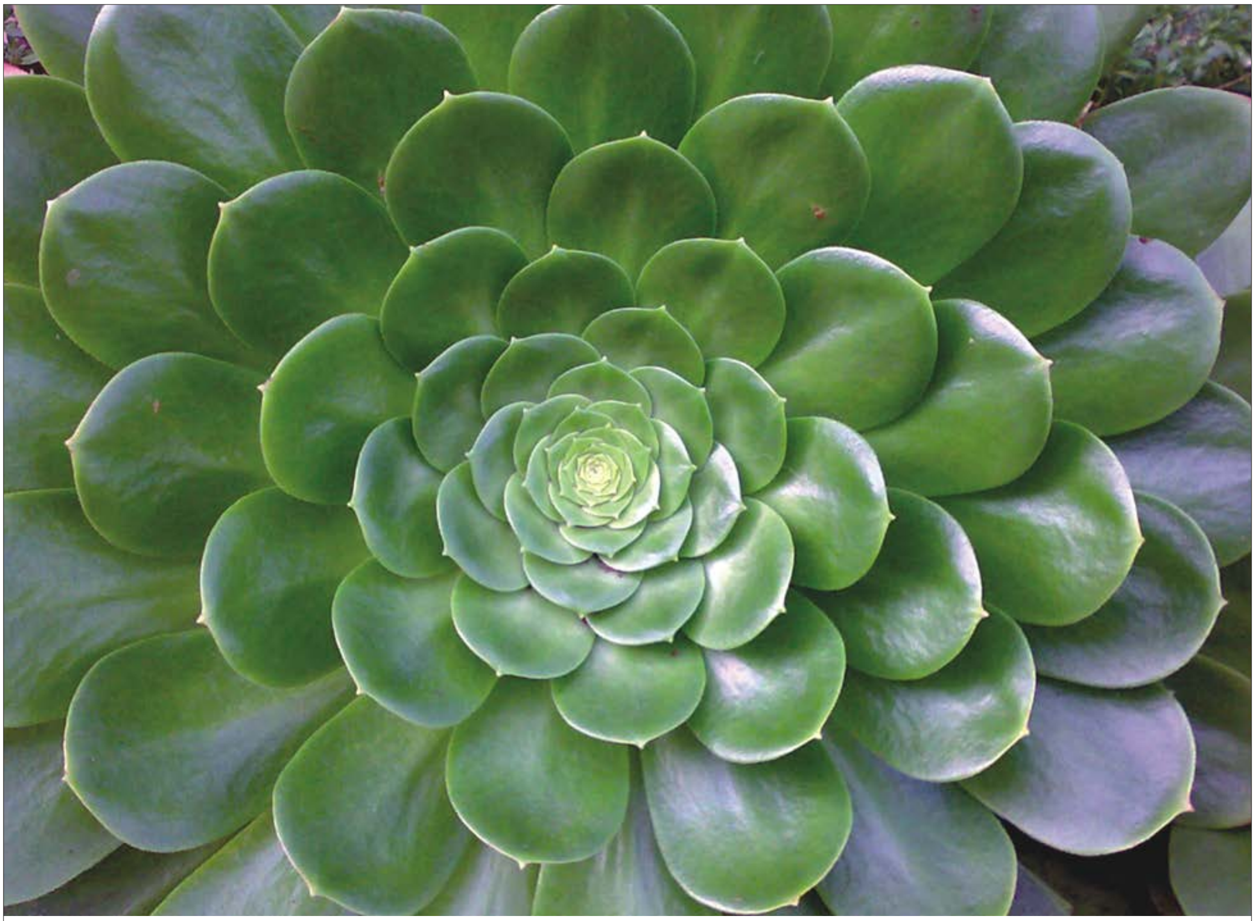

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Evaluation of Orange Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties for Yield and Yield Contributing Parameters in the Humid Tropics of Southwestern Ethiopia

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ABSTRACT

Five orange fleshed sweet potato (*Ipomoea batatas* L.) varieties: four collected from Adami Tulu Agricultural Research Center and one local variety with orange flesh were evaluated at field condition to identify the highest yielding and adaptable variety. The five varieties: Beletech (192026 II), Birtukanie (Saluboro), Kulfo (Lo-323), Tulla (CIP 420027) and a local variety were used as treatments and arranged in randomized complete block design with three replications. Data collected on yield and yield contributing parameters were analyzed using the GLM procedure of SAS version 9.2. Variety had significantly affected root diameter, marketable tuberous root yield and total tuberous root yield. Significantly the highest root diameter (4.9 cm), marketable tuberous root yield (0.78 t ha^{-1}) and total tuberous root yield (0.88 t ha^{-1}) were obtained from variety Tulla. The result of the correlation analysis also revealed that root diameter and number of tuberous roots per plant were significantly and positively correlated with marketable and total tuberous root yield. Likewise marketable tuberous root yield was also significantly and positively correlated with total tuberous root yield. This indicated sweet potato producers targeting tuberous roots should use root diameter, number of tuberous roots per plant and marketable tuberous root yield as selection criteria. Likewise, these yield and yield contributing parameters are important selection parameters which can serve as indicators of adaptability of the sweet potato to the study area and can also be utilized for making improvement in tuberous root yield of sweet potato. Besides, yield is an important agronomic index that shows the adaptability of a variety to its growing environment and accordingly variety Tulla outperformed the three improved OFSP varieties and the local variety in yield and yield contributing parameters. Therefore, variety Tulla (CIP 420027) was identified as the highest yielding and adaptable OFSP variety under the rain fed condition in the humid tropics of Southwestern Ethiopia at Jimma and potentially combats VAD at community level.

Key words: Beta carotene, OFSP varieties, root diameter, Southwestern Ethiopia, yield

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a dicotyledonous plant belonging to the family Convolvulaceae (Tortoe *et al*., 2010). It is one of the most important sources of carbohydrates for small holder farmers in Ethiopia (Amare *et al*., 2014) and the third root and tuber crop after Irish potato and cassava in quantity of consumption in tropical Africa (Laban *et al*., 2015). Sweet potato yields are high per area (Nwankwo *et al*., 2012) per unit of time (Nedunchezhiyan *et al*., 2012). Due to its higher productivity and drought tolerance, the crop can play vital role in achieving food self sufficiency of the region (Amare *et al*., 2014). This makes it an ideal sustainable crop for production in developing countries, where population growth has decreased the amount of arable land per person and increased the use of marginal land for food production (Woolfe, 1992). Sweet potato provides household food security because the crop can be harvested within 3-6 months (Anyaegbunam *et al*., 2008) and also can remain in the ground for "piece meal" harvesting, a common sweet potato "storage" practice in the tropics (Laban *et al*., 2015). In Ethiopia, sweet potato has been cultivated for many years and is important in diet where population growth is highest and land holding is the least (Habtu, 1995). Over 95% of the crop is produced in the Southwestern, Eastern and Southern parts where it has remained for centuries as one of the major subsistence crops especially in the periods of drought (Adhanom *et al*., 1985). The most widely grown sweet potato varieties are white fleshed, with negligible amounts of beta carotene and this could be contributing to vitamin A deficiency (Omiat *et al*., 2005). Vitamin A Deficiency (VAD) is widespread and has severe consequences for young children in developing countries (Low *et al*., 2007) including Ethiopia. Although the yield and beta carotene content of white fleshed sweet potato varieties is low (Wariboko and Ogidi, 2014) in many countries including Ethiopia, there is high potential for increasing both the yield and beta carotene content through the use of improved Orange Fleshed Sweet Potato (OFSP) varieties. The OFSP varieties are rich in beta carotene that the body uses to produce vitamin A (Wariboko and Ogidi, 2014). OFSP varieties are cheap and year round source of vitamin A (Omiat *et al*., 2005) to the poor families in developing countries of East Africa such as Ethiopia because OFSP is well accepted by young children (Low *et al*., 2007) and can combat VAD.

Therefore, the objective of this experiment was to identify promising and adaptable orange fleshed sweet potato variety in terms of yield and yield contributing parameters and hence could combat Vitamin A Deficiency (VAD) at community level in the humid tropics of Southwestern Ethiopia, at Jimma.

MATERIALS AND METHODS

Description of the study site: The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) experimental site during the main cropping season of 2013/14, from June to October under the rain fed condition. Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) is located at about 7°41' N latitude and 36°50' E longitude and at an altitude of 1710 m above sea level (m.a.s.l.). The JUCAVM is situated in the Southwestern part of the country at about 350 km away from Addis Ababa, the capital city of Ethiopia. The experimental site is with the mean maximum and minimum temperature of 26.8 and 11.4°C, respectively and receiving a mean annual rainfall of 1500 mm (BPEDORS, 2000). The site has well-drained soil with loam texture, gentle slope and Nitisols (Nitosols) soil type (FAO., 2006).

Experimental treatments and design: Five different Orange Fleshed Sweet Potato (OFSP) varieties of which four were collected from Adami Tulu Agricultural Research Center and one local variety with orange flesh were used as treatments in this experiment (Table 1). These five OFSP varieties (treatments) were laid out in Randomized Complete Block Design (RCBD) with three replications (Wariboko and Ogidi, 2014).

Experimental procedures: The experimental land was ploughed, harrowed, ridged and well decomposed cattle manure was incorporated into the soil at a rate of 20 t ha^{-1} before planting. Vine cuttings of 30 cm length with six nodes were prepared from the healthy stem of each OFSP

Table 1: Description of the five orange fleshed sweet potato varieties used as experimental treatments

Varieties	Year of release	Breeder/maintainer	Remarks
Local variety	Not well known	Local farmers	Orange fleshed
Beletech (192026 II)	2004	AwARC/SARI	Orange fleshed
Birtukanie (Saluboro)	2008	Sirinka ARC/ARARI	Orange fleshed
Kulfo (Lo 323)	2005	AwARC/SARI	Orange fleshed
Tulla (CIP 420027)	2005	AwARC/SARI	Orange fleshed

AwARC: Aawassa agricultural research center, SARI: South agricultural research institute, Sirinka ARC: Sirinka agricultural research Center, ARARI: Amara agricultural research institute

varieties (Nwankwo *et al*., 2014). Cuttings were planted on the ridges (Anyaegbunam *et al*., 2008) with about three nodes buried in the soil uniformly for all treatments at the spacing of 60 cm between rows and 30 cm between plants (Nwankwo *et al*., 2012) on plots with the size of 2.4×2.4 m containing 4 rows and 8 plants per row resulting in 32 plants per plot. Weeding was done two times using manual method. Earthing up and other cultural practices were done according to the standard recommendation.

Data collection and analysis: To evaluate the yield performance and adaptability of Orange Fleshed Sweet Potato (OFSP) varieties all the data on yield and yield contributing parameters were recorded. Data on Root Diameter (RD), Root Length (RL), Number of Tuberous Roots per Plant (NTRP), Marketable Tuberous Root Yield (MTRY), Unmarketable Tuberous Root Yield (UTRY) and Total Tuberous Root Yield (TTRY) were collected. Finally, data were analyzed using the GLM procedure of SAS Version 9.2 statistical software (SAS., 2002) and treatment means were compared using LSD value at 5% significance level. Correlation analysis among yield and yield contributing parameters was done using Pearson correlation analysis procedure of SAS version 9.2 statistical software (SAS., 2002).

RESULTS AND DISCUSSION

Effect of variety on yield and yield contributing parameters: The results of the current investigation showed that most important yield and yield contributing parameters of the studied Orange Fleshed Sweet Potatoes (OFSPs) varieties significantly ($p<0.05$) varied and showed significant differences among the sweet potatoes evaluated (Table 2). The current finding is more or less in good agreement with Omiat *et al*. (2005), who indicated that varietal effect had a significant influence on the marketable tuberous root yield as well as total tuberous root yield of sweet potato. Similarly, Kathabwalika *et al*. (2013) also observed significant differences in total tuberous root yield among sweet potato varieties in their trial.

Root diameter: Root diameter was highly significantly ($p<0.01$) affected by variety and showed significant differences among the five sweet potato varieties evaluated (Table 2). The highest mean value in root diameter (4.90 cm) was recorded in T5 (Variety Tulla) while the lowest mean value (3.39 cm) was recorded in T1 (the Local Variety) compared to the remaining OFSP varieties (Table 3). The difference observed in root diameter among the OFSP varieties is attributed to their genotypic difference. The current result is in conformity with the finding of Rahman *et al*. (2013), who conclude that sweet potato variety, H19/06 gave significantly the highest tuberous root diameter (6.92 cm) compared to the other varieties included in their study.

Number of tuberous roots per plant: Number of tuberous roots per plant showed none significant ($p>0.05$) difference among the five sweet potato varieties tested (Table 2). Even though

Table 2: Mean square values for yield and yield components of the five types of orange fleshed sweet potatoes as affected by variety

		Yield and yield contributing parameters				
Source of variation	df	RD	NTRP	MTRY	UTRY	TTRY
Treatment (Variety)	4	1.054**	1.463^{ns}	0.058*	0.001^{ns}	0.057*
Error	8	0.124	1.298	0.017	0.002	0.017
CV		8.180	22.000	22.750	55.280	19.28

DF: Degrees of freedom, RD: Root diameter, NTRP: Number of tuberous roots per plant, MTRY: Marketable tuberous root yield, UTRY: Unmarketable tuberous root yield, TTRY: Total tuberous root yield, ns: Non-significant, *: Significant at 5 % , **: Highly significant at 1% probability level

Table 3: Effect of variety on root diameter of the five OFSP types

Treatments	Means for root diameter (cm)
T1 (Local variety)	3.39^{c}
T2 (Beletech (192026 II))	3.91^{bc}
T3 (Birtukanie (Saluboro))	5.00^{a}
T4 (Kulfo (Lo 323))	4.35^{ab}
T5 (Tulla (CIP 420027))	4.90^{a}
LSD	0.66

Means followed by different letters per column differ significantly (p<5%) as established by LSD test, LSD: Least significant difference

Table 4: Effect of variety on number of tuberous roots per plant of the five OFSP types

Treatments	Means for number of tuberous roots per plant (Number)
T1 (Local variety)	4.88
T2 (Beletech (192026 II))	5.20
T3 (Birtukanie (Saluboro))	4.73
T4 (Kulfo (Lo 323))	4.80
T5 (Tulla (CIP 420027))	6.27
LSD	2.15

Means followed by different letters per column differ significantly (p<5%) as established by LSD test, LSD: Least significant difference

the number of tuberous roots per plant were not significantly different among the five OFSP varieties, the highest mean number of tuberous roots per plant (6.27) was recorded in T5 (Variety Tulla) similar to the other yield and yield contributing parameters significantly differing among the varieties. On the other hand the lowest mean number of tuberous roots per plant (4.88) and (4.80) were recorded in T1 (the Local variety) and T4 (Variety Kulfo) respectively compared to the other OFSP varieties evaluated (Table 4). The difference perceived among the OFSP varieties in number of tuberous roots per plant could be attributed to the differences in their genotypic composition. In line with the result of the current study, the highest mean number of tuberous roots per plant was about 5.13 in variety CIP 440267.2 in one study and in another similar study the number of tuberous roots per plant varied from 1.73-6.03 among the varieties studied (Rahman *et al*., 2013). Variety Tulla had the highest number of tuberous roots per plant and this is one important factor for selection of sweet potato varieties and serves as indicator of adaptability of the crop to the study area (Nwankwo *et al*., 2012).

Marketable tuberous root yield: Significant (p<0.05) differences occurred in marketable tuberous root yield among the sweet potato varieties evaluated in this research (Table 2). The highest mean value of marketable tuberous root yield (0.78 t h^{-1}) was recorded from T5 (Variety Tulla), followed by T3 (Variety Birtukanie) however, the lowest mean value of marketable tuberous root yield (0.35 t ha^{-1}) was recorded from T1 (the Local variety) compared to the remaining two OFSP varieties Beletech and Kulfo (Table 5). The differences in marketable tuberous root yield could be attributed to the genetic variations among the OFSP varieties in partitioning photosynthates (Nedunchezhiyan *et al*., 2007).

Table 5: Effect of variety on marketable tuberous root yield of the five OFSP types

Treatments	Marketable tuberous root yield (t ha^{-1})
T1 (Local variety)	0.35^{b}
T2 (Beletech (192026 II))	0.55^{ab}
T3 (Birtukanie (Saluboro))	0.71^{a}
T4 (Kulfo (Lo 323))	0.55^{ab}
T5 (Tulla (CIP 420027))	0.78^{a}
LSD	0.25

Means followed by different letters per column differ significantly (p<5%) as established by LSD test, LSD: Least significant difference

Table 6: Effect of variety on unmarketable tuberous root yield of the five OFSP types

Treatments	Means for unmarketable tuberous root yield (t ha^{-1})
T1 (Local variety)	0.10
T2 (Beletech (192026 II))	0.09
T3 (Birtukanie (Saluboro))	0.08
T4 (Kulfo (Lo 323))	0.06
T5 (Tulla (CIP 420027))	0.11
LSD	0.09

Means followed by different letters per column differ significantly (p<5%) as established by LSD test, LSD: Least significant difference

The result of the current study is in consistent with the finding of Omiat *et al*. (2005), who obtained the highest marketable tuberous root yield from variety Ejumula but the lowest marketable tuberous root yield from variety Arivumaku. In similar study, Nwankwo *et al*. (2012) also indicated sweet potato varieties B21 and E10 had the highest marketable tuberous root yield. Based on the current result we can suggest that variety Tulla was the best variety followed by variety Birtukanie for marketing purposes but the local variety and the two newly introduced OFSP varieties Beletech and Kulfo were considered the poorest varieties for marketing purposes (Omiat *et al*., 2005). Thus, these are important parameters for selection and serve as indicators of adaptability of the crop to the study area. Accordingly variety Tulla can be used as good source of marketable roots where production is aimed at marketable roots (Nwankwo *et al*., 2012).

Unmarketable tuberous root yield: Unmarketable tuberous root yield was none significantly ($p<0.05$) different among the OFSP varieties (Table 2). Similarly Nwankwo *et al*. (2012) also observed none significant differences in unmarketable tuberous root yield among sweet potato varieties in their study. Even though unmarketable tuberous root yield was none significantly different among the OFSP varieties, the highest unmarketable tuberous root yield (0.11 t ha^{-1}) was recorded in T5 (Variety Tulla). On the other hand, the lowest unmarketable tuberous root yield (0.06 t ha^{-1}) was recorded in T4 (Variety Kulfo) which is also not significantly different from T1 (the Local Variety) already grown by the local farmers in the study area (Table 6).

Total tuberous root yield: Significant ($p<0.05$) difference occurred in total tuberous root yield among the OFSP varieties evaluated (Table 2). The highest total tuberous root yield (0.88 t ha^{-1}) was recorded in T5 (Variety Tulla) followed by T3 (Variety Birtukanie) and T2 (Variety Beletech) which were none significantly different from each other. However, the lowest total tuberous root yield (0.61 t ha^{-1}) was recorded in T4 (Variety Kulfo) which is also not significantly different from total tuberous root yield (0.47 t ha^{-1}) obtained from T1 (Local variety) already grown by the local farmers, implying that T4 (Variety Kulfo) was probably the poorest in total tuberous root yield among the newly introduced four OFSP varieties (Table 7). The differences in total tuberous root yield could be attributed to varietal differences among the OFSP varieties (Antiaobong, 2007). This result is in line with Amare *et al*. (2014), who also found significant differences in total tuberous

Table 7: Effect of variety on total root tuber yield of the five OFSP types

Treatments	Means for total root tuber yield (t ha^{-1})
T1 (Local variety)	0.47[c]
T2 (Beletech (192026 II))	0.65[abc]
T3 (Birtukanie (Saluboro))	0.79[ab]
T4 (Kulfo (Lo 323))	0.61[bc]
T5 (Tulla (CIP 420027))	0.88[a]
LSD	0.25

Means followed by different letters per column differ significantly (p<5%) as established by LSD test, LSD: Least significant difference

Table 8: Correlation (Pearson) coefficient among yield and yield contributing parameters: root diameter, No. of tuberous roots per plant, marketable tuberous root yield, unmarketable tuberous root yield and total tuberous root yield in orange fleshed sweet potato varieties

Parameters	RD	NTRP	MTRY	UTRY	TTRY
RD	1.00	0.24[ns]	0.81**	-0.11[ns]	0.77**
NTRP		1.00	0.64*	0.20[ns]	0.68**
MTRY			1.00	-0.08[ns]	0.97**
UTRY				1.00	0.16[ns]
TTRY					1.00

**, * and ns: Significant at 1%, 5% probability level and none significant correlation, respectively, RD: Root diameter, NTRP: No. of tuberous roots per plant, MTRY: Marketable tuberous root yield, UTRY: Unmarketable tuberous root yield and TRTY: Total tuberous root yield

root yield among varieties in their trial. Similarly, Wariboko and Ogidi (2014) also concluded that improved OFSP varieties were higher in total tuberous root yield.

According to Niringiye *et al*. (2014) the highest total tuberous root yield was recorded from sweet potato varieties 23/60/19, 23/60/31, 91/282-5, Sowola (OP)/2 and 282/94/3 while the lowest total tuberous root yield was obtained from varieties 23/60/90, Jewel (OP)/2005/6, Diallel 3, Zapallo/94/8 and the standard checks Dimbuka and New Kawogo, which is in consistent with the result of the current investigation. In another similar study, OFSP variety Tulla showed high and above average total tuberous root yield and hence, this variety is characterized by specific adaptation to the study area (Amare *et al*., 2014). This shows that variety Tulla converted most of its photosynthetic products into carbohydrates stored in tuberous roots below ground. Most carbohydrate accumulated by the variety was translocated to the roots but not to the above ground plant parts and this increase in tuberous roots at the expense of the above ground plant parts growth was also reported by Parwada *et al*. (2011). The evidence from the data in this study indicated that OFSP variety Tulla (CIP 420027) can be grown in Southwestern Ethiopia at Jimma (Ehisianya *et al*., 2012). Hence Tulla (CIP 420027) was identified as the highest total tuberous root yielding variety in the study area and can be beneficial to growers aimed at producing sweet potatoes for tuber production, since yield is an important factor which determines choice of sweet potato varieties for cultivation (Njoku *et al*., 2009).

Correlation among yield and yield contributing parameters of OFSP varieties: In the present study correlation analysis among yield and yield contributing parameters was done and revealed positive and negative associations among the studied yield and yield contributing parameters of OFSP varieties evaluated in the study (Table 8).

Sweet potato root diameter was highly significantly and positively correlated (R = 0.81**) with marketable tuberous root yield and also highly significantly and positively correlated (R = 0.77**) with total tuberous root yield. The current result is in agreement with that of Gunjan (2012), who reported positive correlation of root diameter with marketable tuberous root yield (0.58) and total tuberous root yield (0.63). In similar manner number of tuberous roots per plant is significantly and positively correlated (R = 0.64*) with marketable tuberous root yield and also highly significantly and positively correlated (R = 0.68**) with total tuberous root yield. In line with the result of our current study, Nedunchezhiyan *et al*. (2007) also found that number of tuberous roots per plant was strongly related to total tuberous root yield. Likewise marketable tuberous root yield is also highly significantly and positively correlated (R = 0.97**) with total tuberous root yield. In line with the current study, Gunjan (2012) also reported that marketable tuberous root yield was positively correlated with total tuberous root yield. This indicates that yield is an important agronomic index which shows adaptability of a variety to its growing environment (Antiaobong and Bassey, 2008) and hence variety Tulla (CIP 420027) can be identified as the highest tuberous root yielding and adaptable variety to the study area and also Root Diameter (RD), Number of Tuberous Roots per Plant (NTRP) and Marketable Tuberous Root Yield (MTRY) can be used as important factors for selection of sweet potato to growers aimed at producing sweet potatoes for tuber production and serves as an indicator of adaptability of the crop to the local growing conditions (Nwankwo *et al*., 2012).

CONCLUSION

The current results showed that the most important yield and yield contributing parameters: root diameter, number of tuberous roots per plant, marketable tuberous root yield and total tuberous root yield were significantly varied among the OFSP varieties evaluated. Accordingly, the highest root diameter (4.9 cm), number of tuberous roots per plant (6.27), marketable tuberous root yield (0.78 t ha^{-1}) and total tuberous root yield (0.88 t ha^{-1}) were recorded from variety Tulla. Based on these results, variety Tulla had the best performance in the majority of yield and yield contributing parameters and hence variety Tulla was preferably the best variety compared to the other three improved and newly introduced OFSP varieties as well as the local variety. Actually yield is an important factor which determines choice of sweet potato varieties for cultivation and it is also an important agronomic index which shows adaptability of a variety to its environment. The result of the correlation analysis also showed that root diameter was highly significantly and positively correlated with marketable tuberous root yield (R = 0.81**) and total tuberous root yield (R = 0.77**). In the same way, number of tuberous roots per plant is significantly and positively correlated with marketable tuberous root yield (R = 0.64*) and total tuberous root yield (R = 0.68**). Likewise marketable tuberous root yield is also highly significantly and positively correlated (R = 0.97**) with total tuberous root yield. This indicated that sweet potato producers targeting tuberous roots production should use root diameter, number of tuberous roots per plant and marketable tuberous root yield as selection criteria. Generally, these yield and yield contributing parameters are important factors for selection of sweet potato and can serve as indicators of adaptability of the crop to the study area. Furthermore, yield is an important agronomic index that shows the adaptability of a variety to its growing environment and hence variety Tulla (CIP 420027) can be identified as the highest tuberous root yielding and adaptable variety to the study area under the rain fed condition. Therefore, Tulla (CIP 420027) can be used as the best OFSP variety with optimum yield and highest adaptability in the humid tropics of Southwestern Ethiopia and potentially combat VAD at community level.

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