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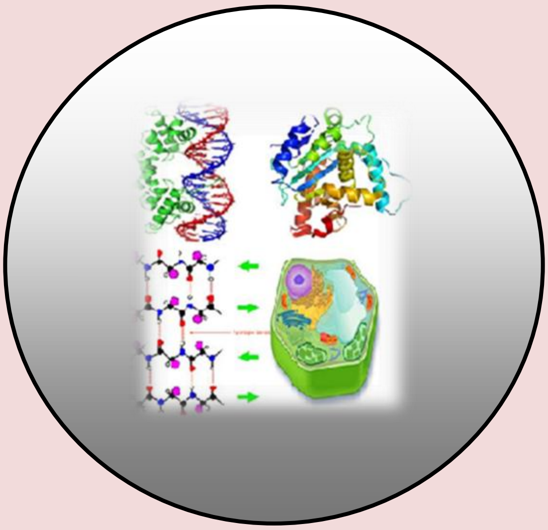

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RESEARCH PAPER

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Yield of Orange Fleshed Sweet Potato (*Ipomoea batatas* (L.) Lam) Varieties as Influenced by NPSB Blended Fertilizer Levels under Jimma Condition, Southwest Ethiopia

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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 is the cheapest source of β-carotene which is a precursor of Vitamin A whose deficiency is a serious public health problem in Ethiopia. A field experiment was conducted at Jimma Agricultural Research Center since 2017 cropping season to evaluate the effect of five different levels of NPSB fertilizer kg ha^{-1} (0, 100, 159, 214 and 239) on yield of three orange fleshed varieties (Kulfo, Tulla and Guntutie).The experiment was arranged in 3X5 factorial RCBD with three replications. Data on yields were collected and subjected to various data analyses. Results revealed that, the interaction effect of varieties and NPSB levels were highly significant influenced the above ground biomass fresh weight, storage root girth, marketable storage root yield ton per hector and harvestable index (P<0.01). Storage root length was significantly highest difference due to the main effect of variety (P<0.01). Guntutie with 159 kg ha^{-1} NPSB blended fertilizer level resulted in significantly highest difference in marketable storage root yield in ton per hectare (63.33 ton ha^{-1}). 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%). The highest marginal rate of return 11732.5 % was obtained in Guntutie with159 kg ha^{-1}. Overall, 159 kg ha^{-1} NPSB should be recommended for its highest yield.
Keywords: Guntutie variety, Marginal rate of return, NPSB levels and Tuber yield.

INTRODUCTION
Sweet potato *(Ipomoea batatas L.)* Lam) is the 7th most important food crop after wheat, rice, maize, potato, barley and cassava (FAO, 2014).

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 (Dantata et al., 2010). 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 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).

Orange fleshed sweet potato (OFSP) varieties have high β-Carotene and can potentially reduce the effects of vitamin A deficiency which is a serious public health problem in Ethiopia (Demissie et al., 2010; Kurabachew, 2015). OFSP are currently at high demand in all developing nations (Tofu et al., 2007). 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. This is presumed to be one of the main reasons for low yield of the crop (CSA, 2016). Splitting of sweet potato tuberous root due to Boron (B) deficiency can reduce the quality of marketable storage tuber yields by 40–60 % (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 bio-fortified OFSP rich in β-carotenes are a proven cost effective strategy for providing vitamin A and cheap 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). 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 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).

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. In Jimma zone with 100 kg ha^{-1} NPSB in blanket recommendation to improve yield and quality of crop (Ethio SIS, 2014; Bellete, 2016). 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, research undertakings were not 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 objectives of:

- To assess the effect of NPSB blended fertilizer levels and varieties on yield and yield component of orange fleshed sweet potato;
- To assess the interaction effect of NPSB blended fertilizer levels and varieties on yield and yield component of orange fleshed sweet potato.

MATERIALS AND METHODS

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 °46' N and longitude 36° 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.

Table 1. Rate of NPSB formulated and tested.

NPSB Treatment Rate		Element content				N added	UREA in kg	N Recom mended
Treatments	NPSB ha^{-1}	N	$P_2 0_5$ (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

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 (Ethio SIS, 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.

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 60 cm 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*0, Kulfo*100, Kulfo*159, Kulfo* 214, Kulfo *239, Tulla*0, Tulla *100, Tulla *159, Tulla * 214, Tulla *239, Guntutie * 0, Guntutie*100, Guntutie *159, Guntutie * 214 and Guntutie * 239 kg ha^{-1} NPSB.

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.

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 (McLean, 1982).

Organic carbon: was determined by the modified Walkley and Black procedure as described by Olson and Sommers (1982).

Total nitrogen: was determined by the Kjeldahl digestion and distillation procedure as described by van Reeuwijk (1992).

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).

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.

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).

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 collected

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 ton per hectare (MSRY ton 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 ton 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 ton 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).

HI= $\frac{\text{Economic yield}}{\text{Biological yield + Economic yield}}$ ....*Eqution(1)*

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).

MSRY: TSRY= $\frac{\text{Markatable storage root yield}}{\text{Total storage root yield}}$ ....Eqution(2)

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 marketable yield obtained.

Total Gross Benefit = Adjusted yield * farm gate price.

Total variable cost = Labour coast + fertilizer cost + transportation cost.

Net benefit = Total gross benefit – Total variable cost.

Marginal rate of return (MRR %) = $\frac{\text{Net benefit}}{\text{Total variable cost}}*100$ ....Equation (3)

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.

$T_{ijk} = \mu + R_i + V_j + F_k + (VF)_{jk} + \varepsilon_{ijk}$ .... Equation (4)

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).

RESULTS AND DISCUSSIONS

Marketable, unmarketable, total storage root number, storage root girth and length

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 ($p<0.01$) (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 2). 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 2). 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 2). 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 seed beds. 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. Busha (2006) reported that, 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. 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 ($P<0.01$).

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 2). The least storage root girth was recorded 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.

Table 2. Main and interaction effect of OFSP varieties with NPSB blended fertilizer on storage marketable storage root number per plant, unmarketable storage root number per plant, total storage root number per plant, storage root girth and storage root length.

Variety	NPSB kgha^{-1}	MSRN per plant	UnMSRNper plant	TSRN per plant	SRG (mm)	SRL(cm)	
Kulfo (LO-323)	0	3.10^{d}	1.27^{b}	4.37^{b}	56.17^{f}	10.33	11.34^{b}
	100	2.60^{ef}	0.27^{f}	2.87^{ef}	72.28^{bcd}	11.67	
	159	2.70^{e}	0.21^{f}	2.91^{ef}	77.25^{ab}	12.40	
	214	2.37^{fg}	0.23^{f}	2.60^{fg}	66.82^{de}	10.64	
	239	2.75^{e}	0.69^{cde}	3.44^{cd}	66.87^{de}	11.37	
Tulla (CIP 20027)	0	2.35^{fg}	0.72^{cd}	3.07^{de}	55.22^{f}	11.99	12.41^{b}
	100	2.02^{h}	0.58^{de}	2.60^{fg}	74.05^{abc}	12.82	
	159	2.10^{gh}	0.20^{f}	2.30^{g}	79.35^{a}	13.40	
	214	2.11^{gh}	0.28^{f}	2.39^{g}	77.21^{ab}	12.30	
	239	2.35^{fg}	0.25^{f}	2.60^{fg}	77.75^{ab}	11.78	
Guntutie (AJAC-I)	0	3.49^{c}	1.57^{a}	5.06^{a}	56.97^{f}	15.83	16.38^{a}
	100	3.33^{cd}	0.50^{e}	3.83^{c}	66.38^{de}	16.06	
	159	4.36^{a}	0.70^{cde}	5.06^{a}	70.99^{cd}	16.40	
	214	2.73^{e}	0.80^{c}	3.53^{c}	69.79^{cd}	16.62	
	239	3.90^{ab}	0.63^{cde}	4.53^{b}	70.34^{cd}	17.19	
Mean		2.82	0.59	3.41	69.42	13.52	13.52
CV (%)		6.82	20.66	8.07	5.18	11.1	11.1
LSD(0.05)		0.33	0.21	0.46	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, Marketable Storage Root Numbers, UnMSRN =Unmarketable Storage Root Number, TSRN=Total Storage Root Numbers SRL=Storage Root Length, SRG = Storage Root Girth, CV =Coefficient of Variations, LSD = Least Significance Difference

Storage root length (16.38cm) was significantly highest on variety Guntutie, in the main effect of variety (Table 2). 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 2). As Guntutie with 0 to 239 kg ha^{-1} NPSB fertilizer increased, tuber length was increased from 15.83cm-17.19cm) (Table 2). 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 kgha^{-1} NPK+5 ton ha^{-1} CM plot.

Marketable, unmarketable, total fresh storage root yield, above ground biomass weight, harvest index and commercial harvest index

The interactions of varieties with NPSB fertilizer rates were resulted in significantly highest difference in mean of marketable, unmarketable, total fresh storage root yield ton per hectare , above ground biomass, harvest index (HI) and ratio of marketable to total storage yield (MSRY: TSRY) ($p<0.01$). 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 3). 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 (15 .7 P kg ha^{-1}; 31.42 P kg ha^{-1} and 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 3). 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 3). 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 3).

Table 3. 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})	AGFB (ton ha^{-1})	HI	CHI
Kulfo (LO-323)	0	28.68^{f}	0.35^{cde}	29.02^{h}	49.52^{cd}	0.369^{fg}	0.9880^{efg}
	100	35.26^{cde}	0.33^{cde}	35.59^{efg}	62.06^{a}	0.364^{fg}	0.9906^{cdef}
	159	47.68^{b}	0.22^{ef}	47.899^{b}	49.84^{cd}	0.489^{bc}	0.9953^{ab}
	214	32.34^{def}	0.35^{cde}	32.69^{fgh}	61.27^{a}	0.347^{g}	0.9890^{defg}
	239	36.3^{cde}	0.54^{b}	36.84^{defg}	57.24^{ab}	0.391^{f}	0.9855^{g}
Tulla (CIP 20027)	0	30.89^{ef}	0.38^{cd}	31.27^{gh}	50.95^{c}	0.379^{fg}	0.9876^{fg}
	100	40.71^{c}	0.82^{a}	41.53^{cd}	52.69^{bc}	0.441^{d}	0.9803^{h}
	159	47.21^{b}	0.38^{cd}	47.59^{b}	49.52^{cd}	0.489^{bc}	0.9920^{bcde}
	214	33.45^{def}	0.25^{def}	33.70^{fgh}	50.95^{c}	0.398^{ef}	0.9926^{abcd}
	239	39.49^{c}	0.14^{f}	39.63^{de}	49.12^{cd}	0.447^{d}	0.9963^{a}
Guntutie (AJAC-I)	0	36.92^{cd}	0.38^{cd}	37.30^{def}	48.81^{cd}	0.433^{de}	0.9895^{defg}
	100	46.67^{b}	0.54^{b}	47.21^{bc}	56.984^{ab}	0.454^{cd}	0.9883^{efg}
	159	63.33^{a}	0.65^{b}	63.98^{a}	45.08^{d}	0.587^{a}	0.9900^{cdef}
	214	60.16^{a}	0.67^{b}	60.83^{a}	61.59^{a}	0.496^{b}	0.9890^{defg}
	239	63.44^{a}	0.39^{c}	63.83^{a}	58.25^{a}	0.523^{b}	0.9940^{abc}
Mean		43.09	0.42	43.51	53.39	0.443	0.9903
CV (%)		7.95	20.29	7.82	5.4	5.17	0.25
LSD (0.05)		5.74	0.14	5.69	5.2	0.038	0.0042

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, HI = Harvestable Index, CHI= Commercial Harvest Index, CV =Coefficient of Variations, LSD= Least Significance Difference

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 3). Means of marketable fresh storage root yield ton per hectare and mean storage root girth in the same varieties with same NPSB level were resulted in significant different. The 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 and 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. Busha (2006) also reported that, increasing P levels from 0 to 25 P kgha^{-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. Application of NPSB fertilizer was effective to this experiment on yield and yield component 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 (Yayeh et al., 2017) which may in turn increase yields of vegetable crops including Potato and sweet potato. 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 t ha^{-1}) NPSB fertilizer, however, it was not significantly different from variety Kulfo, that received 239 kg ha^{-1}(57.24 ton ha^{-1}) NPSB and Guntutie, that received 100 kg ha^{-1} (56.98 ton ha^{-1}) (Table 3). The least above ground biomass fresh weight was scored by variety Guntutie with 159 kg ha^{-1} (45.08 ton ha^{-1}) NPSB fertilizer. 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. 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 3). 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.

The author 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 and the lowest was recorded by the control plot. 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 (CHI) 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 3). 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. 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 62.85 P kg ha^{-1} significantly decreased the percentages of weight loss during storage.

Table 4. Partial budget and sensitivity analysis for mean treatment interaction of OFSP varieties and NPSB blended fertilizer.

Variety	Partial budget analysis							Sensitivity analysis		
	NPSB kg ha^{-1}	TY ton ha^{-1}	Adjustable 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	0	31639.96	98950.04	0
	100	35.59	32.031	160155	31215.55	128939.45	1105.77	34336.00	125818.995	996.60
	159	47.89	43.101	215505	31796.35	183708.65	9429.95	34973.78	180531.215	8578.54
	214	32.69	29.421	147105	32341.95	114763.05D	-12636.65	35572.84	111532.155D	-11517.88
	239	36.84	33.156	165780	32415.6	133364.4	25256.41	35652.76	130127.24	23268.57
Tulla (CIP 20027)	0	31.27	28.143	140715	28768.6	111946.4	0	31639.96	109075.04	0
	100	41.53	37.377	186885	31220.55	155664.45	1782.99	34336.00	152548.995	1612.50
	159	47.59	42.831	214155	31801.35	182353.65	4595.24	34973.78	179181.215	4175.76
	214	33.7	30.33	151650	32346.95	119303.05D	-11556.19	35572.84	116077.155D	-10533.84
	239	39.63	35.667	178335	32420.6	145914.4	36132.17	35652.76	142682.24	33291.72
Guntutie (AJAC-I)	0	37.3	33.57	167850	28773.6	139076.4	0	31639.96	136210.04	0
	100	47.21	42.489	212445	31225.55	181219.45	1718.75	34336.00	178108.995	1554.08
	159	63.98	57.582	287910	31806.35	256103.65	12893.28	34973.78	252936.215	11732.45
	214	60.83	54.747	273735	32351.95	241383.05D	-2698.057	35572.84	238162.155D	-2466.20
	239	63.83	57.447	287235	32425.6	254809.4	18229.938	35652.76	251582.24	16792.94

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

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}; Kulfo with 159 $kgha^{-1}$ and Tulla with 159 kg ha^{-1} (Table 4). Beyond 159 kg ha^{-1} NPSB level, it showed fluctuation. Accordingly, the highest marginal rate of return was obtained at the interaction of Guntutie with 159 kg ha^{-1} (12893.3 %) (Table 4). The Sensitivity of the cost was analyzed at $\pm$10 % inflations on variable coast, mainly 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} (Table 4). As a result the highest marginal rate of return 11732.5 % was observed in interaction of Guntutie with 159 kg ha^{-1} (Table 4). Based on yield and yield related data, positive response was observed in this experiment, in the interaction of all varieties with 159 $kgha^{-1}$ NPSB rate. Therefore, application of 159 $kgha^{-1}$ NPSB fertilizer rate is economical and recommended for sweet potato varieties production under Jimma and its vicinity of Southwest Ethiopia.

Correlations of growth, yield and quality variables

Marketable yield ton ha^{-1} was highly significant positively correlated to SRL (r=0.711), MSRNP (r=0.555), TSRNP (r=0.395), TY ton ha^{-1} (r=0.999), HI (r=0.913) and negatively to (Table 5). In line with this result, Essilfie (2015) reported that, market quality was highly positively correlated with total yield of tuber. Leaf area index (LAI) was highly significant positively correlated to SRL(r=0.692), MSNP (r=0.726), TSRN(r=0.752), MY ton ha^{-1} (r= 0.614), TY ton ha^{-1} (r=0.617) and HI(r=0.520).

Table 5. Correlations of growth, yield and quality variables in interaction of OFSP varieties and NPSB blended fertilizer.

AGFBW	SRL	SRG	MSRN	TSRN	MY t ha^{-1}	TY tha^{-1}	HI	
1	-0.01^{ns}	-0.05^{ns}	-0.06^{ns}	-0.12^{ns}	0.04^{ns}	0.04^{ns}	-0.35*	AGFBW
	1	-0.06^{ns}	0.64**	0.63**	0.71**	0.71**	0.67**	SRL
		1	-0.24^{ns}	-0.46**	0.26^{ns}	0.26^{ns}	0.29*	SRG
			1	0.93**	0.56**	0.56**	0.52**	MSRN
				1	0.40**	0.40**	0.39**	TSRN
					1	0.99**	0.91**	$MYtha^{-1}$
						1	0.91**	$TYtha^{-1}$
							1	HI

SUMMARY AND CONCLUSIONS

Result of this experiment revealed that, Tulla *100 $kgha^{-1}$ NPSB fertilizer was resulted in significantly highest different in vine length (115.93 cm). Above ground fresh biomass weight resulted in significantly highest different in Kulfo*100 kg ha^{-1}(62.06 ton ha^{-1}). Significantly highest different marketable storage root number was scored in Guntutie *159 kg ha^{-1} of NPSB (4.37).

Storage root girth was significantly highest different in Tulla *159 kg ha^{-1} (79.35mm). Storage root length was the highest in main effect of variety Guntutie (17.19cm). Marketable storage root yield ton ha^{-1} was significantly highest different in Guntutie *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 *159 kg ha^{-1}. In correlation analysis Marketable yield ton ha^{-1} was highly significantly and positively correlated to SRL (r=0.711), MSRNP (r=0.555), TSRNP (r= 0.395) and HI (r=0.913). The analyzed partial budget for average of 15 treatments was resulted in highest MRR (12893.3%) in the interaction of variety Guntutie with 159 kg ha^{-1} NPSB. The Sensitivity was also resulted in highest MRR at this same interaction with score of 11732.5%. Fertilizer containing S and B are important for improvement of yield and quality of sweet potato. Over all 159 kg ha^{-1} NPSB was recommended with Guntutei as well as with evaluated variety in terms of yield per hectare in cost effectiveness. Further research will be conducted with other OFSP varieties, for their best response to NPSB fertilizer.

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