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Growth, Yield and Nutritional Quality of Sweet potato (*Ipomoea batatas* (L.) Lam) Varieties as Influenced by Fertilizer type and Rates. A *Review*

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ABSTRACT

Sweet potato (*Ipomoea batatas* (L.) Lam) is one of the economically important and food securing root crop in Ethiopia. Fertilizer has greater effect on the yield of sweet potato crop. Growth parameters are the main important yield determining factors in sweet potato and they are highly influenced by soil fertility and soil amendments. Nitrogen, phosphorus and potassium influence growth and reproductive phase of plant growth. Nitrogen supply has a great influence on the production and distribution of dry matter within the plant, particularly affecting root growth relative to top growth at optimum level.

Optimum application of N and P promotes higher photosynthetic activity and vigorous vegetative growth and promotes the chance for emergence of new vines. Applications of N and P influenced days to maturity. Applications of N and P increase shoot dry weight, tuber dry matter content, tuber number, tuber length, marketable storage root yield and total storage root yield. The total tuber yield of sweet potato increased significantly with up to 1.5 kg ha^{-1} to 2 kg ha^{-1} of boron applications.

Orange flesh sweet potatoes (OFSP) were used in food based intervention and also varieties have a potential contribution to alleviate vitamin A and mineral deficiencies. The β-carotene contents were varying within variety and fertilizer level. Application of phosphorus increase the carotene content of tuberous roots of sweet potato in higher yield and affects the unit weight of root tubers. Increasing the supply of nitrogen fertilizer significantly increases β-carotene content. Increase in carotene content with potassium application, as well as with zinc application. Both Sulfur and Nitrogen involve in protein synthesis, intimately linked and are often assumed to be co-limiting. It has been recognized that for every 15 parts of Nitrogen in protein, there is approximately 1 part of Sulfur (15:1 ratio of N: S). Some of application of Sulfur caused formation of more protein that has a nutritional advantage.

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 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 areas of the world (Kebede and Birru, 2011).

Globally Sweet potato is the 7th most important food crop after wheat, rice, maize, potato, barley and cassava (FAO, 2014). In Africa, Sweet potato is the 2nd second most important root crop after cassava (Ndolo *et al*., 2001; Dantata *et al*., 2010). African farmers produce mostly used for human consumption and to ensure food security (FAO, 2014; Sanginga and Mbabu, 2015).

The use of biofortified OFSP rich in β-carotenes are a proven cost effective strategy for providing vitamin A and 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). They are qualified to solve malnutrition problem (Ndunguru *et al.,* 2009; Emmanuel *et al.,* 2010).

Growth of sweet potato plants were significantly increased with increasing P rate from up to optimum (El-Sayed *et al.*, 2011; Abdissa *et al.,* 2012). Nitrogen up to 45N kg ha^{-1} inhance vegetative growth to the optimum (Ambecha, 2001; Busha , 2006).

Applications of N and P to the optimum level significantly increase tuber length and diameter (Ambecha, 2001; Abdissa *et al*., 2012). Application of P nutrition is very important on growth and productivity of sweet potato plants; as P fertilizer application positively inhanced sweet potato yield as compared with control (El Marsy *et al.,* 2002; Hassen *et al.,* 2005). Plants supplied with adequate amounts of P were reported to form good root system, strong stem, matured early and gave high yield (Rending and Taylor, 1989). Total tuber yield of sweet potato increased significantly with up to optimum application of boron (Byju *et al.*, 2007; Echer and Creste , 2011).

The potential yield of sweet potato reached up to 50 ton ha^{-1} on research station with improved agronomic practices (Workayehu *et al.,* 2011). Sweet potato yield under research field ranged from 30-35 ton ha^{-1} with improved cultivars (Abdissa *et al*., 2012). Average yield of 37.1 ton ha^{-1} was obtained for the Bellala variety of sweet potato with application of different fertilizers (Teshome and Amenti, 2010). Abdissa *et al.*(2011) reported that, sweet potato yield was reach up to 64.4 ton ha^{-1} in the use of agronomic practices from Bellala variety.

Shoot dry matter weight of sweet potato was also highly responsive and greatly affected by the combined application of farmyard manure and phosphorus (Abdissa *et al.*,2012) .Total dry matter production and efficiency of dry matter allocation to storage roots are important factors determining storage root yield. A linear increase was observed in total yield and storage root dry matter in phosphorus application (Nair and Nair, 1995).

Like nitrogen, phosphorus increase the carotene content and specific gravity of tuberous roots during the yield increase period and also affects the unit weight of root tubers (Degras, 2003). Both S and N involve in protein synthesis, intimately linked and are often considered to be co-limiting. It has been recogonised that, for every 15 parts of N in protein, there is approximately 1 part of S (15:1 ratio of N:S) (Schnug and Haneklaus, 2005). 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 wastage 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. The objective this Paper is : t*o review the effect of fertilizer rate and variety on growth, yield and quality of Sweet potato.*

Growth, yield and nutritional quality of sweet potato (*Ipomoea batatas* (L.)Lam) varieties as influenced by fertilizer type and rates

Fertilizer and its role

Fertilizer application rates in Africa have been around 11 kg ha^{-1}, which is not even one tenth for the global average (Zelleke *et al.,* 2010). The result of low fertilizer use in Africa indicated that, cereal crop yields one-third of those in developing Asia and only one-tenth of those in the United States. It is estimated that, enhancing crop yields in Africa by only 1 percent could save two million Africans from poverty. Fertilizer for African green revolution in which they agreed to support an increase in fertilizer use from 8.0 to 50 kg per hectare by 2015 (Zelleke *et al.,* 2010).

A Sweet potato uses more nutrients from the soil. Fertilizer has greater effect on the productivity of this crop. It requires of potassium, nitrogen and phosphorus (Wolf, 1992; Kebede and Birru, 2011).According to Sanwal *et al*. (2007) report, nitrogen, phosphorus and potassium influence vegetative and reproductive stage or phase of plant growth. Because it readily produces adventitious roots and has trailing vines, sweet potato can colonize marginal soils. The application of 300 kg ha^{-1} NPK and 50 kg ha^{-1} N is considered beneficial in the savanna zones of Nigeria. This is to ensure high yields under extensive and commercial production (Mukhtar *et al.,* 2010). On sweet potato, N rate influenced total first order lateral root and second order lateral root number increased by 110% and 214% respectively. There were111% more adventitious roots in the fertilized compartment relative to the unfertilized compartment (Villordon *et al*., 2013). In the pacific regions root crops are important stable food and as a result, improved production systems are required to increase sweet potato yield through the use of inorganic fertilizers (Hartemink *et al.,* 2000).

Bourke (1985b) reported that, even though nitrogen is one of the most abundant elements in plants and animals as it is a major component of proteins, some studies revealed that, nitrogen application reduce Sweet potato yields and recommend low. The reason is that, nitrogen application has a strong effect on the distribution of dry matter within the plant, particularly affecting storage root growth relative to top growth. When nitrogen supply is high, plants tend to grow more tops relative to roots. In the case of sweet potato, high nitrogen may cause excessive growth of the vines at the expense of root tuber yield, delay tuber bulking and maturation (Bradbury and Holloway, 1988).

Role 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 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 leave is rich in carotene which is a precursor of vitamin A and calcium (Mukhtar *et al.,* 2010).

In North Ethiopia, Orange flesh sweet potatoes (OFSP) were used in food based intervention. Result revealed that, 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). Its general trend 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 nutritional advantages especially β-carotene which may it gives direction and confidence for individuals, policymakers and donors to invest on OFSP to alleviate 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 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 27.2mg/100g dwtb), 'Ejumula' (240 ppm or 24.mg/100g dwtb), 'Mayai' (264 ppm or 26.4mg/100g dwtb), and 'Zambezi' (233 ppm or 23.3mg/100g dwtb) were exhibited similar or slightly different β-carotene contents as the control.

Vosawai *et al*. (2015) reported that 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%). Consumers and industrialists prefer sweet potato varieties with high dry matter content (Mwanga *et al*., 2009; Cervantes-Flores *et al.,* 2011). In sweet potato production, 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). Analysis of selected OFSP and YFSP nutrients were done for carbohydrate, crude protein, crude fibre, crude fat, total ash, total reducing sugar, vitamin C and moisture content showed that the OFSP had higher β-carotene content with differences percentage (Emmanuel *et al.,* 2010). The results obtained were presented in Table 1 below.

Table 1. 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	5
Total ash%	4.7	3.5	4	3	4	3
Moisture content%	81	80	17	15	17	15
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 indicated that highest tuber root yields (31.59 t ha^{-1}) were found in CIP 194513.15 and followed by CIP 440267.2 (30.97 t ha^{-1}) and the lowest yield (13.34 tha^{-1}) were obtained in BARI SP 3 cultivar. The maximum dry matter (29.83%) was obtained in H6/07 while the minimum dry matter (17.61%) was obtained in CIP 441132. Among the tested genotypes the highest Vitamin A (919.2 µg/100 g RAE, fwb) were recorded in CIP 440267.2 cultivar and recommended in Bangladesh on the basis of yield and quality mainly of carotenes (Rahman *et al*., 2013).

Four different colour fleshed Sweet potatoes in china: were evaluated for nutrient compositions: dietary fiber content, anthocyanins, total phenolics content and their total antioxidant activity. Starch contents of yellow (Beijing-553) and white (Shangshu-19) were higher, but fat contents were lower than others. Protein content of Shangshu-19 was the highest followed by purple (Jizi-01) and red (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).

Influence of fertilizer on yield and yield components of Sweet potato

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). All growth parameters of “Beaure Gard” cultivar of Sweet potato plants 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 p kg ha^{-1}) (El-Sayed *et al.*,2011). Plants which received 45 kg /fed P_2O_5 (107.14 kg ha^{-1} P_2O_5 or 47.1 P kg ha^{-1}) had showed significant increases in most vegetative growth: main stem length, canopy dry weight, leaf area, total chlorophyll, carotenoids and others (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% and statistically significant(Abdissa *et al.,* 2012). Applications of N and P (46 N kg ha^{-1}, 23P kg ha^{-1}) were significantly increased vine length (Ambecha, 2001). 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 at application rates above 60 P_2O_5 kg ha^{-1}. Teshome *et al.*(2012) confirmed the same idea and he indicate that, Sweet potato benefited little from P to increase its canopy.

Essilfie (2015) reported that, Apomuden grown on 15-30- 30 kg ha^{-1} NPK+ 5 ton ha^{-1}CM plot had the highest vine length than control plots at 12 WAP and Okumkom grown on 30-30-30 kg ha^{-1}NPK rate had the highest vine length than control plots at 12 WAP. Excess 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, Nitrogen beyond 45N kg ha^{-1} inhance 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 on ridge. Commonly adequate supply of Nitrogen (N) is associated with high photosynthetic activity and vigorous vegetative growth thereby increasing internodes lengths.

When P levels increased from 50 to 75P kg ha^{-1}, the increase in shoot fresh weight did not very much. The maximum shoot fresh weight (497 g $hill^{-1}$) was recorded at 25 P kg ha^{-1} on flat seedbed and the highest shoot fresh weight (504g $hill^{-1}$) was recorded at 45 N kg ha^{-1} (Busha,2006). 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 15t 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}+ 90 kg 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).

Influence of fertilizer on average storage root number, storage root length and diameter.

Many researchers reported that, fertilizer influenced the average storage root number, storage root length and diameter of sweet potato in different parts of the world. Dumbuya *et al*. (2016) reported that, Okumkom variety with 60 P_2O_5 kg ha^{-1} gave more marketable storage root numbers than that of the control. 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. 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 than the controle one. Busha (2006) farther reported that, application of 45N kg ha^{-1} and 25P kg ha^{-1} resulted in significance higher difference total tuber number. Abdissa *et al.* (2012) 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 storage root number vary between 4 to 5 in number due to P on sweet potato(Bellala) variety.

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 t 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 5t FYM ha^{-1} and 180kgha^{-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).

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).

Application of P nutrition is very important on growth and productivity of sweet potato plants; as P fertilizer application positively increased sweet potato productivity compared with the untreated control (El Marsy *et al.,* 2002; Hassen *et al.,* 2005). El-Sayed *et al.* (2011) reported that, P rates resulted in a significant effect on total marketable yield of "Beaure Gard" cultivar of sweet potato respectively. He further indicated that, yields were increased with increasing P rate on "Beaure Gard" cultivar of sweet potato respectively Similarly, Yeng *et al*. (2012) reported that, the sole inorganic fertilizer 15:15:15.N.P.K (200 kg IF ha^{-1}) produced marketable storage root yield 76 % and total storage root yield 79% more than the control.

Hassan *et al.* (2005) found that, fertilization of Sweet potato with P fertilizer caused significant increase in marketable and total yield. Busha (2006) also reported that , increasing P levels from 0 to 25 P kg ha^{-1} with interaction of Koka-18 increased total tuber yield by 20 % 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.

Plants supplied with adequate amounts of P were reported to form good root system, strong stem, matured early and gave high yield (Rending and Taylor, 1989). Byju *et al.* (2007) reported that, the total tuber yield of sweet potato increased significantly with up to 1.5 kg ha^{-1} of boron applications and Echer and Creste (2011) reported up to 2 kg ha^{-1} of Boron applications. Further increase of B did not further increase in yield of Sweet potato.

In 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, Dan-Bakalori variety yielded significantly higher than Dan-Zaria (6.715/4.5m2 or 14.92 tha^{-1} and 5.459/4.5m^2 or 12.13 tha^{-1}) application of 150 (67.5: 67.5: 67.5) NPK ha^{-1} respectively. Application of 2.5 ton ha^{-1} poultry manure + 200 kg NPK gave higher fresh storage root weight than application of Agrolyser at 5.4 kg ha^{-1} at 8 WAP harvest (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 (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.

In most Ethiopian soils, tuber yield had been increased by the application of nitrogen fertilizer. The blanket recommended rate of DAP is 175 kg ha^{-1}(80.5 P_2O_5) and should be applied at the time of land preparation or planting; whereas Urea 80 - 100 kg ha^{-1} (36.8 kg N up to 46 kg ha^{-1} N) (Kebede and Birru, 2011). 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 farther indicates that use of Nitrogen beyond 45N kg ha^{-1} inhance 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. 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). An application of 60 kg N ha^{-1} increased yields of 3 USA cultivars but decreased the yields of 3 African cultivars. In the soils of West Africa large responses to nitrogen are often obtained on soils which have been heavily cropped in the past or those subject to heavy leaching (Halavatau *et al.,* 1996).

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. 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. 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). Dumbuya *et al*. (2016) reported that, Okumkom variety with 60 kg ha^{-1} P_2O_5 (36.42%) was significantly higher than other treatments. Boru *et al*. (2017) reported that, the highest percent of dry matter response was recorded at 69 kg ha^{-1} P_2O_5. 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. The 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, 2009).

Influence of fertilizers on nutritional quality of Sweet potato

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, total carotenoids 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 400kg 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 farther indicate that, Okumkom grown on 30-60-60 $kgha^{-1}$ NPK plot had the highest β-carotene content. 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% of the dry matter and Cow dung only (31.3%) from their 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 varieties. Like nitrogen, phosphorus increase the carotene content of tuberous roots during the yield increase period and also affects the unit weight of root tubers (Degras, 2003).

Both S and N involve in protein synthesis, intimately linked and are often considered to be co-limiting. It has been established that for every 15 parts of N in protein, there is approximately 1 part of S (15:1 ratio of N:S).An inadequate S supply will not only reduce yield and crop quality, but it will decrease N use efficiency and enhance the risk of N loss to the environment (Schnug and Haneklaus, 2005). Deficiencies of boron cause a reduction of yield production, quality and irregularly of the cell walls (Pillai *et al*. 1986; Matoh *et al.,* 1996; O'Sullivan *et al*., 1997).

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 (Purcell *et al*., 1982). Application of 100 kg ha^{-1} NPK (15:15:15) at 130 kg ha^{-1} resulted in highest moisture percentage in the leaves of sweet potato and Peak percent of ash content than controle 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).

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). Phosphorus deficient sweet potato plants typically produce tubers with lower specific gravity compared to those with adequate P nutrition (Degras, 2003).. Namo and Babalola (2016) reported that, the specific gravity in the clone TIS.2532.OP.I.13 differed significantly from that of clone TIS.44R1 68 with application of NPK ha^{-1} fertilizer (15:15:15) applied.

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}. 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) applied.

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-El-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 Prates up to 45 kg / fed P_2O_5.

Interaction effect of varieties and fertilizers on qualities, yield and growth of Sweet potato

Four N application levels and 5 Sweet potato accessions were evaluated. 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**).**

In Nigeria, response of 2 improved sweet potato varieties (TIS 8164 and Ex-Igbariam) to 5 rates of potassium fertilizer result revealed that, Ex-Igbariam with 120 and 160 kg ha^{-1} got higher. Ex-Igbariam was more responsive to K(160 kgha^{-1}) application than TIS8164 in longer vines, higher number of leaves and branches per plant 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 at 120 kg ha^{-1}, weight of tubers per plant at 160 kg ha^{-1} and tuber yield per hactar at 120 kg ha^{-1}, respectively (Uwah *et al.,* 2013).

SUMMARY AND CONCLUSIONS

Sweet potato (*Ipomoea batatas* (L.) Lam)is economically important food security crop . Yellow and orange fleshed sweet potato varieties have high nutrient value mainly β-carotene which is a precursor of vitamin A. The β-carotene content of sweet potato common to Africa ranged from 100 to 1,600 μg RAE/100g which agreed with the β-carotene values obtained in some of the varieties of Ethiopia. Nearly all light to deep OFSP farmer varieties clearly contain β-carotene. 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 %

Growth parameters are the main important yield determining factors in sweet potato and they are highly influenced by soil fertility and soil amendments. Nitrogen supply has a strong influence on the distribution of dry matter within the plant, particularly affecting root growth relative to top growth at optimum level Applications of N and P (46 N kg ha^{-1}, 23P kg ha^{-1}) were significantly increased marketable and total tuber yield by 20 %,vine length and decreased at application rates above 60 P_2O_5 kg ha^{-1}. Excess nitrogen can stimulate increased foliage production at the expense of tubers and may also lead to tuber cracking. Nitrogen beyond 45N kg ha^{-1} enhance vegetative growth rather than root growth. Adequate supply of N and P promotes higher photosynthetic activity and vigorous vegetative growth and promotes the chance for emergence of new vines .The maximum shoot fresh weight was recorded at 25 P kg ha^{-1} and 45 N kg ha^{-1}. Plants supplied with adequate amounts of P were reported to form good root system, strong stem, matured early and gave high yield. The total tuber yield of sweet potato increased significantly with up to 1.5 kg ha^{-1} - 2 kg ha $^{-1}$ of boron applications. Further increase of B did not further increase in yield of Sweet potato. Total dry matter production and efficiency of dry matter allocation to storage roots are important factors determining storage root yield. a linear increase in total yield and storage root dry matter in phosphorus application . Shoot dry weight of Sweet potato was also highly responsive and significantly affected by the combined application of farmyard manure and phosphorus and increased by 215.8% .

The β-carotene contents were varying within variety and fertilizer level. 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 varieties. Both S and N involve in protein synthesis, intimately linked and are often considered to be co-limiting. Some of application of Sulfur caused formation of more protein that has a nutritional. Increasing application of nitrogen fertilizer significantly increases β-carotene content. Interactions of Resisto with fertilizer application tended to increase β-carotene content.

(OFSP) rich in β-carotenes which is a proven cost effective strategy for providing vitamin A. The yield responses were varying in variety and place.

Acronyms used

CSA	Central Statistics Authority
DAP	Days After Planting
FAO	Food and Agricultural Organization
tha^1	ton per hectare
OFSP	Orange Fleshed Sweet Potato

WAP	Weeks After Planting
WFO	World Food Program
YFSP	Yellow Fleshed Sweet Potato

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