the most profound effect on increasing root diameter (Abdissa *et al.*, 2012). Due to Nitrogen application, total first order lateral root and second order lateral root number of sweet potato increased by 110% and 214% respectively. There were111% more adventitious roots in the fertilized compartment relative to the unfertilized compartment (Villordon *et al.*, 2013).

2.7. Influence of Fertilizer on Average Storage root yields of Sweet potatoes

The storage roots of sweet potato serve as staple food, animal feed and as a raw material for industrial purposes as a Starch source and for alcohol production (Collins *et al.,* 1995). Its yield influenced by various fertilizers. Byju *et al.* (2007) reported that, the total tuber yield of Sweet potato increased significantly with up to 1.5 kg ha^{-1} and Echer and Creste (2011) reported up to 2 kg ha^{-1} of Boron. Further increase of B did not further increase in yield of Sweet potato.

Bourke (1985b) reported that, excess nitrogen application reduce Sweetpotato yields and recommend low rates to increase yield.

Experiments result Guinea savanna agro-ecological zone, the highest marketable root yields of 21.4 and 23.0 ton ha^{-1} were obtained from combinations of 150 NPK kg ha^{-1} + 1.5 ton CM ha^{-1} and 100 NPK kg ha^{-1} + 3 ton CM ha^{-1} at Wa and Mampong-Ashanti tested site, respectively (Yeng *et al.*,2012). Mukhtar *et al.* (2010) reported that, the two sweet potato varieties, Dan-Zaria and Dan-Bakalori, exhibited significant response to fertilizer rates. Accordingly, Dan-Bakalori yielded significantly higher than Dan-Zaria (6.715/4.5m2 or 14.92 ton ha^{-1} and 5.459/4.5m^2 or 12.13 ton ha^{-1}) application of 150 (67.5: 67.5: 67.5) NPK ha^{-1}, respectively in Nigeria. The varieties of sweet potato used exhibited significant response concerning the number of tubers per hill which in line with the yielding ability of the variety. In South Eastern Nigeria, application of 2.5 ton ha^{-1} poultry manure + 200kg NPK gave higher fresh storage root weight than application of Agrolyser at 5.4 kg ha^{-1} at 8 WAP harvest. Umu-Sp01 variety gave higher number fresh root weight than Umu-Sp03 (Akpaninyang *et al.*, 2015). Interaction of N and P on Koka-18 significantly influenced total tuber yield, marketable and unmarketable tuber weight, harvest index, concentrations of N and P in shoot and tuber. N and P significantly affected total tuber yield and showed positive correlation (Busha, 2006). Vosawai *et al.* (2015) reported that, there was a quadratic increase in yield with increasing levels of N up to 45.5 kg ha^{-1} and yield declined with further increasing N and the highest computed yield at 45.5 kg N $ha^{-1}$was 13.4 ton ha^{-1} in Malaysia.

Ambecha (2011) stated that the use fertilizer vary from region to region and the experience of some African country may applied in our country which is 35 – 45 kg ha^{-1} N, 50-100 kg ha^{-1} P_2O_5 and 85-170 kg ha^{-1}K. He also further indicates that use of Nitrogen beyond 45N kg ha^{-1} enhance vegetative growth rather than root growth. Good yields can be obtained only under conditions of high, but balanced nutrition (Beliyu, 2003). Jackson *et al.* (1992) recommended use of 100-200 kg ha^{-1} DAP for better yield of Sweet potato. Experiment result conducted at Haremaya indicated that applications of N and P(46 kg ha^{-1} N, 23 kg ha^{-1} P) significantly increase marketable tuber yield up to 30.76 ton ha^{-1}, increases tuber number and dry matter content (Ambecha, 2001).

2.8. Influence of Fertilizer on Shoot and Root dry matter weight

Shoot dry weight of sweet potato was also highly responsive and significantly affected by the combined application of farmyard manure and phosphorus. Nitrogen affects the distribution of dry matter within the plant, particularly affecting root growth relative to top growth, delay tuber bulking and maturation (Bradbury and Holloway, 1988). Abdissa *et al.* (2012) stated that, as the rate of FYM decreased from 20 ton ha^{-1} to 0 ton ha^{-1} and concurrently as the rate of P increased from 0 kg ha^{-1} P_2O_5 to 180 kg ha^{-1} P_2O_5, shoot dry weight of Sweet potato (Bellala) increased by 215.8% and was statistically significant. This indicates that even though shoot fresh weight is benefited at the highest level of farmyard manure, shoot dry weight was increased as the proportion of farmyard manure to phosphorus decreased (Ambecha, 2001; Abdissa *et al.*, 2012).

Total dry matter production and efficiency of dry matter allocation to storage roots are important factors determining storage root yield. Some reports indicate a linear increase in total yield and storage root dry matter in phosphorus application (Nair and Nair, 1995). Applications of N and P (46 kg ha^{-1} N, 23 kg ha^{-1} P) significantly increase dry matter content (Ambecha, 2001). All dry matter content of "Beaure Gard" cultivar of sweet potato were significantly increased with increasing P rate from 15 kg /fed P_2O_5 (35.71 kg ha^{-1} P_2O_5 or 15 .7 P kg ha^{-1}) up to 45 kg /fed P_2O_5 (107.14 kg ha^{-1} P_2O_5 or 47.1 kg ha^{-1}p)(El-Sayed *et al.*, 2011). Kathabwalika *et al.* (2016) stated that, dry matter is one of the most important quality aspects in Sweet potato and most of the OFSP genotypes evaluated ranged between 25 and 30% at Malawi. He Further indicated that, dry matter content in the boiled or roasted Sweet potato meal was a property that most preferred by consumers (Kathabwalika *et al.,* 2013). The combination of high dry matter (>25%) and Starch helps in selection of cultivars (Lebot, 2010).

2.9. Influence of Fertilizers on Nutritional quality of Sweet potato

An increase in the rate of applied N to sweet potato caused an increase in root N content. A significant linear relationship between percent of total N in the roots and N application was found in sweet potatoes (Purcell *et al.*, 1982). Some of application of sulfur caused formation of more protein that has a nutritional advantage (Norton *et al.*, 2013). Hu *et al.* (1996) reported that, low concentration of boron in tomato plant had low calcium and cell structure of bean root accommodate minimum levels of proteins content as comparing deficient with normal condition, hence, Boron used for the absorption and accumulation of the micro elements in the plant cell.

Phosphorus tends to increase starch synthesis, but in contrast with N, it hastens maturity. Phosphorus deficient potato plants typically produce tubers with lower specific gravity compared to those with adequate P nutrition (Degras, 2003).

The highest moisture percentage in the leaves of sweet potato was from inorganic fertilizer treated plot and the least from the control plots. Peak percent of ash content was resulted from inorganic fertilized plots and the least from organo-mineral fertilized plots (Kareem, 2013). In crude protein production, the highest percentages were realized from organo-mineral fertilizer treated plots, followed by organic fertilizer treated and the control plots. Crude fiber had the highest percentage from inorganic fertilizer plots, followed by the control plots and followed by organic fertilizer plots. Organo-mineral fertilizer plots with the least percentage. The storage roots produced higher dry matter than the leaves (Kareem, 2013). Applications of N and P (46 kg ha^{-1}N, 23 kg ha^{-1} P) significantly increase protein content (Ambecha, 2001).

In Nigeria a sweet potato were treated to three levels (0, 30 and 60 kg ha^{-1}) of P using single super phosphate (SSP 9% P). The highest P contents in the lamina and yield were recorded at the 5^{th}, 9^{th} and 7^{th} weeks after planting (WAP) at 30 and 60 kg ha^{-1} p, respectively (Akinrinde, 2006). Nyarko (2015) stated that the β-carotene content of the various treatments and NPK 200 kg ha^{-1} (30:30:30) treatment effect was the greatest which scored 32.9% and cow dung only (31.3%) from their dry matter.

Vosawai *et al.* (2015) reported that, effect of N fertilizer and varieties on carbohydrate, total sugar and β-carotene content of sweet potato tuber in Malaysia did not resulted significance difference and the carbohydrate contents of E10073, E10236 and E10051 were in the range of 22.8 – 24.5%. These values were higher than varieties E10136 and E10173 (16.8-18.4%). All quality of "Beaure Gard" cultivar of sweet potato were significantly increased with increasing P rate from 15 kg /fed P_2O_5 (35.71 kg ha^{-1} P_2O_5 or 15 .7 P kg ha^{-1}) up to 45 kg /fed P_2O_5 (107.14 kg ha^{-1} P_2O_5 or 47.1 kg ha^{-1} p). Plants which received 45 kg /fed P_2O_5 (107.14 kg ha^{-1} P_2O_5 or 47.1kg ha^{-1} p) had significant increases in canopy dry weight, leaf area, total chlorophyll, carotenoids and dry matter percentage of tuber root as compared to the other rates (El-Sayed *et al.*, 2011). Saif-EI-Dean (2005) found that, weight loss and decay were negatively correlated with Prates application. Also increasing P rate up to 60 kg /fed P_2O_5 significantly decreased the percentages of the weight loss and decay during storage. El-Sayed *et al.* (2011) reported that, Prates were an effect on storability and reducing weight loss and decay percentages in tuber roots of "Beaure Gard" sweet potato by increasing the P rates up to 45 kg / fed P_2O_5.

2.10. Interaction Effect of Varieties and Fertilizers on Qualities, Yield and Growth of Sweet potato

Experiment was conducted with 4 N application levels (0, 17, 34, 68 kg ha^{-1}) and 5 Sweet potato accessions (E10073, E10236, E10136, E10173 and E10051 in Malaysia. Their interaction effects on β-carotene at zero N level of application to all varieties were low. Increasing application of nitrogen fertilizer significantly increases β-carotene content at 68N kg ha^{-1}. Varieties E10236 (8,016μgg^{-1}) and E10051 (10,505 μgg^{-1}) had markedly significantly higher β-carotene than the rest at 68N kg ha^{-1}, however, non significant from 34N kg ha^{-1} fertilizer. Variety E10051 with 68N kg ha^{-1}scored high carbohydrate (22.4%) and highest total sugar (8.3%) and β-carotene (Vosawai, 2015).

Two OFSP varieties (Resisto and W-119) and Chemical fertilizers were applied at 0%, 50% (75, 15, 95 kg ha^{-1} NPK) and 100% (150, 30,190 kg ha^{-1} NPK) were conducted in South Africa. About 250 kg ha^{-1} potassium nitrate (13% N, 38%K) and 150 kg ha^{-1} superphosphate (10.5% P) at the 50% and doubled at 100% were applied before planting. Two equal top dressings of 150 kg ha^{-1} and 300 kg ha^{-1} limestone ammonium nitrate (28%N), at 50% and 100% fertilizer treatments were applied at 28 and 56 days after planting in respective. Interaction effect showed that, total storage root yield increased by 2 fold at the 50% fertilizer treatment and 3 fold at 100% treatments with Resisto. Interactions of Resisto with fertilizer application tended to increase significantly β-carotene content. Storage roots at 0% fertilizer treatment with contained 133.7μgg^{-1}total β-carotene, while those of the 50% and 100% fertilizer treatments significantly contained 153.1 and 151μgg^{-1} total β-carotene, respectively **(**Laure *et al.*, 2012**).**

A field study was conducted since 2008 in Nigeria to evaluate the response of 2 improved sweet potato varieties (TIS 8164 and Ex-Igbariam) to 5 rates (0, 40, 80,120 and 160 kg ha^{-1}) of potassium fertilizer. Interaction result revealed that, Ex-Igbariam with 120 and 160 kg ha^{-1} significantly higher ($P<0.05$), however, 120 and 160 kg ha^{-1}were non significant. Ex-Igbariam was more responsive to K(160 kg ha^{-1}) application than TIS8164 in longer vines(203.7cm), higher number of leaves(215.4) and branches per plant(17.1) and heavier vine dry weight at all the applied K rates. Ex-Igbariam out-yielded significantly than TIS8164 by 12.5, 12.7 and 13.3% for number of tubers per plant (9) at 120 kg ha^{-1}, weight of tubers per plant(0.73) at 160 kg ha^{-1} and tuber yield per hectare (40.7) at 120 kg ha^{-1}, respectively (Uwah *et al.,* 2013).

In conclusion, there is a variable nutrient demand for the production of sweet potato varieties which vary from variety and place to place.

3. MATERIALS AND METHODS

3.1. Descriptions of the Study Site

The experiment was conducted at Jimma Agricultural Research Center located 366 km South West of Addis Ababa. It is geographically located at latitude 7^{o} 46' N and longitude 36^{o} 47'E having an altitude of 1750 m.a.s.l. The soil of the study area is Nitisol which is the dominant with a pH of 5.3 (Beyene, 2013). The area receives mean annual rainfall of 1737 mm with maximum and minimum temperature of 25.21^{0}C and 12.21^{0}C, respectively (Appendix Table 10).

3.2. Description of Experimental Materials

Experimental materials were three nationally released orange fleshed sweet potato varieties: Kulfo (LO-323), Tulla (CIP 420027) and Guntutie (AJAC-I), and five levels of NPSB blended fertilizer: 0, 100, 159, 214 and 239 kg ha^{-1}, comprising a total of 15 treatment combinations.

The element content of 100kg NPSB were: N=18.9 Nitrogen, P=37.7 P_2O_5, S=6.95 Sulfur and B=0.1 Boron (Bellete, 2016). Fertilizer NPSB had been recommended in blanket recommendation for over 50%, for 11 districts of Jimma zone, including experimental site (EthioSIS, 2014; CSA, 2016). Uniform application of 45 Kg N ha^{-1} (97.82 Kg ha^{-1} Urea) to each treatment was applied by subtracting the amount found in the treatments of NPSB rate tested, which is the optimum recommendation for Sweet potato based on various research recommendations.

Table 3. Rate of NPSB formulated and tested

NPSB Treatment Rate		Element content				N added	UREA in kg	N Recom mended
Treatments	NPSB ha^{-1}	N	P_20_5 (P)	S	B			
Control	0	0	0(0)	0	0	0	0	0
$NPSB_1$	100	18.9	37.7(16.58)	6.95	0.1	26.1	56.73	45
$NPSB_2$	159	30.07	60(26.4)	11.06	0.159	14.93	32.45	45
$NPSB_3$	214	40.355	80.5 (35.4)	14.83	0.21	4.645	10.09	45
NPSB4	239	45.11	90(39.6)	16.59	0.238	0	0	45

3.3. Treatments and Experimental Design

The experiment was set as a 3x5 factorial arranged in randomized complete block design with three replications. Lay out was done considering the slope gradients. The land was divided in three equal blocks, each having 15 equal plots and received 15 treatment combinations. Distance between block was 1.10 m and 80cm between plots. The gross plot size for each treatment was 2.4m x 3.6m (8.64m^2). Each plot had six ridge 60cm apart. The height of ridge was 25 cm. The spacing between rows and plants was 60cm x 30cm, respectively and each plot received 48 plants. The 15 treatments were assigned to each plot by random using SAS. The treatment combinations were: Kulfo X 0, Kulfo X 100, Kulfo X 159, Kulfo X 214, Kulfo X 239, Tulla X 0, Tulla X 100, Tulla X 159, Tulla X 214, Tulla X 239, Guntutie X 0, Guntutie X 100, Guntutie X 159, Guntutie X 214 and Guntutie X 239 kg ha^{-1} NPSB.

3.4. Pre-planting Soil Sampling and Analysis

One composite soil sample was collected from selected area of 47.2m X 14.1m, at the depth of 0-20 cm from a diagonal of 49.26m in 2 ways at 10m interval with staring bench mark of 0.5m out of the selected area. A uniform volume of soil was obtained in each sample by vertical insertion of an auger. Then, the soil sample was analyzed for its chemicals property (pH, OC, N, P, and OM) (AOAC, 2005). The organic matter was calculated by multiplying the result of OC by 1.73 (OM = OC *1.73) (Page, 1982). The samples were air dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve for organic carbon to pass through 0.2 mm sieve to remove the coarser materials. Soil laboratory analyses were made at Jimma Agricultural Research.

3.4.1. Procedures for Pre-planting Soil Chemical Analysis

Soil pH: was measured in a 1:2.5 (soil: water) ratio using a glass electrode pH meter. Approximately 10 g of soil were weighed into a 60 ml plastic shaking bottles and 20 ml of deionised water was added to the soil with a dispenser. The soil-water solution was shaken thoroughly for 10 minutes, after this, the suspension was allowed to stand for 20 minutes, then, re-stirred for another two minutes. The mixture was allowed to settle for 30 seconds before the calibrated pH meter was used to read the pH by immersing the electrode into the upper part of the soil suspension and the pH values recorded (McLean, 1982).

Organic Carbon: was determined by the modified Walkley and Black procedure as described by Olson and Sommers (1982). This procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After reaction, the excess dichromate is titrated against ferrous sulphate. One gram of soil sample was weighed into an Erlenmeyer flask. A blank sample was included. Ten milliliters of 1.0 *N* (0.1667 *M*) potassium dichromate solution was added to the soil and the blank flask. To this, 20 ml of concentrated sulphuric acid was carefully added from a measuring cylinder, swirled and allowed to stand for 30 minutes in a fume chamber. Distilled water (250 ml) and a concentrated orthophosphoric acid (10 ml) were added and allowed to cool. One millimeter of diphenylamine indicator was added and titrated with 1.0 *M* ferrous sulphate solution.

Total Nitrogen: was determined by the Kjeldahl digestion and distillation procedure as described by van Reeuwijk (1992). A 0.5 g soil sample was transferred into a Kjeldahl digestion flask and 5 ml distilled water added to it. After 30 minutes, 5 ml concentrated sulphuric acid and selenium mixture were added and mixed carefully. The sample was placed on a Kjeldahl digestion apparatus for 3 hours until a clear digest was obtained. The digest was diluted with 50 ml distilled water and mixed well until no more sediment dissolved and allowed to cool. The volume of the solution was added to 100 ml distilled water and mixed well. A 25 ml aliquot of the solution was transferred to the reaction chamber and 10 ml of 40 % NaOH solution was added followed by distillation. The distillate was collected in a flask containing 2 % boric acid. The distillate was titrated with 0.02 *N* HC1 solutions with bromocresol green as indicator. A blank distillation and titration were also carried out to take care of traces of nitrogen in the reagent as well as the water used.

Available Phosphorus: The readily acid-soluble forms of P were extracted with HC1:NH_4F mixture (Bray's No. II method) as described by Olsen and Sommers (1982). Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as a reducing agent. A 2 g soil sample was weighed into a 50 ml shaking bottle and 20 ml of extracting solution of Bray (0.03 *M* NH_4F and 0.025 *M* HC1) was added. The sample was shaken for one minute by hand and then, immediately filtered through What man N<u>o</u> 42 filter paper. One ml of the standard series, the blank and the extract, 2 ml boric acid and 3 ml of the colouring agent (ammonium molybdate and antimony tartarte solution) were pipette into a test tube and homogenized. The solution was allowed to stand for 15 minutes for the blue colour to develop to its maximum. The absorbance was measured on a Spectronic 21D Spectrophotometer at 660 nm wavelength. A standard series of 0, 1.2, 2.4, 3.6, 4.8, and 6.0 mg was prepared from 12 mg P/l stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/l in 100 ml volumetric flask and made to the volume with distilled water. Aliquots of 0, 1, 2, 4, 5, and 6 ml of the 100 mg P/l of the standard solution were put in 100 ml volumetric flask and made to the 100 ml mark with distilled water.

3.4.2. Pre-planting Soil Chemical Properties Result.

The pre planting soil sample was resulted in pH of 5.11 which fall in classes of strongly acidic according to Scianna *et al.*(2007), who classify soil acidity on the bases of crop tolerance and performance as ultra-acidic (pH< 3.5), extremely acidic (pH=3.5 - 4.4), very strongly acidic (pH=4.5 - 5.0), strongly acidic (pH=5.1-5.5), moderately acidic(pH=5.6 - 6.0), slightly acid (pH=6.1- 6.5),neutral(pH = 6.6-7.3), slightly alkaline (pH = 7.4-7.8), moderately alkaline (pH =7.9 - 8.4),strongly alkaline (pH = 8.5- 9.0), and very strongly alkaline (pH > 9.0). It had a total nitrogen of 0.117% which fall in low class level according to the rating by Landon(2014), who classified soils having total N of greater than 1.0% as very high, 0.5-1.0% high, 0.2- 0.5% medium, 0.1- 0.2% low and less than 0.1% as very low in total nitrogen content. Available phosphorus content was 3.923 ppm which was fall in low rate according to the rating by Karltun *et al.* (2013), who described soils with available P content of <15 ppm as very low. The organic carbon was 2.447% which was a medium level according to the Netherlands commissioned study by Ministry of Agriculture and Fisheries(1985) which classify soil with organic carbon contents (%) >3.50, 2.51-3.5, 1.26-2.50, 0.60-1.25 and <0.60 as very high, high, medium, low and very low respectively. Generally, analyzed soil result was fall in class of low soil fertility and fertilizer use can be the right way.

3.5. Treatment Management

Vines of 30 cm long having 3 internodes were prepared from the top but not succulent one and lasted for 48 hours, before planting. Vines were planted on July 20, 2017 at 45^O slant on the prepared ridge and one third of them were covered by soil or inserted in ridge. Fertilizer NPSB was applied after 15 days of planting or after checking the success of survival vine and remaining nitrogen rate was applied after 21 days after planting (DAP) in ring placement in slight shallow made ring and covered by light fine soil. All agronomic practices were followed according to the recommendation (hoeing, earthing up, irrigation when necessary, weeding, Pest, and disease protection).

3.6. Data Collection Procedures

Ten plants were tagged from each plot from four interior rows excluding the border rows All yield and yield related data were collected from sample plants. Vegetative data were collected at start flowering and when it fully covered space 105 days after planting. All data collections were done in the morning. Data on quality were collected after the required amount of samples of storage roots were collected and prepared according to the laboratory recommendation from the tagged plant sample.

The samples were freshly prepared for β-carotene; chopped and dried partially by sun and by oven dry method to 11% moisture content and grounded by machine for flour moisture, Ash, crude fiber and fat each 105 gram weighed, packed and sent to laboratory for analysis.

3.7. Data Collected

Number of Vines Per plant (NVP): were counted from ten plants per plot.

Vine Length (VL): was measured by meter tape from average of ten plants per plots.

Vine Thickness (Vthi): was measured by Digital Caliper in mm from ten plants average (main vines) at 20cm above soil

Number of Leaves Per plant (NLP): was counted from average of five plants per plot.

Leaf Area Index (LAI): was measured from average of 15 leaves per plant; of these, 5 from lower, 5 from middle and 5 from top portion of the plants; totally from average five plants per plot leaves of which were un over lapped or responds to light.

Leaf Area: was measured by measuring the length of leaves from the entire attachment of petiole (lobe) to tips of the leaves, then, multiplied by the width, that was measured from large part of the leaves by rulers and finally multiplied by correction coefficient 0.8 for larger width part of the leaves as stated by Sutoro (1991), who used to measure leaf area of two Sweet potato varieties: Daya and Topato at 2 months after planting in Indonesia. Leaf area index (LAI) was calculated by dividing average leaf area (ALA) to the ground area (GA) and multiplied by number of leaves which were not overlapped or responds light per plant. To this experiment, it was 30cm*60cm (0.3m*0.6m), which had an area of $0.18m^2$ per plant.

$LA = 0.8 * L * W$ ………….. Sutoro (1991). ……………….*Equation (1)*

$LAI = \frac{LA}{GA}$……………….Cristofori *et al.* (2007)……………. *Equation (2)*

Where, LAI = is the leaf area index, LA= is area and GA= is the ground area, which is an area that shaded by the leaf canopy.

Storage Root Length (SRL): was measured by a hand ruler (50cm) in cm from ten plants and average of three storage roots (maximum, medium and minimum) from each sampled plants per plot.

Storage Root Girth (SRG): was measured by Digital Caliper (0-150mm) in mm from ten individual plants and average of three storage roots (maximum, medium and minimum) from each sampled plants per plot.

Above Ground Fresh Biomass Weight (AGBFW): was measured using hanging digital balance (50 kg) in kg from ten plants per plot and converted to ton per hectare.

Tuber grade: Tubers were graded into marketable (medium sized 306-399 gram and larger sized 400-645gram) and unmarketable ones (small size 200-306 gram, rotten and green) (Busha, 2006). Also by measuring root diameter from the middle portion of the storage root using Digital Calipers. Storage roots with a diameter of less than 3 cm(30mm) were considered unmarketable, while those with root diameter of 3 cm(30mm) or more were considered as marketable roots (Yeng *et al.*, 2012).

Marketable Storage Root Number Per plant (MSRNP): were counted from ten individual plants per plot.

Unmarketable Storage Root Number Per plant (UNMSRNP): were counted from ten plants per plot.

Total Storage Root Number Per plant (TSRNP): were counted from an average sum of marketable + unmarketable storage root number per plant.

Marketable Storage Root Weight Per plant (MSRWP): was measured by hanging digital balance in kg from ten plants per plot.

Unmarketable Storage Root Weight Per plant (UMSRWP): was measured by hanging digital balance in kg from ten individual plants per plot.

Total Storage Root Weight Per plant (TSWP): was measured from an average sum of marketable + unmarketable storage root weight per plant.

Marketable Storage Root Weight ton per hectare (MSRY t ha^{-1}): was measured by hanging digital balance in kg from ten plants per plot and converted to ton per hectare.

Unmarketable Storage Root Weight ton per hectare (UNMSRY t ha^{-1}): was measured by hanging digital balance in kg from ten plants per plot and converted to ton per hectare.

Total Storage Root Yield ton per hectare (TSRY t ha^{-1}): was measured from an average sum of marketable + unmarketable storage root weight per plant and converted to ton per hectare.

Harvest Index (HI): was estimated as the ratio of the total storage root yield to total biomass at harvest (i.e. sum of the storage root yield and vegetative biomass) (Yeng *et al.,* 2012)

$$\text{HI} = \frac{\text{Economic yield}}{\text{Biological yield} + \text{Economic yield}} \quad \text{...............} \textit{Eqution(3)}$$

Marketable Storage Root Yield to Total Storage Root Yield: was estimated as the ratio of the weight of the marketable storage roots to the total root yield (Yeng *et al.,* 2012).

$$\text{MSRY: TSRY} = \frac{\text{Markatable storage root yield}}{\text{Total storage root yield}} \quad \text{...............} \textit{Eqution(4)}$$

Leaf and Vine Dry Matter (LDM and VDM): samples from vine and leaf were prepared to 100gm fresh weight and dried in an oven dry forced air circulation at 70^{o}Cfor 24-72 hours until they attained constant weight.

Storage Root Dry Matter(SRDM): samples from marketable categories of tubers were taken at random from each harvested plot, sliced, chopped, composited and prepared to 100gm fresh weight and dried in an oven dry forced air circulation at 70^{o}C for 24-72 hours until they attained constant weight.

$$\text{SRDM\%} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of Sample}} * 100 \quad \text{...............} \textit{Eqution(5)}$$

Specific Gravity (SG): Two kg of tubers from marketable category were randomly selected from each harvested plot, and used for the determination of specific gravity. They were washed and air-dried to remove soil particles and to obtain accurate values by weighing first in air and, then, in water, using an electronic weighing balance.

$$\text{Specific gravity(SG gcm}^{-3}) = \frac{\text{Weight of tubrs in air}}{\text{weight of tuber in air} - \text{weight under water}} \quad \ldots \textit{Eqution(6)}$$

Starch Content (SC): Determination of Starch was computed by using the equation of Simmond (1977) which based on specific gravity. It is an indirect way of obtaining dry matter and Starch content of Sweet potato, which was cited by Namo and Babalola (2016). Therefore, Starch content was computed as a regression model:

$$\text{Starch content }\% = -2.86 + 47.1\text{U} \quad \ldots\ldots\ldots\ldots\ldots\ldots \textit{Eqution(7)}$$

$$\text{U} = \frac{5G - 5}{G} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Eqution(8)}$$

Where G = Specific gravity; U=weight under water

Crude fibre: Crude fibre was determined at Debre Zayt Agricultural Research Center (DZARC) using dilute acid and alkali hydrolysis using Fibertec (2010) by Weende method. Exactly 1.5 g of the sample was accurately taken into glass crucible, about 200 ml of boiled 1.25% H_2SO_4 was poured into the flask and the mixture boiled for 30 minutes under reflux condenser. The insoluble matter was washed with boiling 4 times until the residue was free from acid. About 200 ml of boiling 1.25% KOH solution was added into the residue and then heated for 30 minute under reflux condenser. The residue was filtered, washed with boiling water and then the crucible was transferred to the cold extraction unit and washed with acetone. After digestion, the residue was dried at 105°C in an air-convectional oven, cooled in a desiccator until constant weight was obtained. The residue was incinerated in an electric furnace at 525°C until all the carbonaceous matters were burnt. The crucible was left to cool down to below 250°C, then removed from the furnace and transferred to the desiccator, cooled to room temperature and weighed. The crude fibre was calculated and expressed as percentage (AOAC, 2005).

$$\text{Crude fiber (\%)} = \frac{\text{M1} - \text{M2}}{\text{W}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation (9)}$$

Where M1=mass of the crucible (the sand and wet residue); M2 = mass of the crucible (the sand and ash); W = sample weight dry matter basis.

Ash content: The ash content was determined by heating a sample in a muffle furnace (AOAC, 2005). Five grams of sample was weighed and transferred to a furnace at 550°C. It was stayed for minimum of five hours. The ash was weighed and expressed as percentage of the original sample weight on dry weight basis.

$$\text{Ash (\%)} = \frac{M3 - M1}{M2 - M1} * 100 \text{ ....} \textit{Equation (10)}$$

Where M_1 =Weight of the dish; M_2 =Weight of fresh sample and dish; M_3 =Weight of ash and dish.

Moisture Content (MC): The flour moisture contents of the experimental samples were determined according to AOAC (2005) method 925.09 at MARC. The empty dish with its lid was dried in the oven (Leicester, LE67 5FT, England) for 15 min and then transferred into desiccators for cooling before it was weighed to the nearest milligram. About 5g of the sample was transferred to the dish and then the dish was placed inside the oven (Leicester; LE675FT; England) at 103°C in order to dry the samples to a constant weight, cooled in desiccators and re-weighed. Then, the moisture content was estimated by the following formula:

$$\text{Moisture (\%)} = \frac{M2 - M1}{M2} * 100 \text{ ....} \textit{Equation (11)}$$

Where M1 = mass of sample after drying; M2 = mass of sample before drying

β-carotene: Extraction of total β-carotene content was done at JUCAVM, by the method described by Sadler *et al.*(1990).Three fresh tubers were chosen from 45 plots, sliced, washed, dried, chopped and 3g were homogenized. Briefly, 1g of sample was mixed with 1 g $CaCl_2.2H_2O$ and 50 ml extraction solvent (50% hexane, 25% acetone, and 25% ethanol, containing 0.1% BHT) and gently shaken for 30 min. After adding 15 ml of distilled water, the solution was frequently shaken again for a further 15 min. The organic phase, containing the β-carotene was separated from the water phase, using a separation funnel, and filtered using what man filter paper No.1. The extraction procedure was carried out under subdued light to avoid degradation of carotenoids and the extracted samples were stored for analysis. Then, sample was estimated from absorbance read at 450nm using UV-visible spectrophotometer model "V-630 JU companies, Serial No A112761148.T80 China" and compared with β-carotene standard. Pure β-carotene standard (Sigma Aldrich) was used as a standard and the measurement was compared to a standard solution (Appendix Figure 1). To draw the calibration curve, β-carotene standard stock solution was prepared by accurately weight 0.01g β-carotene standard and dissolved in 20 ml solvent which was similar to extraction solvent used to extract samples (50 % hexane, 25 % acetone, and 25

% ethanol) and made the volume to 100 ml using the same solvent. From the stock solution 0, 2, 3, 4 and 5ml were added in to 100ml flask and diluted to give 0, 0.1, 0.2, 0.4, and 0.8 mg/L of β- carotene standard in the same solvent. Then, 0.5 ml of each sample was introduced into5 test tubes, covered with aluminum foil and the absorbance was read 450nm using (UV-Vis spectrophotometer, T80 China).

β- Carotene conversions

β-carotene conversion in the body is estimated to be 6-µg β-carotene = 1µg VA or 12-µg β-carotene =1-µg VA (Trumbo *et al.,* 2001; WHO and FAO, 2005).Trumbo *et al.*(2001); WHO and FAO(2005); van Jaarsveld *et al.*(2006) reported that, the contribution of one hectare of orange fleshed Sweet potato to vitamin A requirements for a households of six family members(one adult male= 600 µg RAE/day; one adult female= 500 µg RAE/day; one 1–3 year old children = 400 µg RAE/day; one 4–6 year old children= 450 µg RAE/day; one 7–9 year old children=500 µg RAE/day and one 10–18 year old adolescent= 600 µg RAE/day. This total of 3050 µg RAE/day/hh was calculated after assuming 20% loss of β-carotene during cooking which was based on the recommended dietary allowance (RDA). The vitamin A value was expressed in µg RAEs (retinol activity equivalents) based on conversion scale which is 12 µg β-carotene = 1 µg retinol = 1 µg VA=1 µg RAE. Based on this, β-carotene yield was calculated as kg or gram or µg β-carotene produced per unit area (ha) per duration.

Partial budget and sensitivity analysis: The partial budget and sensitivity analysis of the interaction of treatments were analyzed for average yield 15 treatments following the rule stated by CIMMYT (1988). The adjusted yield, total gross benefit, variable cost (fertilizer, application and transportation costs), total variable cost (TVC), net benefit (NB) and marginal rate of return were estimated. These can be expressed as follows. Price at field level was computed from producers and from market. Then, price at field was used for this calculation.

Adjusted yield (ton ha^{-1}) = 90 % x yield obtained…………….. (Appendix Table.9),
Total Gross Benefit = Adjusted yield * farm gate price……. (Appendix Table.9),
Total variable cost=Labour coast + fertilizer cost +transportation cost (Appendix Table.7&8),
Net benefit = Total gross benefit – Total variable cost…………….. (Appendix Table.9) and

Marginal rate of return (MRR %) = $\frac{\text{Net benefit}}{\text{Total variable cost}} * 100$ ....*Equation (12)*

……………..... … …………. (Appendix Table.9).

3.8. Data Analysis

All data were subjected to analysis of variance (ANOVA) using the linear model (Lm) SAS statistical software package (SAS, Version 9.3). The total variability was detected using the following model for the

$T_{ijk} = \mu + R_i + V_j + F_k + (VF)_{jk} + \varepsilon_{ijk}$ ………………… *Equation (13)*

Where = T_{ijk} is the total variation for a given yield component, μ is the overall mean, R_i is the i^{th} replication, V_j is the j^{th} variety treatment effect, F_k is k^{th} NPSB blended fertilizer level treatment effect, $(VF)_{jk}$ is the interaction between variety and NPSB blended fertilizer level, and ε_{ijk} is the variation due to random error.

The differences between the mean values were established with Least Significant Difference (LSD) at 1% and 5% of probability level using GLM. Correlations of the variables were tested by SAS statistical software package (SAS, Version 9.3). Besides, partial budget, marginal rate of return, and sensitivity analysis were adopted by using the manual developed by CIMMYT (1988).

4. RESULTS AND DISCUSSION

4.1. Vine length, Vine number and Vine thickness of OFSP.

The result of this experiment revealed that, interaction of variety and NPSB blended fertilizer rate significantly influenced vine number, vine length ($p<0.01$) and vine thickness ($p<0.05$)(Table 4). Sweet potato variety Tulla, which received 159 kg $ha^{-1}$of NPSB fertilizer, recorded significantly the highest vine number (32.27), however, there is no significantly different from the Tulla variety at 214 kg ha^{-1} (30.33), 0 kg ha^{-1}(29.67); Kulfo variety treated with 214 kg ha^{-1}(30.8), 0 kg ha^{-1}(30.5) and 159 kg ha^{-1} (28.47) of NPSB fertilizer. The lowest vine number (20.8) was recorded in Guntutie that, received 159 kg ha^{-1} NPSB fertilizers. The main reason for this least vine number may be due to most of the energy synthesized was used to fill the storage roots than to maintain of vegetative parts. Most of the photosynthates in the vegetative parts are tranislocated to the roots for bulking. This is in line with the idea of Fliert and Braun (1999), who stated that, above ground growth, was inversely to storage root bulking as assimilates goes to the more bulking region.

Sweet potato variety Tulla, that received 100 kg ha^{-1} NPSB fertilizer recorded significantly the highest vine length (115.93 cm), however, it did not significant difference from variety Tulla, that received 214 kg ha^{-1} NPSB (103.4cm); Kulfo that received 0 kg ha^{-1} (114.1cm), 100 kg ha^{-1}(104.07cm), 214 kg ha^{-1}(104cm) and 239 kg ha^{-1} (105.5cm).Variety Guntutie, that received 214 kg ha^{-1} NPSB was resulted in least vine length (85.6cm), however, it did not significant difference from Kulfo with 159 kg ha^{-1} (96.6cm), Tulla with zero fertilizer (86.47cm), Tulla with 159 kg ha^{-1} (98.4cm); Guntutie with zero (90.3cm),100 kg ha^{-1} (97.93cm), 159 kg ha^{-1} (92.93cm) and 239 kg ha^{-1} (94cm) (Table 4). In this result, vine length negatively correlated to yield at the rate of 159 kg ha^{-1} with Kulfo and Tulla. Even though, vine length was least and non significant by Guntutie with 0 and 100 kg ha^{-1} NPSB fertilizer, it increases from 0 to 100 kg ha^{-1} and then decreases beyond 100 kg ha^{-1} (Table 4). In line with this, Boru (2017) reported that, vine length showed increase with applied P up to the rate of 46 kg ha^{-1} P_2O_5 and further increase of P reduced vine length of Awassa-83 sweet potato. Dumbuya *et al.* (2016) reported that, vine length was decreased when the application rate beyond 60 P_2O_5 kg ha^{-1}. Teshome *et al.* (2012) confirmed the same result and reported that sweet potato benefited little from P to increase its canopy.

Vine length result closer to this experiment was reported by El-Sayed *et al.*(2011) in applications of 15, 30 and 45 kg /fed P_2O_5 (35.71 kg ha^{-1} P_2O_5 or 15 .7 P kg ha^{-1}; 71.42 kg ha^{-1} P_2O_5 or 31.42 P kg ha^{-1} and 107.14 kg ha^{-1} P_2O_5 or 47.1P kg ha^{-1}) rate on "Beaure Gard" cultivar of Sweet potato. Moreover, Essilfie (2015) reported that, Apomuden grown on 15-30- 30 kg ha^{-1} NPK+ 5 ton ha^{-1}CM plot had resulted in the highest vine length and significantly different from other amended and the control plots. Okumkom grown on 30-30-30 kg ha^{-1}NPK rate had resulted in the highest vine length and significantly different from the other amended and the control plots. Beside these, Gajanayake *et al.* (2015) reported that, the vine elongation rate during the linear growth phase and node addition rate during the whole season increased linearly with temperature. Hence the temperature of the experimental site was 27.1^{o}C which is optimum for vine growth.

The interaction of variety with NPSB fertilizer rate was resulted in significance difference in Vine thickness. Tulla without fertilizer scored the least vine thickness (4.68mm). The highest was scored in Sweet potato variety Guntutie that received 100 kg ha^{-1} (5.64mm), however, it was not significant different from all treatment combination except Guntutie which received 214 kg ha^{-1} NPSB and Tulla without fertilizer (Table 4). A vine thickness by far more than this experiment was reported by Essilfie (2015) at application of 15-30-30 kg ha^{-1} NPK +5 ton ha^{-1}CM to Apomuden variety which was significantly different from other amended and the control plots. Inversely to this, Dumbuya *et al.* (2016) reported that, P fertilizer application rates had no significant effect on vine girth, but the highest and similar numerical values to this experiment was recorded at 60 kg ha^{-1} P_2O_5 which was the same as to the report of Kareem (2013).

Table 4. Interaction effect of OFSP varieties and NPSB blended fertilizer on means of vine number, length and thickness

Variety	NPSB kg ha^{-1}	Vine number	Vine length(cm)	Vine thickness (mm)
Kulfo (LO-323)	0	30.50^{ab}	114.10^{ab}	5.43^{a}
	100	26.00^{cdefg}	104.07^{abcd}	5.62^{a}
	159	28.47^{abcde}	96.60^{cdef}	5.34^{a}
	214	30.80^{ab}	104.00^{abcd}	5.29^{ab}
	239	24.10^{efghi}	105.50^{abc}	5.42^{a}
Tulla (CIP 20027)	0	29.67^{abcd}	86.47^{ef}	4.68^{c}
	100	24.00^{fghi}	115.93^{a}	5.47^{a}
	159	32.27^{a}	98.40^{cdef}	5.24^{a}
	214	30.33^{abc}	103.40^{abcd}	5.43^{a}
	239	27.65^{bcdef}	100.30^{bcde}	5.42^{a}
Guntutie (AJAC-I)	0	25.60^{defgh}	90.30^{def}	5.29^{a}
	100	22.00^{ghi}	97.93^{cdef}	5.64^{a}
	159	20.80^{i}	92.93^{cdef}	5.24^{ab}
	214	21.53^{hi}	85.60^{f}	4.79^{bc}
	239	25.87^{defgh}	94^{cdef}	5.35^{a}
Mean		26.61	98.66	5.30
CV (%)		9.8	8.6	5.3
LSD(0.05)		4.37	14.08	0.49

Means with the same letters in same column are not significantly different
N =Nitrogen, P =Phosphorus S=Sulfur, B =Boron, CV=Coefficient of Variations,
LSD= Least Significance Difference, ha^{-1} = per hectare,

4.2. Petiole length, Leaf number, Leaf area index (LAI) and Above ground biomass

The interaction effects of varieties with NPSB blended fertilizer were resulted in highly significant differences on petiole length, leaf number and above ground fresh biomass ($p<0.01$) (Appendix Table 1). Sweet potato variety Kulfo, that received 159kg ha^{-1} NPSB fertilizer resulted in the highest significance difference in Petiole length (16.33cm), however, it did not significant different from 100kg ha^{-1} with Tulla (15.19cm); Guntutie with 159 kg ha^{-1}, 214 kg ha^{-1} and 239 kg ha^{-1} (15.34 cm,15.11cm and 15.57cm) NPSB rates respectively (Table 5).

Sweet potato variety Tulla, which received 0 kg ha^{-1} and Kulfo which received 239 kg ha^{-1} NPSB resulted in the highest significant difference leaf numbers (1073.5 and 1044.25) respectively. These treatments did not significant different from Tulla, that received 214kg ha^{-1} and Kulfo, that received 159 kg ha^{-1} (943.5 and 982) respectively (Table 5). Guntutie which received 159 kg ha^{-1}NPSB fertilizers, resulted in the least leaf numbers (520.5), however, it did not significantly different from Guntutie which received 0 kg ha^{-1} (555.1), 100 kg ha^{-1} (655.5), 214 kg ha^{-1} (603.8) and 239 kg ha^{-1}(640.8) NPSB fertilizer. Even though such amount of leaf numbers was not reported, more likely to Variety Kulfo with 239kg NPSB, Essilfie (2015) reported that, the highest number of leaves per plant by Okumkom grown on 30-45-45 kg ha^{-1} NPK which was significantly different from other amended and control plots. In contrast to this, Dumbuya *et al.*(2016) reported that, leaf number did not show any significant differences at the highest 60 P_2O_5 kg ha^{-1} or 26.4 P kg ha^{-1}.

Above ground fresh biomass weight was significantly the highest different by variety Kulfo with 100 kg ha^{-1}(62.06 ton ha^{-1}), 214 kg ha^{-1}(61.27 ton ha^{-1}); Guntutie, that received 214 kg ha^{-1} (61.59 ton ha^{-1}) and 239 kg ha^{-1}(58.25 ton ha^{-1}) NPSB fertilizer, however, it was not significantly different from variety Kulfo, that received 239 kg ha^{-1}(57.24 t ha^{-1}) NPSB and Guntutie, that received 100 kg ha^{-1} (56.98 ton ha^{-1})(Table 5). The least above ground biomass fresh weight was scored by variety Guntutie with 159 kg ha^{-1} (45.08 ton ha^{-1}) NPSB fertilizer.

The above ground fresh biomass weight is the sum of all above ground vegetative parts of sweet potato plants. Kulfo, Tulla and Guntutie variety with 100 kg ha^{-1} of NPSB fertilizer rate someone may harvest higher ton of above ground biomass fresh yield, hence, their leaves used as food for human being in other countries and all of above ground parts were used for feed of cattle's fattening and milk production. For most of sweet potatoes, the above ground fresh biomass weight is inversely related to underground fresh storage root weight. In line with this, Eko-Widaryanto and Saitama (2017) reported that, dry weight partition of Sweet potato plants decline in the upper zone of soil (vegetative) and increase in the root zone and tubers, which resulted in high yield of tuber and inversely when plant production is dominated by vegetative growth, that makes leaves and stems growing excessively and lacking tuber formation due to a little carbohydrate left for tuber formation. Busha (2006) reported that, an increase from 0 to 25 kg ha^{-1} P increased biomass yield significantly. However, increase from 50 to 75 kg ha^{-1} P, there was a significant decrease in biomass yield and the highest biomass was recorded at 25 kg ha^{-1} P on ridge and flat. In Comparison to this experiment, closer above ground biomass fresh weight was reported by Mwanga *et al.*(2009), in varieties: NASPOT-7, NASPOT-8, NASPOT-9 O, NASPOT-10 O, Dimbuka-Bukulula and Tanzania (control) without fertilizer. Abdissa *et al.* (2012) stated that, even though shoot fresh weight of Sweet potato (Bellala) was benefited at the highest level of Farm yard manure (FYM), shoot dry weight was increased as the proportion of FM: P decreased. In general, P is responsible for dry matter production of every part of Sweet potato.

Leaf area index (LAI) was significantly the highest difference ($p<0.01$) by variety Guntutie, in the main effects of variety. LAI was the highest by variety Guntutie, that received 159 kg ha^{-}

^{1}($3m^2 m^{2-1}$) and 239 kg ha^{-1} NPSB ($3m^2$ m^{2-1}), however, it was not resulted significantly different in the interactions (Table.5). At this highest LAI, highest yields were recorded for Guntutie. Also highest harvestable index (HI), highest storage root length and storage root weight per plant were recorded from Guntutie. The LAI was in the range of 1.67 to 3.00 m^2 m^{2-1}. LAI was the highest significantly different in the main effects of the variety, Guntutie (2.75 m^2 m^{2-1}). In line with this experiment, Vosawai *et al.* (2015) reported that, the main effect of variety showed significant effect on LAI of variety E10136. Similarly, Eko-Widaryanto and Saitama (2017) reported that, LAI of 1.64 and 3.49 in his observation of ten varieties of sweet potato 2 months after planting (MAP) in Indonesia. He further indicated that, Sweet potatoes have 3-4 LAI which is an optimum leaf area index.

Leaves are the main surface of physiologically active exchange with the atmosphere. Processes such as: light absorption, photosynthesis, carbon absorption and assimilation, transpiration of water and emissions of organic compounds that easily evaporate through the leaf surface (Cristofori *et al.,* 2007; Fleck *et al.,* 2016). LAI did not influence storage root formation in variety Kulfo and Tulla except Guntutie. In line to this experiment Hue *et al.* (2010) reported that, high LAI on sweet potato did not had an impact on tuber formation and increase of yield. Inversely to this, Eko-Widaryanto and Saitama (2017) reported that, high LAI was caused the difficulty in the formation of generative organs because the plant continues to make the formation of vegetative organs, especially forming of leaves. A variety Guntutie had larger leave than others which was factor for high LAI. In line with this, Eko-Widaryanto and Saitama (2017) reported that, high LAI was affected by some factors like large leaf area and the number of the leaves. Beside these, Gajanayake *et al.* (2015) reported that, temperature optimum for whole-plant leaf area was 26.7°C, which is almost the temperature as that of this experimental site 27.1°C and favorable for leaf area, which resulted in optimum leaf area index.

Table 5. Main and interaction effect of OFSP varieties and NPSB blended fertilizer on petiole length, leaf number, leaf area index and above ground fresh biomass weight

Variety	NPSB kg ha^{-1}	PL(cm)	LN	AGFB (ton ha^{-1})	LAI ($m^2 m^{2-1}$)	
Kulfo (LO-323)	0	13.06^{fg}	785.50^{cdefg}	49.52^{cd}	2.00	
	100	13.31^{fg}	826.67^{bcde}	62.06^{a}	2.00	
	159	16.33^{a}	982.00^{ab}	49.84^{cd}	2.00	2.000^{b}
	214	13.45^{efg}	793.83^{cdef}	61.27^{a}	2.00	
	239	14.67^{bcde}	1044.25^{a}	57.24^{ab}	2.00	
Tulla (CIP 20027)	0	12.78^{g}	1073.50^{a}	50.95^{c}	2.00	
	100	15.19^{abcd}	794.17^{cdef}	52.69^{bc}	2.00	
	159	14.08^{def}	852.50^{bcd}	49.52^{cd}	2.00	1.875^{b}
	214	14.17^{cdef}	943.50^{abc}	50.95^{c}	1.67	
	239	13.49^{efg}	713.13^{defgh}	49.12^{cd}	1.75	
Guntutie (AJAC-I)	0	13.79^{efg}	555.13^{hi}	48.81^{cd}	2.75	
	100	14.01^{defg}	655.50^{efghi}	56.984^{ab}	2.33	
	159	15.34^{abc}	520.50^{i}	45.08^{d}	3.00	2.750^{a}
	214	15.11^{abcd}	603.83^{ghi}	61.59^{a}	2.67	
	239	15.57^{ab}	640.83^{fghi}	58.25^{a}	3.00	
Mean		14.28	773.18	53.39	2.22	2.22
CV (%)		5.05	13.6	5.4	15.	15
LSD (0.05)		1.27	183.5	5.2	NS	0.25

Means with the same letters in same column are not significantly different
N =Nitrogen, P =Phosphorus, S=Sulfur, B =Boron, PL= Petiole Length, LN=Leaf Number, LAI = Leaf Area Index, AGFB= Above Ground Fresh Biomass, CV=Coefficient of Variations, LSD= Least Significance Difference

4.3. Marketable, Unmarketable and Total Storage root number

Storage root number is one of the main components of yield in root and tuber crops; being they are the main edible organ of sweet potato. The result of this experiment showed that interaction of varieties NPSB blended fertilizer significantly influenced marketable, unmarketable and total storage root number ($p<0.01$) (Appendix Table 2). Sweet potato variety Guntutie, that received 159 kg ha^{-1} of NPSB scored significantly highest marketable storage root number (4.36), however, it was not significantly different from Guntutie, that received 239 kg ha^{-1} NPSB (3.90) (Table.6). The least marketable storage root number was scored in variety Tulla that received 100 kg ha^{-1} NPSB (2.02). In line with this, Dumbuya *et al.* (2016) reported that, among 0, 30, 60, 90 and 120 kg ha^{-1} P_2O_5 treatments, Okumkom variety with 60 kg ha^{-1} P_2O_5 resulted significantly different marketable storage root numbers than that of the control and at 120 P_2O_5 kg ha^{-1}. Similar to this experiment, Busha (2006) reported that, the highest marketable storage root numbers $hill^{-1}$ was recorded at the levels of 45N kg ha^{-1} and 25 P kg ha^{-1} fertilizer combinations.

Guntutie without NPSB fertilizer resulted in highly significant different unmarketable storage root number (1.57) and followed by Kulfo without fertilizer (1.27) (Table 6). Inversely to without fertilizer but similar number of unmarketable storage root numbers were reported by Bush (2006), who reported that, the least unmarketable tuber number per hill was recorded at 90 N kg ha^{-1} and 50 P kg ha^{-1}. Hence, fertilizer is a crucial way to improve the marketable storage root of sweet potato and reduce the unmarketable storage root number.

In total storage root number, variety Guntutie, that received 0 kg $ha^{-1}$and 159 ha^{-1} NPSB fertilizer resulted in significantly highest different with 5.07 and 5.06 respectively (Table 6). From this experiment, we can justify that, marketable grades are improved by agronomic practice like use of NPSB blended fertilizer. Due to this, size and weights of tubers were improved in the use of phosphorus containing fertilizers due to more carbohydrate storage (Archer, 1985) which resulted in higher yield.

Variety Guntutie resulted in highly significant difference in its average marketable, unmarketable and total storage root with and without fertilizer. In line with this experiment, El-Sayed *et al.* (2011) reported that, P doses increase from 0 to 45 kg ha^{-1} found to be an increase in total tuber and commercial tuber of sweet potato by 8% and 20% when 15 and 45 P_2O_5 kg ha^{-1} were applied respectively, compared to that obtained without Phosphorus (P). Busha (2006) reported that, effect of P on total tuber number was resulted in significant difference and increased tuber number up to 25 P kg ha^{-1} on ridge and 50 P kg ha^{-1}on flat seedbeds. However, when P levels were increased to 75P kg ha^{-1}, total tuber number recorded was significantly lower than the P level at 50P kg ha^{-1}. Ambecha (2001) also found that, application of 23 P kg ha^{-1} resulted in a significantly higher total tuber number in sweet potato. Busha (2006) further reported that, application of 45 N kg ha^{-1} and 25 P kg ha^{-1} resulted in significant difference in total tuber number. He also reported that, as N level was increased beyond 45N kg ha^{-1} and P level was increased from 50 to 75 P kg ha^{-1}; there was a significant decrease in total tuber number which was an agreement with that of Abdissa *et al.* (2012) who stated that, as the level of P increased from 0 to 180 P_2O_5 kg ha^{-1} average storage root number per plant decreased by 20.3% on sweet potato(Bellala) and the highest storage root number vary between four to five in number.

Table 6. Interaction effect of OFSP varieties and NPSB blended fertilizer on marketable, unmarketable and total storage root number per plant

Variety	NPSB kg ha^{-1}	MSRN per plant	UnMSRN per plant	TSRN per plant
	0	3.10^{d}	1.27^{b}	4.37^{b}
	100	2.60^{ef}	0.27^{f}	2.87^{ef}
Kulfo (LO-323)	159	2.70^{e}	0.21^{f}	2.91^{ef}
	214	2.37^{fg}	0.23^{f}	2.60^{fg}
	239	2.75^{e}	0.69^{cde}	3.44^{cd}
	0	2.35^{fg}	0.72^{cd}	3.07^{de}
	100	2.02^{h}	0.58^{de}	2.60^{fg}
Tulla (CIP 20027)	159	2.10^{gh}	0.20^{f}	2.30^{g}
	214	2.11^{gh}	0.28^{f}	2.39^{g}
	239	2.35^{fg}	0.25^{f}	2.60^{fg}
	0	3.49^{c}	1.57^{a}	5.06^{a}
	100	3.33^{cd}	0.50^{e}	3.83^{c}
Guntutie (AJAC-I)	159	4.36^{a}	0.70^{cde}	5.06^{a}
	214	2.73^{e}	0.80^{c}	3.53^{c}
	239	3.90^{ab}	0.63^{cde}	4.53^{b}
Mean		2.82	0.59	3.41
CV (%)		6.82	20.66	8.07
LSD (0.05)		0.33	0.21	0.46

Means with the same letters in same column are not significantly different
N =Nitrogen =Phosphorus, S=Sulfur =Boron, MSRN=Marketable Storage Root Numbers, UnMSRN =Unmarketable Storage Root Number, TSRN=Total Storage Root Numbers, CV = coefficient of Variations, LSD = Least Significance Difference,

4.4. Storage root girth and Storage root length

Interactions of varieties with NPSB fertilizer resulted in significantly highest different on means of storage root girth (P<0.01). The main effect of the variety resulted in significantly highest different on storage root length (P<0.01) (Appendix Table 2). Storage root girth was significantly highest difference by variety Tulla that received 159 kg ha^{-1} (79.35 mm), however, it did not significant different from Tulla with 214 kg ha^{-1} (77.21mm), 239 kg ha^{-1} (77.75mm), 100 kg ha^{-1} (74.05mm) and Kulfo that received 159 kg ha^{-1} (77.25mm) NPSB fertilizer (Table 7). The least storage root girth was recoreded from Kulfo, Tulla and Guntutie with zero level of NPSB fertilizes (56.17 mm, 55.22 mm and 56.97 mm) respectively, which had statistically parity to each other. The storage root girth was increased as NPSB increased from 0 to 159 kg ha^{-1} rate and fluctuates beyond 159 kg ha^{-1} in all tested varieties. Storage root girth played a significant role, in increasing storage root fresh weight mainly for Tulla and kulfo variety. Storage root girth reported in this study was consistent with the report of Essilfie (2015), who reported that, Apomuden grown on 15-30-30 kg ha^{-1} NPK + 5 ton ha^{-1} compost plot had the highest marketable tuber diameter and the lowest was recorded by the control. Besides, El-Sayed *et al.*(2011) reported that, P rates had significant effect on average storage root girth at 35.71 kg ha^{-1} P_2O_5 or 15 .7 P kg ha^{-1}; 71.4 kg ha^{-1} P_2O_5 or 71.42 P kg ha^{-1} and 107.14 kg ha^{-1} P_2O_5 or 47.1P kg ha^{-1} on "Beaure Gard" cultivar of Sweet potato. In Indonesia, Sari and B-2 scored a large tuber diameter (Eko-Widaryanto and Saitama, 2017), which was similar figuratively with this experiment without fertilizer.

Storage root length (16.38cm) was significantly highest on variety Guntutie, in the main effect of variety (Table.7). Kulfo and Tulla with 0 to 159 kg ha^{-1} NPSB fertilizer showed an increase in storage root length and fluctuate beyond 159 kg ha^{-1} NPSB (Table 7). As Guntutie with 0 to 239 kg ha^{-1} NPSB fertilizer increased, tuber length was increased from 15.83cm-17.19cm) (Table 7). Closely to this, Eko-Widaryanto and Saitama (2017) reported that, tuber length varies from 17.75 - 30.74 cm. Storage root length can contribute for storage root fresh weight which resulted in measurable yield of orange fleshed sweet potatoes. Related to this experiment, Essilfie (2015) reported that, Okumkom grown on 30-60-60 kg ha^{-1} NPK plot scored the highest average tuber length and the least average tuber length recorded by 15-15-15 kg ha^{-1} NPK+5 ton ha^{-1} CM plot.

Table 7. Main and interaction effect of OFSP varieties with NPSB blended fertilizer on storage root girth and storage root length

Variety	NPSB kg ha^{-1}	SRG (mm)	SRL (cm)	
Kulfo (LO-323)	0	56.17[f]	10.33	11.34[b]
	100	72.28[bcd]	11.67	
	159	77.25[ab]	12.40	
	214	66.82[de]	10.64	
	239	66.87[de]	11.37	
Tulla (CIP 20027)	0	55.22[f]	11.99	12.41[b]
	100	74.05[abc]	12.82	
	159	79.35[a]	13.40	
	214	77.21[ab]	12.30	
	239	77.75[ab]	11.78	
Guntutie (AJAC-I)	0	56.97[f]	15.83	16.38[a]
	100	66.38[de]	16.06	
	159	70.99[cd]	16.40	
	214	69.79[cd]	16.62	
	239	70.34[cd]	17.19	
Mean		69.42	13.52	13.52
CV (%)		5.18	11.1	11.1
LSD(0.05)		5.95	NS	1.13

Means with the same letters in same column are not significantly different
N =Nitrogen, P =Phosphorus, S=Sulfur, B =Boron, SRL=Storage Root Length, SRG = Storage Root Girth, CV =Coefficient of Variations, LSD = Least Significance Difference

4.5. Marketable, Unmarketable and Total Fresh storage root weight Per plant

Mean of marketable, unmarketable and total fresh storage root weight per plant were significantly highest different in the interactions OFSP variety with NPSB fertilizer ($p<0.01$) (Appendix Table.3). Mean of marketable fresh storage root weight per plant were significantly highest different by variety Guntutie, that received 159 kg ha^{-1},214 kg ha^{-1} and 239 kg ha^{-1} NPSB fertilizer rate (1.14 kg,1.08 kg and 1.14 kg) respectively (Table 8). Next to these, Kulfo and Tulla, those received 159 kg ha^{-1} NPSB fertilizer, were scored marketable storage weight of 0.8583kg and 0.8497 kg per plant respectively. In line with this, Dumbuya *et al.*(2016), reported that, among 0, 30, 60, 90 and 120 P_2O_5 kg ha^{-1} fertilizers with Okumkom variety in Ghana, marketable root yield per plant was significantly highest difference at application of 60 kg ha^{-1} P_2O_5 than those of 30 kg ha^{-1} P_2O_5 and control one.

Variety Tulla with application of 100 kg $ha^{-1}$of NPSB fertilizer resulted in significantly highest difference in means of unmarketable fresh storage root weight (0.0148 kg) per plant (Table 8). This result was directly proportional to mean of vine length and vine thickness with same variety and level NPSB fertilizer, however, it was inversely to quality grade or marketable yield. Application of 239 kg ha^{-1} NPSB on variety Kulfo scored 0.0097 kg unmarketable fresh storage root weight. Application 100 kg ha^{-1}, 159 kg ha^{-1} and 214 kg ha^{-1} levels of NPSB on Guntutie scored 0.0098 kg, 0.0116 kg and 0.0119 kg of unmarketable fresh storage root weight per plant respectively (Table 8).

Mean of total fresh storage root weight per plant was significantly highest different by variety Guntutie, that received 159 kg ha^{-1}, 214 kg ha^{-1} and 239 kg ha^{-1} NPSB, with the score of 1.15kg, 1.09kg and 1.149kg respectively (Table 8). Following this highest significance, Kulfo and Tulla, those received 159 kg ha^{-1} NPSB fertilizer scored 0.862 kg and 0.856 kg per plant in their respective way; however, they did not significant difference from each other and from Guntutie with 100 kg ha^{-1} (0.849kg) per plant (Table 8).

In general, these varieties were resulted significant different with 159 kg ha^{-1} NPSB. This rate will be used to harvest more storage root weight per plant. In line with this, Essilfie (2015) reported that, application of 30-60-60 kg ha^{-1} NPK to Apomuden differed significantly from other amended and the control plots in storage root fresh weight per plant in Nigeria. In Indonesia, Sari variety had high and followed by P-sollosa in fresh storage root weight per plant which was similar in figurative weight, but differ in treatment to this experiment (Eko-Widaryanto and Saitama, 2017).

Table 8. Interaction effect of OFSP varieties and NPSB fertilizer on marketable, unmarketable and total storage root weight per plant

Variety	NPSB kg ha^{-1}	MSRWP(kg)	UnMSRWP(kg)	TSRWP(kg)
	0	0.5161^{f}	0.0062^{cde}	0.5224^{h}
	100	0.6347^{cde}	0.0059^{cde}	0.64061^{efg}
Kulfo (LO-323)	159	0.8583^{b}	0.0039^{ef}	0.8622^{b}
	214	0.5821^{def}	0.0063^{cde}	0.5884^{fgh}
	239	0.6534^{cde}	0.0097^{b}	0.66312^{defg}
	0	0.5559^{ef}	0.0068^{dc}	0.5628^{gh}
	100	0.7328^{c}	0.0148^{a}	0.7475^{cd}
Tulla (CIP 20027)	159	0.8497^{b}	0.0068^{dc}	0.8565^{b}
	214	0.6021^{def}	0.0045^{def}	0.6066^{fgh}
	239	0.7107^{c}	0.0026^{f}	0.7134^{de}
	0	0.6646^{cd}	0.0068^{dc}	0.6714^{def}
	100	0.8400^{b}	0.0098^{b}	0.8498^{bc}
Guntutie (AJAC-I)	159	1.1400^{a}	0.0116^{b}	1.1516^{a}
	214	1.0829^{a}	0.0119^{b}	1.0949^{a}
	239	1.1419^{a}	0.0071^{c}	1.1490^{a}
Mean		0.7756	0.0075	0.7831
CV (%)		7.95	20.20	7.80
LSD(0.05)		0.103	0.0025	0.1025

Means with the same letters in same column are not significantly different N=Nitrogen, P=Phosphorus, S=Sulfur, B=Boron, MSRWP=Marketable Storage Root Weight Per plant, UnMSRWP = Unmarketable Storage Root Weight Per plant, TSRWP=Tal Storage Root Weight Per plant, CV= Coefficient of Variations, LSD= Least Significance Difference

4.6. Marketable, Unmarketable and Total Fresh storage root yield ton Per hectare

The interactions of varieties with NPSB fertilizer rates were resulted in significantly highest difference in mean of marketable, unmarketable and total fresh storage root yield ton per hectare ($p<0.01$) (Appendix Table 3). Mean of marketable fresh storage root yield ton per hectare was significantly highest different by variety Guntutie, that received 159 kg ha^{-1}, 214 kg ha^{-1} and 239 kg ha^{-1} NPSB fertilizer (63.33 ton ha^{-1}, 60.16 ton ha^{-1} and 63.44 ton ha^{-1}) respectively (Table.9). Following these, variety Kulfo and Tulla, that received 159 kg ha^{-1} NPSB fertilizer, scored 47.68 ton ha^{-1} and 47.21 ton ha^{-1} yield respectively, however, they did not significant difference from each other and from Guntutie with 100 kg ha^{-1} NPSB which scored 46.67 ton ha^{-1} marketable yield. At 159 kg ha^{-1} NPSB, Kulfo scored 39.84%, Tulla scored 34.56 % and Guntutie scored 41.7% marketable yield advantage over the control. At this rate Kulfo scored 9.6%, Tulla scored 8.7 % and Guntutie scored 31.9% marketable yield advantage over all the interaction mean of treatments. In line with this, El-Sayed *et al.* (2011) reported that, P rates resulted in a significant effect on total marketable yield at 15, 30 and 45 kg /fed P_2O_5 (35.71 kg ha^{-1} P_2O_5 or 15 .7 P kg ha^{-1}; 71.4 kg ha^{-1} P_2O_5 or 31.42 P kg ha^{-1} and 107.14 kg ha^{-1} P_2O_5 or 47.1P kg ha^{-1}) on "Beaure Gard" cultivar of sweet potato. Similarly, Yeng *et al.* (2012) reported that, the sole inorganic fertilizer 30:30:30.N.P.K (200 kg IF ha^{-1}) produced marketable storage root yield 76 % more than the control, which can be very significant for a small holder farmer in Guinea savanna. Hassan *et al.* (2005) found that, fertilization of Sweet potato with P fertilizer caused significant increase in marketable and total yield.

Mean of unmarketable fresh storage root yield (0.82 ton ha^{-1}) was significantly highest different by variety Tulla, that received 100 kg ha^{-1} of NPSB fertilizer (Table 9). It was Followed by Kulfo with 239 kg ha^{-1}(0.54 ton ha^{-1}) and Guntutie with 100 kg ha^{-1}, 159 kg ha^{-1} and 214 kg ha^{-1} were scored 0.54 ton ha^{-1}, 0.65 ton ha^{-1} and 0.67 ton ha^{-1} unmarketable fresh storage root yield respectively, however, they did not significant difference from each other (Table 9). Means of total fresh storage root yield ton per hectare was significantly highest different by variety Guntutie, that received 159 kg ha^{-1}, 214 kg ha^{-1}, and 239 kg ha^{-1} NPSB which scored 63.98 ton ha^{-1}, 60.83 ton ha^{-1} and 63.83 ton ha^{-1} respectively (Table.9). Following this significantly highest difference, Kulfo and Tulla, those received 159 kg ha^{-1} NPSB fertilizers scored 47.899 ton ha^{-1} and 47.59 ton ha^{-1} in their respective way; however, they did not significant difference from each other and Guntutie with 100 kg ha^{-1} NPSB which scored 47.21 ton ha^{-1} (Table 9).

Means of marketable fresh storage root yield ton per hectare and mean storage root girth with the same variety that received the same NPSB level were resulted in significant different. These tested varieties with 159 kg ha^{-1} were resulted in high yield. At 159 kg ha^{-1} NPSB, Kulfo scored 39.41%, Tulla scored 34.2 % and Guntutie scored 47.7% total yield advantage over the controle. From this fact, both varieties and agronomic practices have an influence on storage root number and girth which has a relation with weight per plant (hill) and yield ha^{-1}. In line with this, Dumbuya *et al.*(2016) reported that, among 0, 30, 60, 90 and 120 kg ha^{-1} P_2O_5 treatments with Okumkom variety in Ghana, significant highest root yield was recorded at 60 kg ha^{-1} P_2O_5 fertilizer. Yeng *et al.* (2012) reported that, sole inorganic fertilizer 30:30:30NPK (200 kg ha^{-1}) produced total root yield 79% more than the control.

El-Sayed *et al.* (2011) indicated that, yields were increased with increasing P rate at 15, 30 and 45 kg /fed P_2O_5 (35.71 kg ha^{-1} P_2O_5 or 15 .7 P kg ha^{-1}; 71.4 kg ha^{-1} P_2O_5 or 31.42 P kg ha^{-1} and 107.14 kg ha^{-1} P_2O_5 or 47.1 P kg ha^{-1}) on "Beaure Gard" cultivar of sweet potato respectively. Busha (2006) also reported that, increasing P levels from 0 to 25 P kg ha^{-1} increased total tuber yield by 20 % with Koka-18 on ridge. Ambecha (2001) found that, application of 46 N kg ha^{-1} along with 23 P kg ha^{-1} recorded significantly the highest total tuber yields on Sweet potato which was further supported by the positive correlation between total tuber yield and the N and

P applied. Again Busha (2006) reported that, increasing N level from 0 to 45 N kg ha^{-1} and P level from 0 to 25 P kg ha^{-1} significantly increased total tuber yield (ton ha^{-1}). He further indicate that, increasing N and P supply beyond 45 kg ha^{-1} and 25 kg ha^{-1} respectively did not bring about significant increase in total tuber yield.

Essilfie (2015) reported that, a significant difference occurred between Okumkom grown on the different rate of amendments of fertilizer like 10 ton ha^{-1} CM , 30-30-30 kg ha^{-1} NPK, 15-15-15 kg ha^{-1} NPK + 5 ton ha^{-1} CM, 30-45-45 kg ha^{-1} NPK,15-23-23 kg ha^{-1} NPK +5 ton ha^{-1} CM , 30-60-60 kg ha^{-1} NPK,15-30-30 kg ha^{-1} NPK +5 ton ha^{-1} CM produced a yield of 38.0, 52.0, 66.0, 49.0, 62.0, 85.0, 93.0 and 89.3 in ton ha^{-1} of yield respectively. Different researchers report different yield potential of Sweet potato varieties. In line to this experiment figurative yield, Abdissa *et al.*(2011) reported that, Sweet potato yield can reach up to 64.4 ton ha^{-1} in the use of agronomic practices from Bellala variety. Gurmu and Mekonen (2017) reported that, Hawassa-09 (TIS-8250) is a WFSP variety gave a mean storage root yield of 49.2 ton ha^{-1} with 56% and 283% yield advantage over the standard (released variety) and local check evaluated respectively, in southern area without fertilizer. Application of NPSB fertilizer was effective to this experiment on yield and quality of OFSP, being, it contains S and B nutrients. In line with this, Byju *et al.*(2007) reported that, boron prevent splitting of tubers; as a result, total tuber yield increased significantly in application B up to 1.5 kg ha^{-1} and further increase in the rate of B fertilizer did not yield any further significant increase in total tuber yield. Application of sulfur containing fertilizers like NPS improves availability of micronutrients through amending the soil pH (Marschner, 1996; Yayeh *et al.*, 2017) which may in turn increase yields of vegetable crops including Potato and Sweet potato.

Saif-EI-Dean (2005); El-Sayed *et al.* (2011) found that, weight loss and decay were negatively correlated with P rates application. Increasing P rate up to 60 kg /fed P_2O_5 or 142.85 P_2O_5 kg ha^{-1} or 62.85 P kg ha^{-1} significantly decreased the percentages of weight loss during storage. Furthermore, as this experiment conducted on the ridge, higher marketable and total storage root yield per hectare was observed. Similar to this, Brobbey (2015); Dumbuya *et al.* (2016) reported that, ridge had increased yield of sweet potato. It increased 38% of sweet potato yield (Ennin *et al.*, 2007; Ennin *et al.*, 2009) and yam (Danquah *et al.*, 2014). This may it be due to less Evapotranspiration from soil moisture, facilitate aeration, root development and other agronomic activities.

Table 9. Interaction effect of OFSP varieties and NPSB blended fertilizer on means of marketable, unmarketable and total storage root yield.

Variety	NPSB kg ha^{-1}	MSRY (ton ha^{-1})	UnMSRY (ton ha^{-1})	TSRY (ton ha^{-1})
Kulfo (LO-323)	0	28.68^{f}	0.35^{cde}	29.02^{h}
	100	35.26^{cde}	0.33^{cde}	35.59^{efg}
	159	47.68^{b}	0.22^{ef}	47.899^{b}
	214	32.34^{def}	0.35^{cde}	32.69^{fgh}
	239	36.3^{cde}	0.54^{b}	36.84^{defg}
Tulla (CIP 20027)	0	30.89^{ef}	0.38^{cd}	31.27^{gh}
	100	40.71^{c}	0.82^{a}	41.53^{cd}
	159	47.21^{b}	0.38^{cd}	47.59^{b}
	214	33.45^{def}	0.25^{def}	33.70^{fgh}
	239	39.49^{c}	0.14^{f}	39.63^{de}
Guntutie (AJAC-I)	0	36.92^{cd}	0.38^{cd}	37.30^{def}
	100	46.67^{b}	0.54^{b}	47.21^{bc}
	159	63.33^{a}	0.65^{b}	63.98^{a}
	214	60.16^{a}	0.67^{b}	60.83^{a}
	239	63.44^{a}	0.39^{c}	63.83^{a}
Mean		43.09	0.42	43.51
CV (%)		7.95	20.29	7.82
LSD(0.05)		5.74	0.14	5.69

Means with the same letters in same column are not significantly different
N=Nitrogen, P=Phosphorus, S=Sulfur, B=Boron, MSRY=Marketable Storage Root Yield, UnMSRY= Unmarketable Storage Root Yield, TSRY = Total Storage Root Yield, CV =Coefficient of Variations, LSD= Least Significance Difference,

4.7. Harvest index (HI), Ratio of Marketable to Total storage root yield (MSRY: TSRY), Leaf dry matter, Vine dry matter and Storage root dry matter

The interaction of Varieties and NPSB fertilizer rate resulted in significantly highest difference on means of harvest index (HI), ratio of marketable to total storage yield (MSRY: TSRY) and storage root dry matter content ($p<0.01$);leaf dry matter and vine dry matter($p<0.05$) (Appendix Table 4).

Guntutie, that received 159 kg ha^{-1} NPSB fertilizer was resulted in highly significant difference in mean of harvest index (0.58). Following this, Guntutie with 239 kg ha^{-1} (0.52) and 214 kg ha^{-1}(0.49) were resulted in high HI, however, they did not significant difference from each other. Also from Tulla and Kulfo with 159 kg ha^{-1} those scored 0.48 and 0.48 harvest index (HI) respectively (Table.10). The harvest index was proportional to marketable and total fresh storage root yield in ton ha^{-1} and also with marketable and total fresh storage weight per plant. It was also the result of marketable storage root number, total storage root number, storage root girth and storage root length. It was inversely proportional to above ground fresh biomass weight. In line with this, Busha (2006) found that, N and P application resulted in significant differences in fresh weight harvest index. As the combination levels of N and P increased beyond 45 N kg ha^{-1} and P levels from 25 to 75 P kg ha^{-1}, a significant decrease in fresh weight harvest index was recorded. He further indicated that, increasing N levels from 0 to 45 N kg ha^{-1} and P levels at 0 – 23 P kg ha^{-1}, recorded the maximum fresh weight base harvest index. Essilfie (2015) reported that, application of 30-45-45 kg ha^{-1} NPK to Apomuden produced the highest harvest index (0.65) and the lowest was recorded by the control plot (0.52). He also indicated that, 30-30-30 kg ha^{-1} NPK, 30-60-60 kg ha^{-1} NPK and 15-30-30 kg ha^{-1} NPK+5 ton ha^{-1} CM plots had the same mean (0.64).

Besides, Mbwaga (2007) stated that, high yielding varieties invest more assimilates in roots than in leaves. This is true for varieties SP2001/264, 199024.1 and 440443 which had low foliage to root ratio. However, low yielding varieties like 199004.2 and 102020.2 had high foliage to root ratio. Hartemink *et al.* (2000); Yeng *et al.* (2012) reported that, higher fresh vine weight at harvest tends to lower storage root yield and subsequently lower harvest index. This could be attributed to high partitioning of assimilates to vegetative biomass at the expense of storage roots or sinks and they have observed that high vegetative growth results in low root yield and subsequently lower harvest index.

Marketable to total storage root ratio of 0.996 was significantly highest different by variety Tulla , that received 239 kg ha^{-1} NPSB Fertilizer, however, it did not significant different from Kulfo with 159 kg ha^{-1} and Guntutie with 239 kg ha^{-1} NPSB which scored 0.995 and 0.994 respectively (Table 10). Marketable to total storage root ratio was ranged from 0.980 to 0.996. An agreement to this, Essilfie (2015) reported that, of Application of 15-23-23 kg ha^{-1} NPK+5 ton ha^{-1} CM to Apomuden produced the highest marketable to total storage root ratio (0.97) and the least (0.86) was recorded by the control. He further stated that, Okumkom grown on 30-30-30 kg ha^{-1} NPK and 15-15-15 kg ha^{-1} NPK+5 ton ha^{-1} CM plots had scored the same, with their highest marketable to total storage root ratio (0.91) and the least (0.73) scored 15-30-30 kg ha^{-1} NPK + 5 ton ha^{-1} CM plot. He also decided that, there was no significant difference between amendments and the control in marketable to unmarketable storage root ratio

Mean leaf dry matter 23.77 % was recorded as significantly highest different by variety Guntutie, that received 214 kg ha^{-1} NPSB fertilizer, however, it did not significantly differ from Guntutie with 0 kg ha^{-1}, 100 kg ha^{-1} and 159 kg ha^{-1} (21.39%, 22.12% and 21.14%) and Kulfo with 239 kg ha^{-1}(21.44%) NPSB fertilize in their respective way (Table 10). Variety Kulfo with

214 kg ha^{-1}NPSB was scored the least 17.72% leaf dry matter. In Tulla with NPSB fertilizer, there was an increase in leaf dry matter from 18.02 to 20.51% with an increased of NPSB from 0 to 239 kg ha^{-1} respectively (Table 10). Unlike Tulla, Kulfo decreased in leaf dry matter content (19.6 to 17.72%) as NPSB fertilizer increased from 0 to 214 kg ha^{-1} in respective Way.

Mean of vine dry matter of 18.86 % was recorded as significantly highest different by variety Kulfo that received 100 kg ha^{-1} NPSB, however, it did not significantly differ from the Tulla without fertilizer (18.03%), Guntutie without (17.06%) and Guntutie with 100 kg ha^{-1} (17.35%) NPSB fertilizer (Table.10).Vine dry matter was played a great role for significantly highest result of above ground fresh biomass weight in variety Kulfo, which received 100 kg ha^{-1}. It was proportional to vine length. Therefore, Kulfo with 100 kg ha^{-1} was resulted in best harvest of above ground fresh biomass as well as vine dry matter weight. This may be important for feed of animals beside its fresh storage root for food in current climate situation in which erratic rains and drought become a prone.

Mean dry matter of storage root 35.4% was recorded as significantly highest different by Variety Tulla, which received 159 kg ha^{-1} NPSB fertilizer. This was not significantly different from Tulla with 239 kg ha^{-1} (33.39%), kulfo with 159 kg ha^{-1} (33.48%) and 214 kg ha^{-1} (33.23%) (Table 10). The dry matter increased from 24.23 to 33.48% as NPSB fertilizer increased from 0 to 159 kg ha^{-1} with Kulfo variety, from 25 to 35% as NPSB fertilizer rate increased from 0 to159 kg ha^{-1} with Tulla and from 22.07 to 30.52% as NPSB fertilizer increased from 0 to 214 kg ha^{-1} with Guntutie (Table.10). In line with this study, Dumbuya *et al.* (2016) reported that, among 0,30,60,90 and 120 kg ha^{-1} P_2O_5 treatments with Okumkom variety in Ghana, root dry matter content at 60 kg ha^{-1} P_2O_5 (36.42%) was significantly higher than other treatments, except for the 90 kg ha^{-1} P_2O_5 (35%). Dry matter is one of primary important in any food and feed crops. Most scholars' literatures sated that, orange fleshed Sweet potatoes had a lower dry matter which was less than white fleshed Sweet potatoes. Those varieties of Sweet potato scored more than 25% dry matter, are said to be more important, mainly orange fleshed Sweet potatoes. From this experiment result, we founded that, 22.1% - 35.4% of dry matter by varieties with NPSB fertilizer (Table 10).

This experiment was resulted in an improvement of dry matter, in application of NPSB fertilizer to Sweet potato varieties (Kulfo, Tulla and Guntutie), which is important for fresh storage root of OFSP. Similar to this experiment, Afuape *et al.* (2014), found that, dry matter ranged between 24.16 (CIP 199034.1) and 34.17% (TIS 87/0087) in his evaluation of 14 Sweet potato genotypes with application of NPK (60:60:60) fertilizer 400 kg ha^{-1} in Nigeria. Gwandu *et al.* (2012)

reported that, dry matter ranged from 22.8% to 42.2% in varieties, he had tested. In terms of coast benefit analysis, yield and quality, varieties with 159 kg ha^{-1} are more important for best harvest of yield as well as dry matte, being it improved to preferred higher level. In line with this, Alemayehu and Jemberie (2018) reported that, dry matter was significantly influenced by interaction effect of NPS fertilizer and Potato variety (NPS rate × variety). El-Sayed *et al.* (2011) found that, P rates reflected a significant effect on storage root dry matter wich scored 26.84 - 30. 47 % at 15, 30 and 45 kg /fed P_2O_5 (35.71 kg ha^{-1} P_2 O_5 or 15 .7 P kg ha^{-1}, 71.4 kg ha^{-1} P_2O_5 or 31.42 P kg ha^{-1} and 107.14 kg ha^{-1} P_2O_5 or 47.1 P kg ha^{-1}) with "Beaure Gard" cultivar of Sweet potato respectively. Boru *et al.* (2017) reported that, the highest percent of dry matter response was recorded at 69 kg ha^{-1} P_2O_5 and the least dry matter was recorded at control. Kareem (2013) indicated that, application of phosphorus lead to trapping enough solar energy for higher food production which will finally be tranislocated to the roots for appreciable tuber development, better root dry matter and bulking which is the ultimate target of crop production.

The highest root dry matter was recorded on ridge and on flat at 25 P kg ha^{-1} and 45 N kg ha^{-1} respectively. Increased P level from 0 to 25 P kg ha^{-1} resulted in increased root dry matter over the control by 46 % g per hill on ridge. But when N levels were increased beyond 45 N kg ha^{-1} and P levels were increased from 50 to 75 P kg ha^{-1} respectively, there was no significant variation in root dry matter of Sweet potato Koka-18 (Busha, 2006). He further indicated that, N levels increased beyond 45N kg ha^{-1}, significant decreased storage root dry matter by 12% or by 49 g hill $^{-1}$. The highest root dry matter (337.7 g hill $^{-1}$) was recorded at 45 kg ha^{-1} N and 25 kg ha^{-1} of P level. Yeng *et al.*(2012) reported that, storage root dry matter content ranged from 11.5 to 34.3% and varied significantly in different with the highest at 150 kg IF + 1.5 ton CM ha $^{-1}$ and 50 kg IF + 4.5 ton CM ha^{-1} treatments which was three times that obtained in the control in Guina savanna. In general, a good supply of phosphorus is associated with increased root growth, roots proliferate extensively, encourage extensive exploitation of immobile nutrients and increase root dry matter through efficient uses.

Tulla scored the highest dry matter and followed by Kulfo. In line with this, Nyarko (2015) reported that, Santom Pona showed significant difference as compared with Apomuden with dry matter of 34.4% and 21.9% respectively. Afuape (2014) reported that, Variety King-J which is light orange-fleshed sweet potato scored average storage root dry matter of 30-32%, Variety Mother's Delight which is deep orange-fleshed sweet potato, scored dry matter of 20-22% and Variety UM USP/2 which is pure white-fleshed sweet potato scored mean dry matter of 28% in Nigeria. Vimala *et al.* (2011) stated that, dry matter content of 42 hybrids line evaluated varied from 18.5 - 29.2% in India. Mwanga *et al.(*2009) stated that, NASPOT -7 scored average dry matter weight of 30.1% across the site in Uganda. The combination of high dry matter (>25 %) and starch helps in selection of cultivars (Lebot, 2010).

Table 10. Interaction effect of OFSP varieties and NPSB blended fertilizer on means of harvest index (HI), marketable to total storage root yield ratio, leaf dry matter, vine dry matter

Variety	NPSB kg ha^{-1}	HI	CHI	LDM (%)	VDM (%)	SRDM (%)
Kulfo (LO-323)	0	0.369^{fg}	0.9880^{efg}	19.60^{bcdef}	15.32^{cdefg}	24.23^{ij}
	100	0.364^{fg}	0.9906^{cdef}	19.12^{cdef}	18.86^{a}	28.18^{efg}
	159	0.489^{bc}	0.9953^{ab}	18.52^{def}	15.68^{cdef}	33.48^{ab}
	214	0.347^{g}	0.9890^{defg}	17.72^{f}	14.30^{fg}	33.23^{abc}
	239	0.391^{f}	0.9855^{g}	21.44^{abc}	14.65^{defg}	27.25^{fgh}
Tulla (CIP 20027)	0	0.379^{fg}	0.9876^{fg}	18.02^{ef}	18.03^{ab}	25.05^{hi}
	100	0.441^{d}	0.9803^{h}	18.49^{ef}	16.04^{bcdef}	31.26^{bcd}
	159	0.489^{bc}	0.9920^{bcde}	19.28^{cdef}	16.5^{bcde}	35.40^{a}
	214	0.398^{ef}	0.9926^{abcd}	20.03^{bcdef}	16.68^{bcd}	30.67^{bcde}
	239	0.447^{d}	0.9963^{a}	20.51^{bcde}	15.63^{cdef}	33.39^{abc}
Guntutie (AJAC-I)	0	0.433^{de}	0.9895^{defg}	21.39^{abc}	17.07^{abc}	22.078^{j}
	100	0.454^{cd}	0.9883^{efg}	22.12^{ab}	17.35^{abc}	25.77^{ghi}
	159	0.587^{a}	0.9900^{cdef}	21.14^{abcd}	14.49^{efg}	29.31^{def}
	214	0.496^{b}	0.9890^{defg}	23.77^{a}	15.69^{cdef}	30.52^{cde}
	239	0.523^{b}	0.9940^{abc}	19.68^{bcdef}	13.46^{g}	28.19^{efg}
Mean		0.443	0.9903	20.076	16.04	29.29
CV (%)		5.17	0.25	7.98	7.94	5.95
LSD(0.05)		0.038	0.0042	2.65	2.14	2.89

Means with the same letters in same columns are not significantly different
LDM =Leaf Dry Matter, VDM = Vine Dry Matter, SRDM = Storage Root Dry Matter,
HI = Harvestable Index, CHI= Commercial Harvest Index, CV =Coefficient of variations,
LSD=Least Significance Difference

4.8. Beta Carotene (β-carotene) Content

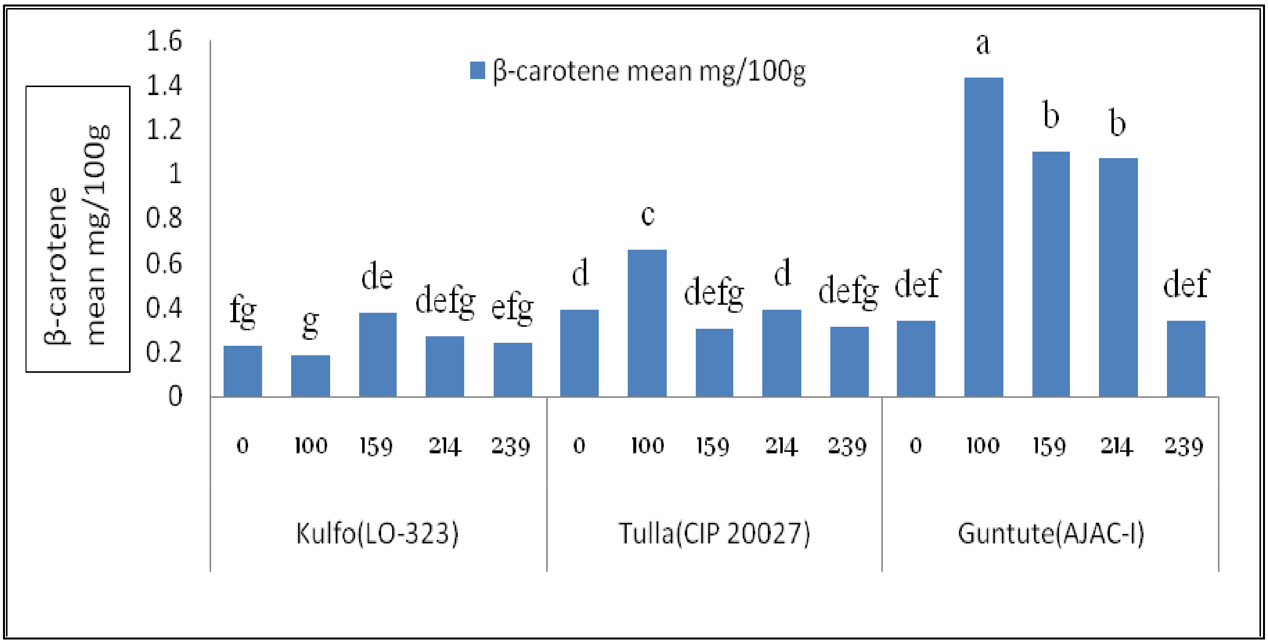
β-carotene content of fresh storage root of OFSP significantly highest different in interactions of OFSP varieties and NPSB fertilizer ($p<0.01$) (Appendix Table.5). OFSP variety Guntutie, that received 100 kg ha^{-1} NPSB was scored 1.4298mg/100g fwb β-carotene, which was significantly highest different. It was followed by Guntutie with 159 kg ha^{-1} and 214 kg ha^{-1} which scored 1.098mg/100g fwb and 1.065 mg/100g fwb β-carotene content respectively (Figure 1). OFSP Variety Kulfo, that received 159 kg ha^{-1} and 214 kg ha^{-1} NPSB fertilize were scored 0.376mg/100g fwb and 0.267mg/100g fwb of β-carotene respectively. OFSP variety Tulla that received 100 kg ha^{-1} scored 0.6619 mg/100g of β-carotene (Figure 1; Appendix Table 6).

In terms of β-carotene yield per hectare, high β-carotene contents were obtained from OFSP variety Guntutie with 159 kg ha^{-1}, 214 kg ha^{-1}, and 239 kg ha^{-1} NPSB fertilizer. Following this, variety Kulfo, which received 159 kg ha^{-1} and Tulla, which received 100 kg ha^{-1} NPSB fertilizer, scored high β-carotene content due to indirect influence of mean marketable fresh storage root yield in ton ha^{-1}(Figure 2; Appendix Table 6). Therefore, 159 kg ha^{-1} NPSB fertilizer with these OFSP varieties is important for further harvest of high β-carotene content mg/100g per hectare.

The β-carotene contents were varying within variety and fertilizer level. In line with this, Degras (2003) reported that, applications of phosphorus increase the carotene content of tuberous roots of sweet potato in higher yield and affects the unit weight of root tubers. Afuape *et al.* (2014) reported that, β-carotene between 0.58 µg/g or 0.058mg/100g fwb (NRSP/05/3D) and 20.82 µg/g or 2.1mg/100 fwb (CIP440293) in his evaluation of 14 sweet potato genotypes with application of NPK (60: 60: 60) fertilizer 400 kg ha^{-1} in Nigeria. Abd El-Baky *et al.* (2010) founded increases in carotene content with potassium application, as well as with zinc application. Essilfie (2015) indicated that, organic and inorganic fertilizers either singly or in combination resulted in significant effect on β-carotene content of tubers which varies from 1.1-14.9 mg/100g for Apomuden and 0.2- 0.7 mg/100g for Okumkom. He further indicate that, Okumkom grown on 30-60-60 kg ha^{-1} NPK plot had the highest β-carotene content (2.87mg/100g) of tubers followed by 15-23-23 kg ha^{-1} NPK+5 ton ha^{-1} CM with the lowest by 15-15-15 kg ha^{-1} NPK+5 ton ha^{-1} CM. Nyarko (2015) found that, the β-carotene content of NPK 200 kg ha^{-1} (30:30:30) treatment effect was highest which scored 32.9% its dry matter. Laurie *et al.*(2012) reported that, β-carotene yield increased two-fold at the intermediate(50% was 75, 15 and 95 kg ha^{-1}) and four-fold at the high (100% treatment 150, 30 and 190 kg ha^{-1}) NPK fertilization treatment respectively with Resisto and W-119 orange fleshed Sweet potatoes. He also reported that β-carotene content was 14% higher for both intermediate (50%) and high (100%) fertilizer treatments, compared to the 0% fertilizer treatment with Resisto and W-119 OFSP.

The genotype Guntutie scored highest β-carotene. Similarly, Mbwaga (2007) reported that, among genotypes, β-carotene concentration was significantly different and the concentration in roots varied from 0.13 to 55.27 µg/100g or 0.00013 to 0.05527 mg/100g. Variety 101055 SPK004 and Resisto resulted in high average β-carotene concentration across sites and the lowest varieties were 440443 and SPNO that accumulated low β-carotene concentration of 6.37µg/100g (0.00637mg/100g) and 0.70 µg/100g (0.00070mg/100g), respectively. This is very low concentration as compered to this experiment result even at zero fertilizer level. The β-carotene amounts found in mango (*Mangifera indica*) (245-625 µg/100g fwb) also less than this experiment (Mulokozi, 2003). The β-carotene amounts reported by Mbwaga (2007) by far lower than the amount in Mango and the amount obtained in this experiment. Vimala *et al.* (2011)

reported that, Hybrid varieties like 106097-13, 106582-17, 106665-4, 106735-10 and 106735-11 scored β-carotene concentration of 1.17, 1.17, 1.32, 1.04 and 1.32mg/100g respectively in India. Kathabwalika *et al.* (2016) reported that, genotypes LU06/0258(2019.5 µg/100 g or 2.0195 mg/100g) and LU06/0299 (1489.7 µg/100 g or 1.4897 mg /100) scored β- carotene value which was similar to Guntutie with interaction of NPSB fertilizer rate.



Mean= 0.51236, CV (%) =15.58 , LSD(0.05) = 0.1375
Means with the same letters on the top of bar are not significantly different
CV = Coefficient of Variations, LSD= Least Significance Difference,

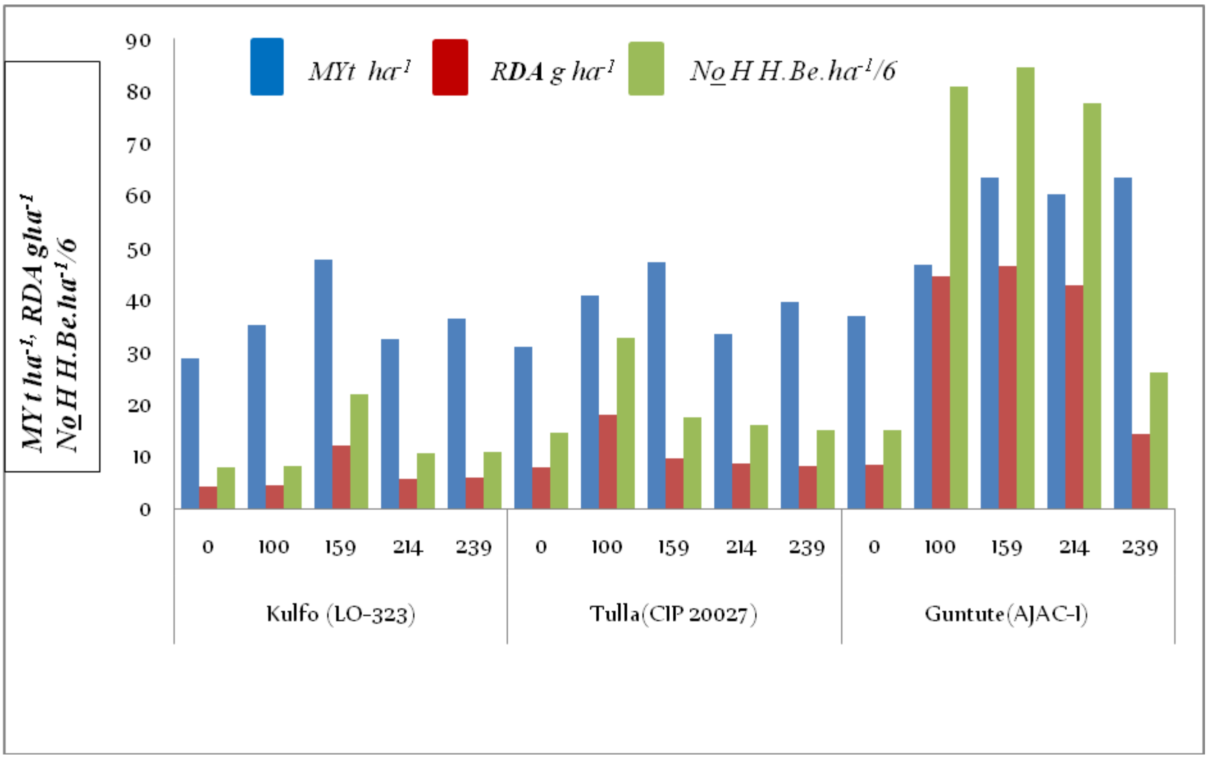
Figure 1. Interaction effect of variety and NPSB blended fertilizer on means β-carotene concentrations of orange flashed Sweet potatoes.

4.8.1. Conversion of β-carotene to Retinol activity equivalent (RAE) or Recommended dietary allowance (RDA)/day in µg (g) and Benefited households.

Carotenoids in the body are less effective. Isotopic dilution studies of β-carotene conversion in healthy well-nourished and unnourished peoples showed variable conversion ratios (Ho *et al.*, 2009). The reason for the relatively poor conversion of β-carotene to VA is multi-factorial. Among these, carotenoids are poorly absorbed from most foods (Veda *et al.*, 2006). Carotenoid absorption a highly variable and depends on the carotenoids, its food matrix and the individual. β-carotene is better absorbed from orange colored fruits and vegetables than from leafy green vegetables (O'Connell *et al.*, 2007). People and animal with low VA status appear to convert a greater percentage of β-carotene to VA (Tanumihardjo, 2008).

Currently, carotenoids conversion in the body is estimated to be 6-µg β -carotene: 1-µg VA or 12-µg β-carotene: 1-µg VA (Trumbo *et al.*, 2001; WHO and FAO, 2005). Trumbo *et al.*(2001); WHO and FAO (2005); van Jaarsveld *et al.*(2006) reported that, the contribution of one hectare of orange fleshed sweet potato to vitamin A requirements for a households of six (one adult male = 600 µg RAE/day; one adult female = 500 µg RAE/day; one 1–3 year old children = 400 µg RAE/day; one 4–6 year old children = 450 µg RAE/day; one 7–9 year old children = 500 µg RAE/day and one 10–18 year old adolescent = 600 µg RAE/day. These totals of 3050 µg RAE/day/hh were calculated after assuming 20% loss of β-Carotene during cooking which was based on the recommended dietary allowance (RDA). The vitamin A value was expressed in µg RAEs (retinol activity equivalents) based on conversion scale which is 12 µg trans-β-Carotene = 1 µg retinol = 1 µg RAE). Based on this, β-Carotene yield was calculated as kg (g) β-Carotene produced per unit area (ha).

Based on this principles stated, this experiment was resulted in high yield of RAE (RDA) retinol g ha^{-1} by Guntutie, which received 100 kg ha^{-1}, 159 kg ha^{-1} and 214 kg ha^{-1} NPSB, that scored RAE of 44.49, 46.4 and 42.74 g ha^{-1}, which allowed enough for house hold of 81, 84.5 and 77.8 (486, 507 and 466.8 peoples) for six months (Figure 2; Appendix Table 6). Kulfo with NPSB fertilizer had resulted in 4.37 g ha^{-1} to 11.95 g ha^{-1} which allowed enough for 8 to 21.8 households (48 to 130.8 Peoples) for six (6) months. Tulla with NPSB fertilizer had resulted in 8.22 g ha^{-1} to 17.96 g ha^{-1}, which allowed enough for 15 to 32.7 households (90 to 196.2 peoples) for six (6) moths (Figure 2; Appendix Table 6). In line with this, Laurie *et al.* (2012) reported that, one hectare of orange fleshed Sweet potato produced a yield of 24.6–28.4 ton ha^{-1}, at the intermediate water application, which can potentially provide vitamin A for maximum up to 452–730 members of households (of six persons) for over a period of 180 days. Kurabachew (2015) reported that, OFSP which is rich in β-carotene has the potential to mitigate vitamin A deficiency problem in families those vulnerable to this problems and other food items.



MY ton ha^{-1} = Marketable Yield tone per hectare; g ha^{-1}=gram per hectare; RDA= Recommended Dietary Allowance; No H H.Be.ha^{-1}/6=Number of House Hold Benefited from a hectare for six months

Figure 2. Marketable yield, amount of RAE gram per hectare and number of house hold benefited for six months in interaction of variety and NPSB blended fertilizer OFSP.

4.9. Specific gravity, Starch, Crude fiber, Ash and Flour moisture content

The interaction of variety with NPSB fertilizer resulted in significantly highest different in specific gravity and starch ($p<0.05$); Crude fiber, ash and flour moisture content ($P<0.01$) (Appendix Table 5). Specific gravity is the weight of the tuber compared to the weight of the same volume of water. It is one way of the determinants of dry matter, starch and yield. Specific gravity of storage root (1.15 g cm^{-3}) was significantly highest by variety Tulla, which received 159 kg ha^{-1} NPSB fertilizer, however, it did not significantly different from Kulfo with 159 kg ha^{-1}(1.143), 214 kg ha^{-1} (1.140 g cm^{-3}) and Tulla with 239 kg ha^{-1}(1.143 g cm^{-3}) (Table 11). Guntutie without fertilizer resulted in least score (1.088 gcm^{-3}). Specific gravity was lowest for Guntutie which was inversely to both fresh moisture and flour moisture content. NPSB fertilizer was an effect on specific gravity, as it was stated above. It was increased, as the rate of NPSB fertilizer increased with varieties. An agreement to this, Degras (2003) reported that, Phosphorus deficient potato plants typically produce tubers with lower specific gravity compared to those with adequate P nutrition. Namo and Babalola (2016) reported that, the specific gravity in the clone TIS.2532.OP.I.13 significantly different from that of clone TIS.44R1 68 with application of 15:15:15 kg ha^{-1} N P K fertilizer. He further indicates that a linear positive relationship observed between the specific gravity and the dry matter content during the wet season as well as starch content. Specific gravity, Starch and dry matter contents are the widely accepted measurements of potato quality and root crops and these may be affected by genotype and agromic practice (Mebratu, 2014; Mbah *et al.,* 2015).

Starch content was significantly highest different by variety Tulla, that received 159 kg ha^{-1} (28.21%), however, it did not significantly different from Tulla with 239 kg ha^{-1} (26.47%), Kulfo with 159 kg ha^{-1} and 214 kg ha^{-1}, that scored 26.58% and 26.36% Starch content (Table 11). Even though, an improvement in starch content, variety with NPSB fertilizer, Guntutie had the lowest. This may it be influenced by genetic or varietal. Closely to this experiment, Afuape *et al.* (2014) reported that, starch content ranged from 17.58% (EX-OYUNGA) and 22.0%, (NRSP/05/1 B) in his evaluation of 14 sweet potato genotypes with application of NPK (60:60:60) fertilizer 400 kg ha^{-1} in Nigeria. Namo and Babalola (2016) reported that, the mean starch content across the clones varied from 17.42% in the clone TIS.44R168 to 19.77% in the clone TIS.8441 with application of the fertilizer per hectare (NPK 15:15:15). Afuape (2014) stated that, Variety UM USP/2 which is pure white-fleshed sweet potato scored mean starch of fresh roots 18.24% and Variety Mother's Delight (UMUSPO/3) which deep orange fleshed sweet potato scored starch of 17-19%. In general with application of fertilizer we can further improve the Starch content of orange flashed sweet potatoes.

Crude fiber content was significantly highest different in variety Kulfo without fertilizer (8.98%), however, it did not significantly different from Kulfo with 239 kg ha^{-1} (8.29%). In this treatment, application of NPSB fertilizer reduced the fiber content from 0 to 214kg ha^{-1} with Kulfo and Guntutie (8.98 % to 5.82 % and 7.55% to 5.66%) respectively (Table.11). Inversely to this, NPSB from 0 to 159 kg ha^{-1} with Tulla resulted in increased crude fiber from 5.26% to 7.82% in respective order. Even though, fertilizer rate had an influence, variety had determinant effect in response to fiber content. In line with this, Emmanuel *et al.* (2010) reported that, 4% in OFSP and 5% in YFSP flours. Afuape (2014) reported that, sweet potato is a good source of dietary fiber (2.5-3.3 g/100 gm) having with important vitamins like vitamin A, C and B6, as well as potassium and iron. He Further reported that, Variety King-J which is light OFSP scored average Crude fibre of 1.47%, Variety Mother's Delight (UMUSPO/3) which deep OFSP had Crude fibre of 2.0% and Variety UM USP/2 which is Pure WFSP scored mean Crude fibre of 1 .04% in Nigeria.

Ash content is the best reflection of the mineral content of the food material. Ash content was significantly highest in Kulfo with 239 kg ha^{-1} (5.11%) NPSB fertilizers. Following this, Kulfo with 159 kg ha^{-1} (4.68%), 214 kg ha^{-1} (4.64%) and Guntutie with 214 kg ha^{-1}(4.70%) resulted in highest scores; however, they did not significantly differed from each other (Table.11). Ash content in Kulfo increased from 4.47 to 5.11% as NPSB increased from 0 to 239 kg ha^{-1}, which was inversely to crude fiber in same treatment. In line with this experiment, Emmanuel *et al.* (2010) reported that, 4% ash in OFSP and 3% ash in YFSP. Closer to this experiment, Afuape (2014) reported that, variety King-J which is light orange-fleshed Sweet potato scored average Ash content of 1.3%, variety Mother's Delight (UMUSPO/3) which deep orange-fleshed sweet potato had Ash content of 1.5% and variety UM USP/2 which is pure white-fleshed sweet potato mean Ash content of 1.5% in Nigeria.

Flour moisture content was significantly highest different in variety Guntutie with 214 kg ha^{-1} (7.79%). This did not significant different from 100 kg ha^{-1}(6.96%), 239 kg ha^{-1} (7.43%) and kg ha^{-1}; Tulla without NPSB (7.28%), 159 kg ha^{-1} (7.44) and Kulfo with 100 kg ha^{-1} (7.63%) (Table.11). Emmanuel *et al.* (2010) reported that, 17% flour moisture in OFSP and 15% in YFSP. Therefore, agronomic practices and variety have an effect on moisture content of sweet potato.

Table 11. Interaction effect of OFSP varieties and NPSB blended fertilizer on specific gravity, Starch, crude fiber, Ash and flour moisture

Variety	NPSB kg ha^{-1}	SG (gcm^{-3})	Starch (%)	Crude fiber (%)	Ash (%)	Flour Moisture (%)
	0	1.100[gh]	18.38[ij]	8.98[a]	4.474[bcd]	5.7985[fgh]
	100	1.120[cde]	21.95[efg]	6.95[cd]	4.525[bc]	7.6347[ab]
Kulfo (LO-323)	159	1.143[ab]	26.58[ab]	5.98[ef]	4.684[b]	6.369[efg]
	214	1.140[ab]	26.36[abc]	5.82[ef]	4.649[b]	5.416[h]
	239	1.115 [ef]	21.12[fgh]	8.29[ab]	5.112[a]	6.850[bcde]
	0	1.103[fg]	19.11[hi]	5.26[f]	4.150[de]	7.284[abcd]
	100	1.133 [bc]	24.65[bcd]	5.59[f]	4.483[bcd]	5.632[gh]
Tulla (CIP 20027)	159	1.150 [a]	28.21[a]	7.82[bc]	4.016[e]	7.448[abc]
	214	1.130[bcd]	24.15[bcde]	6.69[de]	3.959[e]	6.150[efgh]
	239	1.143[ab]	26.47[abc]	7.28[cd]	4.494[bc]	6.737[cde]
	0	1.088[h]	16.36[j]	7.55[bcd]	4.469[bcd]	6.425[efg]
	100	1.103[fg]	19.77[ghi]	5.66[f]	4.208[cde]	6.968[abcde]
Guntutie (AJAC-I)	159	1.123[cde]	22.957[def]	5.66[f]	4.500[bc]	6.514[def]
	214	1.130[bcd]	24.02[cde]	5.86[ef]	4.701[b]	7.796[a]
	239	1.117[def]	21.96[efg]	5.8[ef]	4.358[bcd]	7.432[abc]
Mean		1.123	0.42	6.56	4.438	6.708
CV (%)		0.78	6.6	8.18	4.55	7.46
LSD (0.05)		0.0145	2.53	0.89	0.033	0.85

Means with the same letters in same columns are not significantly different
N= Nitrogen, P =Phosphorus, S=Sulfur , B =Boron, %=Percentage, kg=kilogram
CV=Coefficient of Variations, LSD= Least Significance Difference, SG=Specific Gravity,
gcm^{-3} =gram cubic centimeter,

4.10. Correlations of Growth, Yield and Quality Variables

β-carotene was highly significant positively correlated with SRL (r=0.520), MSRN (r=0.397), MSRWP (r= 0.495), TSRWP(r=0.503), MY ton ha^{-1} (r=0.495),TY ton ha^{-1}(r=0.501), (r=0.475); significant positively correlated to LAI (r=0.315) and TSRNP (r=0.306) and high significant negatively correlated to crude fiber (r=-0.475)(Table.12). Marketable yield ton ha^{-1} was highly significant positively correlated to LAI (0.614), SRL (r=0.711),β-carotene (r=0.495), MSRNP (r=0.555),TSRNP(r=0.395), MSRW (r=1), TSRWP (r= 0.999),TY ton ha^{-1}(r=0.999), HI (r=0.913) and negatively to VL (r=-0.379) and crude fiber (r=-0.384)(Table 12). In line with this result, Essilfie (2015) reported that, market quality was highly positively correlated with total yield of tuber. Total yield ton ha^{-1} was highly significant positively correlated to LAI(r=0.617), SRL (r=0.713), β-carotene (r=0.501), MSRNP(r= 0.556),TSRNP(r= 0.398), MSR WP (r=0.999), TSRWP (r=0.999), MSR ton ha^{-1}(r=0.999), HI(r=0.912) and negatively to VL(r=-0.376) and crude fiber(r=-0.386)(Table 12).

Leaf area index (LAI) was highly significant positively correlated to SRL(r=0.692), MSNP (r=0.726), TSRN(r=0.752), MSRWP(r=0.614),TSRWP(r=0.618), MY ton ha^{-1} (r= 0.614), TY ton ha^{-1} (r=0.617),HI(r=0.520); significant positively correlated to β-Carotene (r=0.315) and negatively to RDM(r=-0.300),SG (r=-0.307), and Starch(r=-0.301). Storage root dry matter (RDM) high significant and positively correlate to SRG(r =0.768), HI(r=0.299), SG(r=0.759), Starch (r=0.771) negatively to MSRN(r=-0.441), TSRN(r=-0.647) and LAI (r=-0.30). Starch was highly positively significant to SRG(r=0.771), RDM (r=0.99), SG(r=0.989) and significant negatively correlated to LAI (r=-0.301), MSRNP(r=-0.439) and SRNP (r=-0.648) (Table 12). An agreement to this result, Namo and Babalola (2016) reported that, a linear positive correlation was observed between dry matter and Starch content during the two seasons.

Crude fiber was significant negatively correlated to SRL(r=-0.351), β-Carotene(r=-0.475), MSRWP(r=-0.384), TSRWP(r=-0.385), MY ton ha^{-1} (r=-0.384), TY ton ha^{-1}(r=-0.386) and positively correlated to VL(r=0.396) (Table 12). Vine length was significant negatively correlated to most of the parameters. Therefore, NPSB applications which mostly contain p in proportion did not influence on most the vegetative part like vine length. But it influence and plays appositive role in yield attributed parameters around storage root and quality of storage root of orange fleshed Sweet potato.

Table 12.Correlations of growth, yield and quality variables in interaction of OFSP varieties and NPSB blended fertilizer

LAI	AGF BW	SRL	SRG	SR DM	β-car	MS RN	TS RN	MSR WP	TSRW P	MY t ha^{-1}	TY tha^{-1}	HI	SG	Starch	Fiber	Ash	
-0.47 **	0.04 Ns	-0.59 **	0.16 ns	0.18 ns	-.17 Ns	-0.35 *	-0.35 *	-0.38 *	-0.38 **	-.38 **	-0.38 *	-0.36 *	0.18 ns	0.18 ns	0.40 **	0.17 ns	VL
1	0.09 Ns	0.69 **	-0.21 ns	-0.30 *	0.32 *	0.73 **	0.75 **	0.61 **	0.62 **	0.61 **	0.62 **	0.52 **	-0.31 *	-0.30 *	-0.21 ns	0.05 ns	LAI
	1	-0.01^{ns}	-0.05^{ns}	-0.02^{ns}	-0.02^{ns}	-0.06^{ns}	-.12^{ns}	0.04^{ns}	0.04^{ns}	0.04^{ns}	0.04^{ns}	-0.35*	-0.01^{ns}	-0.01^{ns}	-0.17^{ns}	0.26^{ns}	AGFBW
		1	-0.06 ns	-0.24 ns	0.52 **	0.64 **	0.63 **	0.71 **	0.71 **	0.71 **	0.71 **	0.67 **	-0.258 ns	-0.241 ns	-0.351 *	-0.15 ns	SRL
			1	0.77 **	-.03 Ns	-0.24^{ns}	-0.46 **	0.26 Ns	0.26 Ns	0.26 Ns	0.26 Ns	0.29 *	0.759 **	0.771 **	-0.051 ns	-0.15 ns	SRG
				1	-.11 Ns	-0.44 **	-0.65 **	0.19 Ns	0.18 Ns	0.19 Ns	0.17 Ns	0.21 Ns	0.989 **	0.999 **	-0.11 ns	-0.11 ns	SRDM
					1	0.397 **	0.31 *	0.50 **	0.50 **	0.50 **	0.50 **	0.48 **	-0.129 ns	-0.107 ns	-0.475 **	-0.10 ns	β-car
						1	0.93 **	0.56 **	0.56 **	0.56 **	0.56 **	0.52 **	-0.462 **	-0.439 **	-0.116 ns	0.079 ns	MSRN
							1	0.40 **	0.40 **	0.40 **	0.40 **	0.39 **	-0.661 **	-0.648 **	0.012 ns	0.112 ns	TSRN
								1	0.99 **	1 **	0.99 **	0.91 **	0.192 ns	0.195 ns	-0.384 **	0.023 ns	MSRWP
									1	0.99 **	0.99 **	0.91 **	0.185 ns	0.189 ns	-0.385 **	0.028 ns	TSRWP
										1	0.99 **	0.91 **	0.192 ns	0.195 ns	-0.384 **	0.023 ns	MYtha^{-1}
											1	0.91^{XX}	0.187^{ns}	0.19^{ns}	-0.39**	0.03^{ns}	TYtha^{-1}
												1	0.21^{ns}	0.21^{ns}	-0.30^{ns}	-0.09^{ns}	HI
													1	0.99**	-0.12^{ns}	-0.09^{ns}	SG
														1	-.116^{ns}	-105^{ns}	Starch
															1	0.162^{ns}	Fiber
																1	Ash

ns = non significant
*** = significant at 1%*
** = significant at 5 %*
LAI = leaf area index
AGBW =above ground fresh biomass weight
SRG = storage root length
SRL = storage root girth
SRDM =storage root dry matter
β- car =beta carotene
MSRN =marketable storage root number
TSRN =total storage root number
MSWP =marketable storage root weight per plant
TSRWP = total storage root weight per plant
MYtha^{-1} = marketable yield ton per hectare
TYtha^{-1} = total yield ton per hectare
HI = harvestable index
SG =specific gravity

4.11. Partial Budget and Sensitivity Analysis

Partial budget was analyzed for average of 15 treatment combination and resulted in highest gross income, net benefit and marginal rate of return in interaction of Guntutie with 159 kg ha^{-1},214 kg ha^{-1} and 239 kg ha^{-1}; Kulfo with 100 kg ha^{-1} and 159 kg ha^{-1} and Tulla with 100 kg ha^{-1} and 159 kg ha^{-1}(Appendix Table 7, 8 and 9; Table 13). Accordingly, the highest marginal rate of return was obtained at the interaction of Guntutie, Kulfo and Tulla with 159 kg ha^{-1} with 805.19%, 577.76% and 573.41, respectively (Table 13). The Sensitivity of the cost was analyzed at +10% inflations on variable coast, maily of fertilizer coast for average of 15 treatment combination and resulted highest growth income, net benefit and marginal rate of return in interaction of Guntutie with 159 kg ha^{-1}, 214 kg ha^{-1} and 239 kg ha^{-1}; Kulfo with 100 kg ha^{-1} and 159 kg ha^{-1} and Tulla with 100 kg ha^{-1} and 159 kg ha^{-1}(Appendix Table 7, 8 and 9; Table 13). Accordingly, the highest marginal rate of return was obtained at the interaction of Guntutie, Kulfo and Tulla with 159 kg ha^{-1} wth 723.21%, 516.19% and 512.30 respectively (Table 13). Based on yield and quality related data, positive response were observed in this experiment, in the interaction of all varieties with 159 kg ha^{-1} NPSB rate. Therefore, application of 159 kg ha^{-1} NPSB fertilizer rate is economical and recommended for sweet potato varieties production under Jimma and its vicinity of Southwest Ethiopia.

Table 13. Partial budget and sensitivity analysis for mean treatment interaction of OFSP varieties and NPSB blended fertilizer.

Variety	Partial budget analysis							Sensitivity analysis		
	NPSB ha^{-1}	TY $t\ ha^{-1}$	Adju yield 90%	Gross income	Total variable cost	Net benefit	MRR%	Total variable cost (+10 %)	Net benefit	MRR%
Kulfo (LO-323)	0	29.02	26.118	130590	28763.6	101826.4	354.01	31639.96	98950.04	312.73
	100	35.59	32.031	160155	31215.55	128939.45	413.06	34336.005	125818.995	366.43
	159	47.89	43.101	215505	31796.35	183708.65	577.76	34973.785	180531.215	516.19
	214	32.69	29.421	147105	32341.95	114763.05	354.84	35572.845	111532.155	313.53
	239	36.84	33.156	165780	32415.6	133364.4	411.42	35652.76	130127.24	364.98
Tulla (CIP 20027)	0	31.27	28.143	140715	28768.6	111946.4	389.12	31639.96	109075.04	344.73
	100	41.53	37.377	186885	31220.55	155664.45	498.59	34336.005	152548.995	444.28
	159	47.59	42.831	214155	31801.35	182353.65	573.41	34973.785	179181.215	512.33
	214	33.7	30.33	151650	32346.95	119303.05	368.82	35572.845	116077.155	326.30
	239	39.63	35.667	178335	32420.6	145914.4	450.06	35652.76	142682.24	400.19
Guntutie (AJAC-I)	0	37.3	33.57	167850	28773.6	139076.4	483.34	31639.96	136210.04	430.50
	100	47.21	42.489	212445	31225.55	181219.45	580.35	34336.005	178108.995	518.72
	159	63.98	57.582	287910	31806.35	256103.65	805.19	34973.785	252936.215	723.21
	214	60.83	54.747	273735	32351.95	241383.05	746.11	35572.845	238162.155	669.50
	239	63.83	57.447	287235	32425.6	254809.4	785.82	35652.76	251582.24	705.64

N = Nitrogen; P = Phosphorus; S= Sulfur; B = Boron; $t\ ha^{-1}$ = ton per hectares, TY=Total Yield
Adju = Adjustable yield; MRR = Marginal Rate of Return;

5. SUMMARY AND CONCLUSIONS

Sweet potato (*Ipomoea batatas* (L.) Lam) is economically important food security crop in Ethiopia. Orange fleshed sweet potato (OFSP) is rich in β-carotenes which is a proven cost effective strategy for providing vitamin A. The average national yield of sweet potato is about 8 ton ha^{-1} which is very low as compared to the world's average production 14.8 ton ha^{-1}. The major cause of the low yield is the use of poor agronomic practices, scarcity of information on the appropriate type and rates of fertilizers recommendations and shortage of improved varieties having high nutritional and dry matter value. Vitamin A deficiency (VAD) is a serious public health problem in Ethiopia.

Result of this experiment revealed that, means of VL, AGBFWT, TSRN, SRG, MSRWP, TSRWP, MSRY ton ha^{-1}, TSRY ton $ha^{-1}$and HI were highly significant ($p<0.01$) in the interaction of OFSP varieties with NPSB fertilizer. Tulla X 100 kg ha^{-1} NPSB fertilizer was resulted in significantly highest different in vine length (115.93 cm). The least vine length was scored at Kulfo X 159 kg ha^{-1} (96.6cm). Leaf area index (LAI) was resulted in significantly highest different in Guntutie X 159 kg ha^{-1}($3m^2m^{2-1}$) and 239 kg ha^{-1} NPSB ($3m^2m^{2-1}$). Above ground fresh biomass weight resulted in significantly highest different in Kulfo X 100 kg ha^{-1} (62.06 ton ha^{-1}) and 214 kg ha^{-1}(61.27 ton ha^{-1}).

Significantly highest different marketable storage root number was scored in Guntutie X 159 kg $ha^{-1}$of NPSB (4.37). Storage root girth was significantly highest different in Tulla X 159 kg ha^{-1} (79.35mm), followed by Tulla with 214 kg ha^{-1}(77.21mm), 239 kg ha^{-1} (77.75mm) and Kulfo X 159 kg ha^{-1} (77.25mm). Storage root length was the highest in Guntutie (17.19cm). Marketable storage root weight was significantly the highest in Guntutie X 159 kg ha^{-1}, 214 kg ha^{-1},239 kg ha^{-1} NPSB (1.14 kg, 1.08 kg and 1.14 kg), respectively. Marketable storage root yield ton ha^{-1} was significantly highest different in Guntutie X 159 kg ha^{-1}, 214 kg $ha^{-1}$and 239 kg ha^{-1} NPSB with score 63.33 ton ha^{-1}, 60.16 ton ha^{-1} and 63.44 ton ha^{-1} respectively. Mean of harvest index (0.58) was significantly highest in Guntutie X 159 kg ha^{-1}.

Significantly highest different means of β-carotene content was recorded by Guntutie X 100 kg ha^{-1} NPSB which scored 1.4298mg/100g fwb. Guntutie X 159 kg ha^{-1} and 214 kg ha^{-1} scored 1.098mg/100g fwb and 1.065 mg/100g fwb β-carotene content respectively. High yield of RAE was recorded in Guntutie X 159 kg ha^{-1} that scored 46.4 g ha^{-1} RAE, that was enough for house hold of 84.5 (507 peoples) for six months. Storage root dry matter was highest in Tulla X 159 kg ha^{-1} (35.4%). The dry matter increased from 24.23 to 33.48%; 25 to 35% as NPSB increased from 0 to159 kg ha^{-1} with Kulfo and Tulla, respectively and from 22.07 to 30.52% in Guntutie, as NPSB increased from 0 to 214 kg ha^{-1} which implies the same flow in Starch content.

In correlation analysis, β-carotene was highly significantly and positively correlated with MSRWP (r=0.495), TSRWP(r=0.503), MY ton ha^{-1} (r=0.495), LAI (r=0.315) and highly significantly and negatively correlated to crude fiber (r=-0.475). Storage root dry matter was highly significantly and positively correlated to SRG(r=0.768), HI(r=0.299), SG(r=0.759), STARCH(r = 0.771) and negatively to LAI(r = -0.30). Marketable yield ton ha^{-1} was highly significantly and positively correlated to LAI (r=0.614), SRL (r=0.711), β-carotene (r=0.495), MSRNP (r=0.555), TSRNP (r= 0.395), MSRWP (1), TSRWP (r=0.999), HI (r=0.913) and negatively to VL (r=-0.379) and crude fiber (r=-0.384).

The analyzed partial budget for average of 15 treatments was resulted in highest MRR at Guntutie, Kulfo and Tulla X 159 kg ha^{-1} with 805.19%, 577.76% and 573.41, respectively. The Sensitivity was also resulted in highest MRR at these same the interaction with score 723.21%, 516.19% and 512.30, respectively. Fertilizer containing S and B are important for improvement of yield and quality of sweet potato. Over all 159 kg ha^{-1} NPSP was recommended with Guntute in terms of yield, β–carotene and Starch quality per hectare with cost effectiveness. Tulla with 159 kg ha^{-1} NPSP mainly recommended for high yield of starch and dry matter. Based these results, application of 159 kg ha^{-1} NPSB fertilizer rate is economical and recommended for sweet potato varieties production under Jimma and its vicinity of Southwest Ethiopia. Further research will be conducted with other OFSP varieties having low dry matter and β-carotene for their best response to NPSB fertilizer. Being Guntutie our country collection resulted in high yield and β-carotene, further indigenous collection and evolution should be done for yield and quality.

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7. APPENDIX

Appendix Table 1. Mean Square of ANOVA for vine number, vine length, vine thickness, petiole length, leaf number, leaf area index (LAI) and above ground biomass fresh weight.

Source	Df	Vine number	Vine length	Vine thick	Petiole length	Leaf number	LAI	AGFBW
Var	2	143.66**	621.09**	0.115^{ns}	2.73*	420704.01**	3.49**	98.88**
NPSB	4	27.63*	142.96^{ns}	0.287*	4.62**	3089.52^{ns}	0.084^{ns}	172.28**
Rep	2	2.56^{ns}	15.66^{ns}	0.005^{ns}	1.05^{ns}	18802.13^{ns}	0.193 ^{ns}	22.54^{ns}
Var*NPSB	8	20.84**	167.30*	0.184*	2.55**	51004.13**	0.118 ^{ns}	40.81**
Error	28	6.92	72.83	0.079	0.52	11213.68	0.11	8.48

*** = Significance at 0.01, * = Significant at 0.05, Cv = Coefficient of variations*
Df = Degree freedom, thick = thickness, LAI = Leaf Area Index, AGFBW = Above Ground Fresh Biomass Weight, ha^{-1} = per hectare

Appendix Table 2.Mean Square of ANOVA for marketable, unmarketable, total storage root number per plant, storage root girth and storage root length

Source	Df	MSRNP	UnMSRNP	TSRNP	SRG	SRL
Var	2	7.6281**	0.7973**	13.3209**	153.0928*	106.2354**
NPSB	4	0.7015**	0.9370**	2.1456**	471.569**	2.1165^{ns}
Rep	2	0.0467^{ns}	0.0303^{ns}	0.6710 ^{ns}	62.4552^{ns}	0.1013^{ns}
Var*NPSB	8	0.3399**	0.1444**	0.4539**	39.19**	1.0534^{ns}
Error	28	0.0369	0.0148	0.0756	12.97	2.62

*** = significance at 0.01 * = significant at 0.05, Msrn=Marketable storage root numbers, UnMSRN =Unmarketable Storage Root Number, TSRN=Total Storage Root Numbers, SRG=Storage Root Girth, SRL= Storage Root Length*

Appendix Table 3 .Mean Square of ANOVA for marketable, unmarketable and total storage root weight per plant in kg per plant and marketable, unmarketable and total storage root yield in ton per hectare

Source	Df	**MSRWP**	UnMSRWP	TSRWP	MSRY ton ha^{-1}	**UnMSRY ton ha^{-1}**	TSRY ton ha^{-1}
Var	2	0.462**	0.00003836**	0.471**	1428.72**	0.118**	1454.76**
NPSB	4	0.158**	0.00001930**	0.158**	489.58**	0.059**	489.54**
Rep	2	0.002 ^{ns}	0.00000142^{ns}	0.002^{ns}	7.36^{ns}	0.004^{ns}	7.04^{ns}
Var*NPSB	8	0.030**	0.00003618**	0.031**	93.39**	0.112**	96.18**
Error	28	0.0038	0.00000232	0.0037	11.74	0.007	11.59

*** = significance at 0.01; * = significant at 0.05, MSRWP = Marketable Storage Root Weight Per plant, UnMSRWP = Unmarketable Storage Root Weight Per plant, TSRWP = Total Storage Root Weight Per plant, MSRY = Marketable Storage Root Yield, UnMSRY = Unmarketable Storage Root Yield, TSRY = Total Storage Root Yield,*

Appendix Table 4.Mean Square of ANOVA for harvestable index (HI),CHI leaf, vine and storage root dry matter weight of orange fleshed Sweet potato

Source	Df	HI	CHI	LDM %	VDM %	SRDM %
Var	2	0.0408**	0.00000089^{ns}	27.8112**	4.31222^{ns}	61.4178**
NPSB	4	0.0222**	0.00005408**	1.71737^{ns}	11.0787**	102.5128**
Rep	2	0.00025^{ns}	0.00000631^{ns}	0.5894^{ns}	1.2272^{ns}	1.1355^{ns}
Var*NPSB	8	0.00168**	0.00005264**	6.655*	4.2767*	8.7956**
Error	28	0.00052	0.0000062	2.567	1.6233	3.0432

***= significance at 0.01,   * = significant at 0.05, D f = Degree freedom, HI= Harvestable Index, LDM=Leaf Dry Matter, VDM= Vine Dry Matter, SRDM= Storage Root Dry Matter*

Appendix Table 5.Mean Square of ANOVA for β-carotene, specific gravity, Starch content, crude fiber, ash and flour moisture root dry matter

Source	Df	B-carotene	Specific gravity	Starch	Crude fiber	Ash	Flour moisture
Var	2	1.401**	0.00151**	47.75**	4.293**	0.686**	1.446**
NPSB	4	0.337**	0.00226**	81.66**	2.68**	0.096^{ns}	0.425^{ns}
Rep	2	0.009^{ns}	0.0000159^{ns}	0.91^{ns}	0.18^{ns}	0.041^{ns}	0.328^{ns}
Var*NPSB	8	0.2256**	0.000184*	6.61*	4.15**	0.164**	0.309**
Error	28	0.006	0.000077	2.32	0.28	0.041	0.256

*** = significance at 0.01;   * = significant at 0.05*

Appendix Table 6.Mean concentrations of β-carotene yield ha^{-1} in mg (μg), RAE (RDA) μg (g) ha^{-1} and number of house hold benefited ha^{-1} for six (6) months.

Variety	NPSB ha-1	MY t ha^{-1}	β-car con mg / 100g	β-car con mg ha^{-1}	β-car con μg ha^{-1}	20% lost β-car con μg ha^{-1}	RAE(DRA) retinol μg ha^{-1}	RAE(RDA) retinol g ha^{-1}	No H .H. Be.ha^{-1} /6m
Kulfo (LO-323)	0	28.68	0.2250	64530	64530000	51624000	4302000	4.3	7.8
	100	35.26	0.1857	65477.82	65477820	52382256	4365188	4.37	8
	159	47.68	0.3761	179324.48	179324480	143459584	11954965.33	11.95	21.8
	214	32.34	0.2674	86477.16	86477160	69181728	5765144	5.77	10.5
	239	36.3	0.2432	88281.6	88281600	70625280	5885440	5.89	10.7
Tulla(CIP 20027)	0	30.89	0.3871	119575.19	119575190	95660152	7971679.333	7.97	14.5
	100	40.71	0.6619	269459.49	269459490	215567592	17963966	17.96	32.7
	159	47.21	0.3041	143565.61	143565610	114852488	9571040.667	9.57	17.4
	214	33.45	0.3912	130856.4	130856400	104685120	8723760	8.72	15.9
	239	39.49	0.3123	123327.27	123327270	98661816	8221818	8.22	15
Guntutie(AJAC-I)	0	36.92	0.3372	124494.24	124494240	99595392	8299616	8.3	15.1
	100	46.67	1.4298	667287.66	667287660	533830128	44485844	44.49	81
	159	63.33	1.0989	695933.37	695933370	556746696	46395558	46.4	84.5
	214	60.16	1.0656	641064.96	641064960	512851968	42737664	42.74	77.8
	239	63.44	0.3389	214998.16	214998160	171998528	14333210.67	14.33	26.1

RAE= Retinol Activity equivalent, RDA= Recommended Dietary Allowance, mg = milligram, μg =microgram
No H .H. Be.ha^{-1} /6m = Number of house hold benefited from one hectare for six months *MY t*
ha^{-1} = Marketable yield ton per hectare, β-car con mg / 100g = β-carotene content milligram per 100 gram

Appendix Table 7. Coast of fertilizer used for partial budget analysis

Fertilizer treatment	Unit	NPSB Fertilizer rate	Price /kg	Total price	+10% sensitivity	UREA	Price /kg	Total price	+10% sensitivity	Total Sum	+10% Sensitivity total
NPSB0	Kg	0	16	0	0	0	15	0	0	0	0
NPSB1	Kg	100	16	1600	1760	56.73	15	850.95	936.045	2450.95	2696.045
NPSB2	Kg	159	16	2544	2798.4	32.45	15	486.75	535.425	3030.75	3333.825
NPSB3	Kg	214	16	3424	3766.4	10.09	15	151.35	166.485	3575.35	3932.885
NPSB4	Kg	239	16	3648	4012.8	0	15	0	0	3648	4012.8

Appendix Table 8.Variable Coast of labors and seedling/cuttings used for partial budget analysis

Activities	Unit	Man power and other	Unit/daily payment	No of days	Frequency	Total	10%
Site clearing	No	20	26	2	1	1040	1144
Oxen force	0x No	4	50	6	4	4800	5280
Plowing	No	2	26	6	4	1248	1372.8
Cutting preparation	No	10	26	2	1	520	572
Coast of cutting	No	55556	0.1	1	1	5555.6	6111.16
Ridge preparation	No	20	26	3	1	1560	1716
Planting	No	15	26	2	1	780	858
Fertilizer application	No	15	26	2	2	1560	1716
Hoeing and weeding	No	15	26	2	4	3120	3432
Earthing up	No	20	26	2	2	2080	2288
Harvesting	No	20	26	4	1	2080	2288
Transporting	No	20	26	4	1	2080	2288
Guard	No	1	26	90	1	2340	2574
Total						28763.6	31639.96

Appendix Table 9. Summary of partial budget and sensitivity analysis for interaction s of variety with NPSB blended fertilizer rates.

Variety	Partial budget analysis										Sensitivity analysis		
	NPS B ha^{-1}	TY t ha^{-1}	Adju yield 90%	Price kg^{-1}	Gross income	Fertilizer coast	Labour and cutting coast	Total variable cost	Net benefit	MRR%	Total variable cost (+10 %)	Net benefit	MRR%
Kulfo (LO-323)	0	29.02	26.118	5	130590	0	28763.6	28763.6	101826.4	354.01	31639.96	98950.04	312.73
	100	35.59	32.031	5	160155	2450.95	28764.6	31215.55	128939.45	413.06	34336.005	125818.995	366.43
	159	47.89	43.101	5	215505	3030.75	28765.6	31796.35	183708.65	577.76	34973.785	180531.215	516.19
	214	32.69	29.421	5	147105	3575.35	28766.6	32341.95	114763.05	354.84	35572.845	111532.155	313.53
	239	36.84	33.156	5	165780	3648	28767.6	32415.6	133364.4	411.42	35652.76	130127.24	364.98
Tulla(CIP 20027)	0	31.27	28.143	5	140715	0	28768.6	28768.6	111946.4	389.12	31639.96	109075.04	344.73
	100	41.53	37.377	5	186885	2450.95	28769.6	31220.55	155664.45	498.59	34336.005	152548.995	444.28
	159	47.59	42.831	5	214155	3030.75	28770.6	31801.35	182353.65	573.41	34973.785	179181.215	512.33
	214	33.7	30.33	5	151650	3575.35	28771.6	32346.95	119303.05	368.82	35572.845	116077.155	326.30
	239	39.63	35.667	5	178335	3648	28772.6	32420.6	145914.4	450.06	35652.76	142682.24	400.19
Guntutie(AJAC-I)	0	37.3	33.57	5	167850	0	28773.6	28773.6	139076.4	483.34	31639.96	136210.04	430.50
	100	47.21	42.489	5	212445	2450.95	28774.6	31225.55	181219.45	580.35	34336.005	178108.995	518.72
	159	63.98	57.582	5	287910	3030.75	28775.6	31806.35	256103.65	805.19	34973.785	252936.215	723.21
	214	60.83	54.747	5	273735	3575.35	28776.6	32351.95	241383.05	746.11	35572.845	238162.155	669.50
	239	63.83	57.447	5	287235	3648	28777.6	32425.6	254809.4	785.82	35652.76	251582.24	705.64

TY ton ha^{-1} = Total yield per hectare, Adju=Adjustable, MRR= Marginal Rate of Return.

Appendix Table 10. Climate data for 6 and 1 years for experimental studied site at JARC

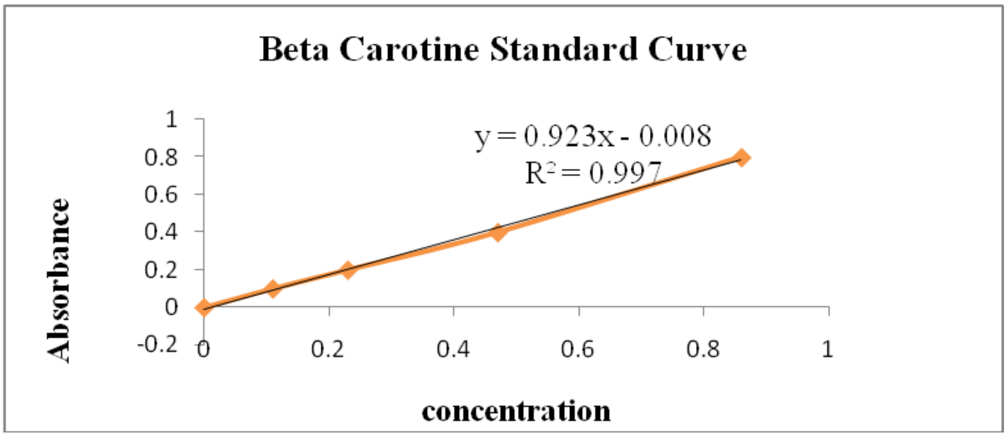
Climate data for six years					
Years	Total rf mm	Mean T °c min	Mean T°c max	Mean RH %	Years
2012	1546	13.5	25	56.3	2012
2013	2191.6	13.7	26.5	64.2	2013
2014	1508.5	12.3	24.5	59.1	2014
2015	1676.6	11.7	25	72.7	2015
2016	1682.2	11.7	23.2	70.4	2016
2017	1818.9	10.4	27.1	75.7	2017
	1737.3	12.21	25.22	66.4	
Climate data for one years					
Years	Months	Total Rf mm	Mean min T °c	Mean max T°c	Mean RH %
2017	January	85.2	9.5	26.6	73.1
	February	95.8	9.9	26.6	73.1
	March	75.2	10.4	25.5	72.7
	April	76.6	10.6	26.6	66.9
	May	281.3	10.9	26.8	89.4
	June	148.2	10.4	26.5	74.5
	July	184.1	10.5	28.3	78.7
	August	177.3	11	28.2	80.3
	September	348.7	11.3	26.9	73.1
	October	318.9	10.9	26.5	75.8
	November	27.6	10.2	28.5	75
	December	.	9.3	28.3	75.8
		1818.9	10.40833	27.108	75.7

Source: JARC (2018)

Appendix Table 11. Pre planting analyzed soil data for experimental site at JARC

Pre planting soil data for one composite sample					
Soil parameters	pH (1:2.5)	N%	P(PPM)	OC	OM
Result	5.11 ^{sa}	0.117^{vl}	3.923^{vl}	2.447^{m}	4.23331

^{sa} = strongly acidic, ^{ma} = moderately acidic, ^{l} = low, ^{m} = moderate/medium,
^{vl} = very low ^{h} = high, pH=power of hydrogen, N=Nitrogen, P = Available phosphorus, PPM = Pascal per millennium, OC=organic carbon, OM=organic matter

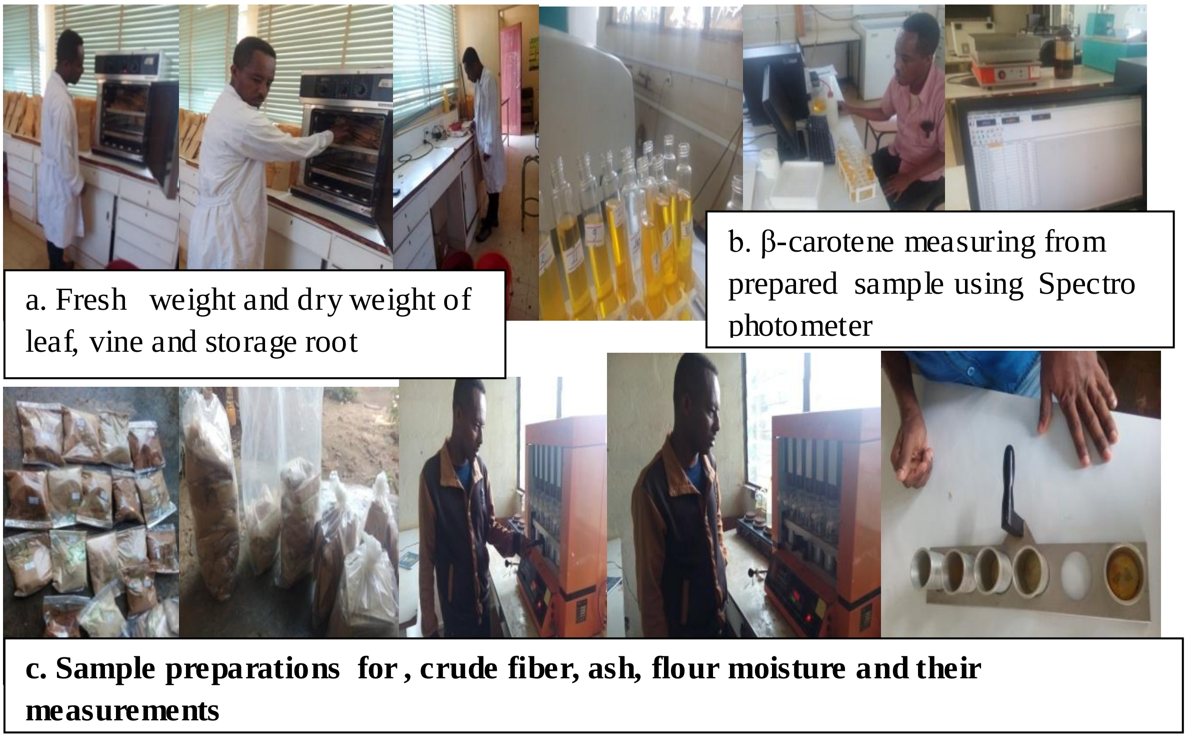


Appendix Figure 1.Standard curve for β-carotene

Appendix Figure 2.Seedling to vegetative growth stage activity

Appendix Figure 3. (a)Field performance evaluation at tuber formation stage; (b) growth data collections

Appendix Figure 4.Harvesting, data collection and processing activity for nutritional quality assessment.



Appendix Figure 5. Sample preparation and measurement of qualities.

Appendix Figure 6.Post harvest soil sample preparation for analysis.