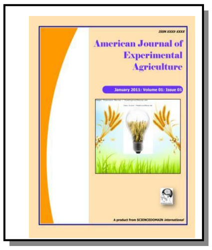

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Yield and Yield Components of Sweet Potato as Influenced by Plant Density: In Adami Tulu Jido Kombolcha District, Central Rift Valley of Ethiopia

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ABSTRACT

Two best performing, morphologically different sweet potato varieties namely, Balella and Bareda, were used to determine optimum spacing between plants and rows in central rift valley of Ethiopia by participating different influential factors from the commencement of the activity. The results indicated that total tuber yield of Balella (644 $\pm$105 q ha^{-1}) performed better with spacing 20 cm x 80 cm than the rest of the treatments i.e., 20 cm x 60 cm (590 $\pm$104 q ha^{-1}) and 50 x 60 cm (522 $\pm$137 q ha^{-1}). But the net marketable yield obtained at spacing combination of 20 cm x 60 cm (590$\pm$104 q ha^{-1}) was by far better being followed by 20 cm x 80 cm and 50 cm x 60 cm that gave average yield of 583$\pm$82 q ha^{-1} and 463$\pm$93 q ha^{-1}, respectively. Correlation matrix of dependent variables resulted that green top weight was significantly correlated with total and marketable root yield (0.887** and 0.846**, respectively). This indicated that variation in total root yield and marketable root yield was accounted by the linear function of total green top yield r^2=78.7 % and r^2=71.6%, respectively. For Bareda, 20 cm x 60 cm spacing gave total yield of 409 $\pm$ 257 q ha^{-1} followed by 20 cm x100 cm and 30 cm x 60 cm that gave yield of 347 $\pm$ 139 q ha^{-1} and 294 $\pm$ 63 q ha^{-1}, respectively. The correlation of green top and total root yield obtained for Bareda was strong and positive (r=0.689**).

Keywords: FRG, Sweet potato, spacing and yield;

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ABBREVIATIONS

FRG: Farmer Research Group; Q/ha: Quintal per hectare; RD: Root Diameter; RL: Root Length; GT: Green Top; MR: Marketable; UMR: Unmarketable; TQ: Total Quintal; SAS: Statistical Analysis System; DA: Development Agent; Kg: kilogram; cm: centimeter; CV: coefficient of variation.

1. INTRODUCTION

Among the most important root and tuber crops, Sweet potato (*Ipomea batatus* L.) is one of the major traditional food crops of Ethiopia (Endale et al., 1994). It is an attractive crop among farmers due to its high productivity, universal uses, high caloric content and good taste. It is a known crop gifted with high potential to tolerant adverse environmental conditions such as drought, low soil fertility, high rainfall and it requires very little labor and care compared to other crops (CIP, 1995). Fresh sweet potato provides about 50% more calories than Irish potato (Backumisky, 1983). Apart from its high caloric content, sweet potato is also one of the cheapest potential sources of vitamin A to alleviate problem of night blindness and infant mortality from which millions of children from sub-Saharan Africa are facing. With all its desirable traits, Sweet potato greatly contributes to food security and farmers' income (Terefe, 1994).

Based on CSO report of 1993/94 the national average yield of sweet potato in Ethiopia was 7 tons per hectare. However, previous 2006 and 2007 research result of Adami Tulu Agricultural Research Center (ATARC) reported the yield up to 37.1 tons per hectare from improved varieties. This indicates that the national as well as the regional yield is by far lower than the attainable yield obtained at research station. There are a number of constraints that hinder the production and productivity of sweet potato under farmers' circumstances. Among these, lack of appropriate agronomic practices has been a limiting factor and farmers are complaining of difficulty in management activities for different varieties (like those having long vine and horizontal root growth system and the other short vine and roots developing vertically downward). Therefore, evaluation and selection of different inter and intra row spacing by participating farmers based will improve production and productivity of the crop, which has great contribution for increment of the national average yield. Therefore, this research was done with the objectives

- To identify optimum inter and intra row spacing for two sweet potato varieties and
- To increase farmers' abilities and participation in conducting research activities

2. MATERIALS AND METHODS

2.1 DESCRIPTION OF THE STUDY AREA

The peasant association is located 2.5km western of Adami Tulu Agricultural Research Center that is located in the central rift valley (CRV), 167km south of Addis Ababa on Awassa road. It lies at a latitude of 7°9'N and 38°7'E longitude. It has an altitude of 1650 meter above sea level and a bimodal unevenly distributed average annual rainfall of 760 mm. Rainfall extends from February to September with a dry period in May to June, which separates the preceding ''short'' rains from the following "long'' rains. The pH of soil is 7.88 fine sandy loams with sandy clay having sand, silt, clay in proportion of 34%, 48% and 18% respectively (Adami Tulu Research Center profile, 1998).

2.2 EXPERIMENTAL METHODOLOGY

The experiment was conducted on three groups of target farmers field organized as FRG (Farmers' Research Group) that had been participating in production of the crop starting from variety screening and selection during the year 2006 and 2007. Among many of the farmers, those three were selected based on interest to work in groups, able to provide trial land and willing to organize and work with the rest member farmers starting from land preparation up to best treatment selection. Two best performing varieties in the area; Bareda and Belela were selected because of morphological representation of the sweet potato varieties cultivated by those farmers living in the district and high amount of yield obtained per unit area of land. General description of the two varieties has been given in Table 1. A group of multidisciplinary researchers and DA (Development Agents) together with those farmers suggested twelve treatments including check (30 cm x 60 cm) between plants and rows, respectively. Four level of spacing between two consecutive plants with in a row (20, 30, 40 and 50cm) and three levels between two consecutive rows (60, 80,100cm) forming twelve treatments as follows: 20cm x 100cm, 20cm x 60cm, 20cm x 80cm, 30cm x 100cm, 30cm x 60cm, 30cm x 80cm, 40cm x 100cm, 40cm x 60cm, 40cm x 80cm and 50cm x 100cm between plants and rows respectively were investigated. Uniform vine of 45cm long from the top was used and planted at the onset of main rainy season June 2007 and harvesting was done after four months when physiological maturity and better tuber development attained. All agronomic practices like weeding, earthing up and other routine activities were conducted as per the recommendation set for the crop. However, fertilization was not applied because of good yield obtained during variety screening without any input.

2.3 STATISTICAL ANALYSIS

All the collected agronomic data was analyzed using SAS statistical package at 95% confidence interval. If there were significant difference among treatments, mean separation was made using Duncan Multiple Range Test (DMRT) for root diameter (cm), root length (cm), Green top (Kg), Marketable weight in (q ha^{-1}), unmarketable yield (q ha^{-1}), total yield (q ha^{-1}). To determine the strength of relationship among dependent variables correlation matrix was done using Gen-stat version (7.2).

3. RESULTS AND DISCUSSION

3.1 PARTICIPATORY RESEARCH APPROACH VIEWED AS TECHNOLOGY ADOPTION

In the past many years due to lack of awareness, participating farmers having rich pool of indigenous knowledge in technology generation has not been done. As a result many of the research outcome generated by researchers were not readily accepted and adopted by farmers that made it shelved after completion in Ethiopia in general and in the study area in particular. However, currently the government of Ethiopia set strategy of research development by involving the important key factors like farmers, local and international NGOs working with and for farmers, Ministry of Agriculture, etc. who have direct and indirect contribution for the ultimate technology adoption. As a result, stake holder identification, training, role, and responsibility sharing was made before the commencement of the field plantation. At the time of maturity, field day and visit were organized to evaluate the performance of the crop and for awareness creation.

3.2 BELELLA VARIETY

The statistical analysis of Belella (variety with short vine and roots developing vertically down ward) showed that there were high significant difference for all the yield estimate parameters except total unmarketable yield that gave nonsignificant difference at $p < 0.05$ (Table 2). As regard to average root diameter per plant, spacing of 20 cm x 100 cm gave the highest thickness of 7. 2±66 cm followed by 40 cm x 100 cm and 50 cm x 60 cm that gave thickness of 7±1.5 cm and 6.9 ±17cm, respectively. This result was similar with the findings of (Enus and Razzaque 1977) done at Bangladesh; the lowest root weight that highly correlated to root diameter and length 304.20 g/plant was obtained from the closer spacing (15 cm x 75 cm) between plants and rows respectively. Root weight per plant was increased with increase in plant density and it was highest with the value of 693.82 g/plant. Bainco (1975) found similar result in potato, where increased plant density decreased the tuber weight per plant.

Table 1: General description of the two varieties

Sl. No.	Characteristics	Variety Belella	 Bareda
1	Maturity period	- Early (90-120) days in the study area	- Medium (90-150)days
2	Root color	- Light white while raw and yellow when boiled	- Deep white at both stage
3	Taste	- Milder	- Too sugary
4	Market preference	- Moderate to high	- Extremely demanded
5	Root growth habit	- Vertically downward(carrot root system) - Easy for farmers while they harvest root for consumption and market display	- Grows horizontally - It is very complicated for harvesting - Roots are liable to cut while digging - Resulted in to much unmarketable root yield because of bruising injury during harvesting and soil born disease and insect pests
6	Vine development	- Vertical up ward and free of soil born disease and insect pest that will be aggravated by rainfall splash. - Easy to conduct different cultural practice because of the manageable vine.	- Grows horizontally, affected by soil born disease and insect pest - It is a tiresome and futile activity for farmers while they are doing different cultural practices
7	Preference by farmers	- Highly preferred because of easy cultural practice, high yield and early maturity	- Less preferred because of difficulty in management, disease incidence, low yield and medium maturity

Source: Personal observation and long year practical experiences of research work with the crop

Values of total tuber yield indicated that Balella variety with spacing 20 cm x 80 cm performed better yield (644 ± 105 q ha^{-1}) than the rest of the treatments 20 cm x 60 cm and 50 cm x 60 cm, with the yield value of 590 ± 104 q ha^{-1} and 522 ± 137 q ha^{-1}, respectively. But the net marketable yield obtained at spacing combination of 20 cm x 60 cm (590 ± 104 q ha^{-1}) was by far better followed by 20 cm x 80 cm and 50 cm x 60 cm that gave average yield of 583 ± 82 q $ha^{-1}$and 463±93 q ha^{-1}, respectively. In the latter two spacing, the tuber got enough space for better absorption of water and nutrient that helped in extending and thickening of the root system. But this makes the tuber less preferred by the market because of higher cooking time, more fiber development, more susceptible to the attack of insects like weevil and extra fuel need.

The unmarketable yield was high at 20 cm x 80cm spacing, as majority of the tuber fell under the range of oversize i.e., > 500 g/tuber. Of all treatments 50 cm x 60 cm spacing combination yielded highest unmarketable tuber yield (88 ± 124 q ha^{-1}) followed by 30 x 100 cm (65±89 q ha^{-1}) and 20 cm x 80 cm (61±54 q ha^{-1}). This work is also in close agreement with the result obtained by Telleyrad (1981). This confirms that the plant density significantly increased the root size.

Root size was higher (125.87 g/root) in wider spacing at 75 cm x 60 cm. Both 75 cm x 40 cm and 75 cm x 30 cm plant spacing produced identical root size. The lowest size of root was obtained from closer spacing (75 cm x 15cm). It showed that closer spacing produced roots with comparatively less weights.

As shown in Table 2, the CV of unmarketable q/ha was 136.9% that was very high and put it beyond the unacceptable limit of range. But sometimes it happened because of out layers with both maximum and minimum that had been obtained with different spacing combinations which put it under unmarketable range.

Table 2. Result of mean and standard error comparison of Balella variety on farm

Variable	**Root Diameter (cm)**	**Root Length (cm)**	**Green Top (Kg)**	**Marketable Root (q/ha)**	**Unmarketable Root (q/h)**	**Total Yield (q/ha)**
DF	2	2	2	2	2	2
20 x 100	7. 2±.66a	15±3.4ab	3E4±8E3ab	438±110abc	42±21a	479±116abc
20 x 60	5.5±.25bcd	13±.62ab	2E4±1E4ab	590±104a	0±0 a	590±104a
20 x 80	4.9±.1d	14±2.2ab	3E4±2E4ab	583±82a	61±54 a	644±105a
30 x 100	6.1±.25abcd	15±2.2ab	4E4±4E4a	384±221bcd	65±89 a	449±309abc
30 x 60	5±1.1d	12±2.6ab	2E4±9E3ab	332±74bcd	12±21 a	344±63bc
30 x 80	5.6±.63bcd	14±2.2ab	2E4±1E3ab	288±1.3cd	12±21 a	300±110bc
40 x 100	7±1.5ab	15±1.4ab	1E4±5E3ab	285±43cd	57±81 a	323±68bc
40 x 60	5.3±.5d	14±1.2ab	1E4±5E3ab	324±36bcd	12±20 a	336±27bc
40 x 80	6±1.4abcd	14±1.8ab	1E4±5E3ab	278±54cd	22±20 a	299±57bc
50 x 100	5.4±0.29cd	16±3.6a	4E4±4E4ab	294±77bcd	28±17 a	322±83bc
50 x 60	6.9±.17abc	13±2.8ab	2E4±1E4ab	463±93ab	88±124 a	522±137ab
50 x 80	6.1±1.3abcd	15±.91ab	1E4±8E3ab	233±47d	28±32 a	260±38c
CV%	**13.51**	**15.13**	**66.55**	**24.3**	**136.9**	**28.12**

**Mean of the same letter across the row indicates non-significant difference among the treatments at (p<0.05).*

***Key:** Under size<100gms, Small size 100-200gms, Medium size200-400, Large size 400-500gms, Over size >500gms; Marketable includes (small size, medium and large size), unmarketable includes all diseased, malformed, over and under sized tubers respectively.*

Table 3. Results of SAS output (Mean±SE) of average treatments across different trial farmers as compared by different variables

Variable	D.F.	Rep1♠	Rep2♣	Rep3®
RD	11	5.6±.98a	12±6.3a	59±.97a
RL	11	14±1.5ab	15±2.9a	13±1.7b
GT	11	1E4±6E4b	4E4±3E4a	2E4±6E3b
MR	11	342±102b	430±172a	351±140b
UMR	11	45±50a	43±56a	10±16a
TQ	11	388±136ab	470±189a	360±142b

RD= root diameter; RL=root length; GT= green top; MR: Marketable; UMR: Unmarketable; TQ: Total Quintal;

3.2.1 YIELD PERFORMANCE ACROSS THE LOCATION

For effective treatment performance, evaluation of the research findings should be done at different location to capture diversity of biotic factors. Biotic factors that have been really observed at farmers' situation were soil fertility variation, management difference among farmers, rainfall frequency and intensity variation. But before the starting of farmers participatory approach, for the last many years, research output doesn't consider the varietal performance across diversified location. As a result the yield outcome obtained at research station and recommended by researchers could not be attained at farmers' real diversified and working condition that led to no or low technology adoption. As indicated in the Table 2, except of root diameter the rest dependent variables (total tuber yield, marketable yield, green top and average root length) were highly significant and supporting the above justification. That means blocking the treatments across a location increase the precision of the experiment by removing the experimental error from treatments within a block.

The result of the correlation matrix indicated that green top weight is significantly correlated with total and marketable root yield (0.887** and 0.846**, respectively) (Table 4).

Table 4. Correlation matrix of different dependent variables of variety Balella

Correlation matrix Balella								
GT	1.000							
IL	0.707**	1.000						
MQ	0.846**	0.665**	1.000					
RD	0.263	0.256	0.302	1.000				
RL	0.502**	0.499	0.574**	0.520**	1.000			
RNP	0.391	0.574**	0.349	0.060	0.381	1.000		
RWP	0.505**	0.468	0.596**	0.471	0.748**	0.435	1.000	
TQ	0.887**	0.630**	0.980**	0.306	0.578**	0.343	0.628**	1.000
	GT	IL	MQ	RD	RL	RNP	RWP	TQ

GT= green top; IL= inter-node length; MQ= marketable yield in quintal; RD= root diameter; RL=root length; RNP= root number per plant; RWP=root weight/plant; TQ= total root yield in quintal.

That is variation in total root yield and marketable root yield were accounted by the linear function of total green top yield having r^2=78.7 % and r^2=71.6%, respectively. This finding agrees with the work of Zelalem et al. (2009) done on Irish potato that Positive and highly significant correlation was obtained between above and underground biomass (r = 0.77**) indicating the existence of close association between them. However various research activities done by different scholars (Mortia, 1969; Sadanandan, 1973; Revindran and Nambisa, 1987; Onwueme and Shinha, 1991), on diversified root and tuber crops indicated that more vegetative growth as the expense of tuber initiation and development for any treatment application that facilitate green top weight.

3.3 BAREDA VARIETY

It is clear form Table 5 that the general yield performance of the Bareda variety was much lower than that of yield obtained by Belella. In general 20 cm x 60 cm spacing gave total yield of 409±257 q/ha followed by 20 cm x 100 cm and 30 cm x 60 cm that gave 347±139 q/ha and 294 ± 63 q/ha, respectively. Among all the treatments 40 cm x100 cm gave the lowest performance (129±69 q/ha) followed by 50 cm x 100 cm (144 ±34 q/ha) and 30 cm x 80 cm (185±111 q/ha). It is indicative of the fact that if spacing between plant and rows increases beyond provision of enough nutrients, the net number of vine decreases resulting into lower yield, since the net number of vine is positively correlated with yield obtained at the end of the day.

Table 5. Result of Bareda variety on farm having twelve treatments (according to 2000 SAS version) with mean ± Comparison

Variable	Root Diameter(cm)	Root length (cm)	Green top(kg/ha)	Marketable root(q/ha)	Unmarketable root(q/ha)	Total root(q/ha)
DF	3	3	3	3	3	3
20 x 100	4.3±1a	19±1.3 a	3E4±3E3bcd	322±115ab	25±27a	347±139ab
20 x 60	4.2±0.91a	19±1.9 a	3E4±2E4ab	396±267a	13±11 a	409±257a
20 x 80	4.4±102a	17±2.6 a	4E4±1E4a	220±3.7abc	41±50 a	188±167ab
30 x 100	4.8±1.4a	20±2.0 a	3E4±2E4bcd	270±164abc	17±4.9 a	281±160ab
30 x 60	3.6±1.2a	19±3.2 a	2E4±3E3bcd	290±71abc	4.6±8 a	294±63ab
30 x 80	4±1.4a	21±1.2a	2E4±1E4bcd	176±103bc	8.3±12 a	185±111ab
40 x 100	5.5±1.2a	20±5.2 a	2E4±1E4d	110±40c	19±29 a	129±69b
40 x 60	5.3±0.66a	21±309a	3E4±2E4abc	323±136ab	6.9±12 a	330±132ab
40 x 80	5.1±1.4a	19±2.6 a	2E4±1E4dc	220±131abc	13±12 a	233±130ab
50 x 100	5.7±1.4a	17±0.81 a	1E4±7E3d	130±36bc	14±4.1 a	144±34b
50 x 60	4±0.85a	20±4.6 a	2E4±4E3d	170±74bc	3.7±6.4 a	174±71ab
50 x 80	5±2.2a	19±0.6 a 9	1E4±9E3d	154±93bc	27±19 a	181±109ab
CV(%)	14.2	12.81	31.9	42.86	138.16	50.14

*Df= degree of freedom; CV= coefficient of variation; *Mean of the same letter across the row indicates non significant difference among the treatments at (p<0.05)*
Key: *Under size<100, Small size 100-200gm, medium size200-400 gm, large size 400-500 gm, Over size >500g; Marketable tuber includes (small size, medium and large size), unmarketable tuber includes all diseased, malformed, over and under sized tubers respectively*

Relative to Belella that showed strong and positive correlation among different dependent variables, Bareda resulted with weak correlation (Table 6).

Table 6. Simple correlation coefficients among different dependent parameters for variety Bareda

Correlation matrix among different dependent variables of Bareda variety								
GT	1.000							
IL	0.071	1.000						
MQ	0.635**	-0.258	1.000					
RD	-0.110	0.021	0.249	1.000				
RL	0.392	0.058	0.284	0.208	1.000			
RNP	0.427	-0.016	0.383	0.006	0.214	1.000		
RWP	0.088	0.206	0.323	0.473	0.264	0.542**	1.000	
TQ	0.689**	-0.003	0.853**	0.326	0.364	0.577**	0.579**	1.00
	GT	IL	MQ	RD	RL	RNP	RWP	TQ

GT= green top; IL= inter-node length; MQ= marketable yield in quintal; RD= root diameter; RL=root length; RNP= root number per plant; RWP=root weight/plant; TQ= total root yield in quintal.

Similar to Belella, the correlation of green top and total root obtained for Bareda was also strong and positive (r=0.689**). The correlation of total yield with that of root number per plant and root weight per plant were also positive and highly significant showing r value of r=0.577** and r=0.579**, respectively.

4. CONCLUSIONS AND RECOMMENDATION

Root and tuber crop in general and sweet potatoes in particular are the crops that need to be cultivated for food security for countries like Ethiopia where population is growing at alarming rate. It thrives best in areas where there is difficulty in field crop production that is pronounced due to current global warming from which many developing countries are suffering. There for it is paramount important to increase production and productivity of the crop by adopting different agronomic practices out of which working for optimum plant density is the major. Since Bareda represents those all varieties whose vine grows horizontally and that develop root roots divergent, the result obtained from finding holds true for the rest. Therefore, 20 cm x 60 cm between two consecutive plants and rows should be adopted for those farmers involved in sweet potato production in central rift valley of Ethiopia. But for the variety Belella (20 x 80 cm) between plants and rows respectively should be followed to come up with economical and dependable root yield.

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