CHAPTER 8

EFFECT OF PLANTING DENSITY AND CULTIVAR ON YIELD AND YIELD COMPONENTS OF SWEET POTATO IN ETHIOPIA

8.1 ABSTRACT

The effects of population density (50,000, 55,555, 75,000, and 100,000 cuttings per hectare) on the performance of three Ethiopian sweet potato cultivars were studied. The objectives were to determine the effect of plant population on yield and yield components and to investigate possible differences in the response among cultivars. Field studies were conducted during 2001 with the cultivars, Falaha (early maturing), Bareda (intermediate maturing) and Awasa-83 (late maturing). Total and marketable yields were found to be the highest at a population of 100,000 and the lowest at 50,000. The total fresh tuber yield increased from 50t ha $^{-1}$ at a population density of 50,000 to 82t ha $^{-1}$ at 100,000 plants ha $^{-1}$. Of the total yield 77% was marketable with approximately 35% large, 28% medium, and 14% small. Tuber size distribution was not affected by increasing planting density. The cultivars produced similar total and marketable storage root yields, but with a clear tendency towards more large storage roots in the case of Bareda, and more small storage roots in the case of Falaha.

The cultivar x planting density interaction was not significant, indicating that for all the parameters concerned the three cultivars reacted similarly on changes in plant population.

8.2 INTRODUCTION

Sweet potato has a long history as a lifesaver. Sweet potato kept millions from starvation in famine-plagued China in the early 1960s. In Uganda, when a virus ravaged cassava crops in the 1990s, rural communities depended on the sweet potato to keep hunger at bay. In the densely populated, semi-arid plains of eastern Africa, sweet potato is called cilera abana "protector of the children" http://www.cipotato.org/sweetpotato/sweetpotato.htm (2002). This alludes to the vital role it plays in thousands of villages where people depend on the crop to combat hunger. Sweet potato is high in carbohydrates and vitamin A and can produce more edible energy per hectare per day than wheat, rice, or cassava. It has an abundance of uses ranging from consumption of the roots or leaves to processing into animal feed, starch, flour, candy and alcohol.

It was first domesticated in Central America, but is now basically a crop of Asia, which accounts for about 93% of world production (FAO, 2000). Sweet potato is the sixth most important food crop in the world (FAO, 2000). It is also the third most important root crop in Africa (FAO, 2000). In Sub-Saharan Africa sweet potato is the third most important root crop after cassava (*Manihot esculenta*) and yam (Dioscorea spp.) (Ewell & Mutuura, 1994).

Although African farmers produce only about 9 million tons of sweet potato annually, most of the crop is cultivated for human consumption. African yields are quite low at 4 to 5t ha^{-1} about a third of the Asian yields, indicating huge potential for future growth and improvement of the crop. In Africa the crop is grown on small scale, primarily to help ensure food security of the rural households (Ewell & Mutuura, 1994).

Ethiopia is one of the drought stricken countries of the world. Sweet potato is cultivated in Ethiopia mostly for storage roots for human consumption and the vegetative parts as animal feed. It ranks third after Enset (*Ensete ventricosum* Welw. Cheesman) and *Solanum* potato as the most important root crop produced in the country. Sweet potato is mainly grown by small scale, resource poor farmers. Although yields obtained are generally low, there is good potential for the crop since climatic and soil factors are largely favourable. The crop has relatively few pests and diseases, and pesticides are rarely used. Sweet potato can be grown in poor soils with little or no fertilizer.

Storage root yields vary widely between cultivars, location, and season (Austin & Aung, 1973; Wilson & Lowe, 1973). Fresh storage root yields of about 10 to 25t ha^{-1} in 16 to 20 weeks has been obtained in many countries (Bhagsari & Harmon, 1982; Li & Kao, 1985; Secreto & Villamayor Jr., 1985; Sen *et al*., 1988; Bhagsari, 1990; Rao & Sultana 1990). The world average storage root yield of sweet potato has been estimated to be 14.8t ha^{-1} (FAO, 2000). According to FAO the national average storage root yield of sweet potato is 8t ha^{-1} in Ethiopia. Experimental storage root yields ranging between 30 and 73t ha^{-1} have been reported by Hossain *et al*., (1987), Siddique *et al*., (1988), Hall & Harmon, (1989), Bhagsari & Asheley, (1990) and Varma *et al*., (1994). Under experimental conditions at Melkassa and Awasa Agricultural Research Centres, storage root yields ranging from 46 to 139t ha^{-1} were obtained (Chapter 6).

Wide variability in storage root yield among sweet potato cultivars and individual plants of the same cultivar has been attributed to cultivar, propagation material, environment, and soil factors (Lowe & Wilson, 1975). In Ethiopia faulty land preparation, sub or supra-optimal plant population, improper method and depth of planting, lack of fertilization and carelessness during harvesting are some of the practices that may contribute to low and varying yields.

In high density plantings, interplant competition is greater and individual plant yields are lower and storage roots are smaller in size. Sweet potato is typically spaced 30 cm apart within the row and in rows approximately 90 cm apart (http://www.rec.udel.edu/class/kee/nov22.html). A 55,555 planting density is the recommended population for research purposes in Ethiopia, but local farmers consider this plant population sub optimum. To obtain 55,555 plants per hectare cuttings are spaced 30 cm apart within the row and in rows 60 cm apart. Fresh vine yield (above ground biomass) varies between 11 and 45.7t ha^{-1} (Singh & Mandal, 1976; Li & Kao, 1985; Sen *et al.*, 1990; Mukhopadhyay *et al.*, 1992). Yield per unit area is reportedly higher when cuttings are densely planted, however, production problems such as pests and diseases may be greater at high plant densities.

For successful sweet potato production in Ethiopia the optimum planting density have not yet been established and therefore, this experiment was designed with the following objectives:

- to determine the effect of planting density on yield and yield components; and
- to investigate differences in response to planting density among cultivars.

8.3 MATERIALS AND METHODS

A field experiment was conducted during 2001 at Awasa Research Centre in southern Ethiopia. The experiment reported in Chapter 8 was conducted on the same field and under the same climatic conditions as those reported in Chapters 6 and 7. The chemical and physical soil properties, weather data, and cultural practices are presented in Chapter 6.

A 3 x 4 factorial experiment in a randomized complete block design with four replications was planted. Treatments applied were three cultivars (Falaha, Bareda, and Awasa-83) and four planting densities (50,000, 55,555, 75,000, and 100,000 cuttings per hectare). The cultivars represent different maturity groups. Falaha is an early maturing cream-fleshed cultivar with a recommended growing period ranging from 90 to 105 days. Bareda is an intermediate maturing cream-fleshed cultivar with a recommended growing period ranging from 120 to 135 days, and Awasa-83 is a late maturing white-fleshed cultivar with a recommended growing period of more than 150 days. Awasa-83, Bareda, and Falaha are nationally released cultivars in Ethiopia.

The different planting densities were obtained by adapting the row and in row spacings. For the 50,000 cuttings per hectare a spacing of 0.5 m between rows and 0.4 m between cuttings (50 cm x 40 cm) was used. Each plot consisted of six rows of 3 m with 8 cuttings per row. The gross plot size of the 50,000 planting density was 8.4 m^2, and the net harvested area was 4 m^2. For the 55,555 cuttings per hectare treatment the rows were spaced 0.6 m apart and cuttings in the row were spaced 0.3 m (60 cm x 30 cm). Each plot consisted of 5 rows of 3 m and each row contained 10 cuttings. The gross plot size of the 55,555 planting density was 9 m^2 and the net harvested area was 4.32 m^2. For the 75,000 cuttings per hectare a between row spacing of 0.6 m and an in row spacing of 0.3 m (60 cm x 20 cm) was used. Each plot consisted of five rows of 3 m and each row contained 15 cuttings. The gross plot size for the 75,000 cuttings per hectare was 9 m^2 and the net harvested area was 4.68 m^2. For the 100,000 cuttings per hectare a spacing of 0.5 m between rows and 0.2 m between cuttings (50 cm x 20 cm) was used. Each plot consisted of six rows of 3 m and each row contained 15 cuttings. The gross plot size for the 100,000 planting density was 9 m^2 and the net harvested area was 5.2 m^2.

The land was deep plowed, harrowed and disced. Ridges were made using a tractor mounted ridger. Thirty centimeter long vine cuttings were prepared from the terminal and the middle portions of the vine. The experiment was planted on 2 June 2001, and was conducted under rain-fed conditions. The recommended sweet potato cultural practices were followed. The 30 cm cuttings of Awasa-83, Bareda and Falaha were planted vertically with two thirds (20 cm) of the lengths under the soil while the remaining one third (10 cm) was above the soil surface. No fertilizer was applied. Weeds were effectively controlled manually. No serious pest or disease problems occurred during the growing season. A one-time harvest was made on 5 November 2001. In each plot the two border rows as well as one plant at each end of the remaining three rows were discarded.

The experimental details regarding the grading of storage roots into small, medium, large, undersize, and oversize roots are presented in Chapter 7.

The experimental data were subjected to standard analyses of variance using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 1989) to determine the effect of main factors and interaction between them. Differences at $P \leq 0.05$ level were used as a test of significance and means were separated using Tukey's t-test.

8.4 RESULTS AND DISCUSSION

Effect of plant population

The effect of plant population on storage root fresh mass per hectare is presented in Table 8.1. As the plant population increased form 50,000 to 100,000 plants ha $^{-1}$ the total fresh root yield increased by 63%, to 81.6t ha $^{-1}$. The marketable root yield increased by 72% to 65.6t ha $^{-1}$. The small storage root yield increased by 76% to 11.1t ha $^{-1}$, the medium storage root yield by 95% to 25.7t ha $^{-1}$ and the large root yield by 54% to 28.9t ha $^{-1}$ (Table 8.1). Li & Yen (1988) conducted an experiment using two cultivars (Tainung 62 and Tainung 63), two levels of irrigation (non-irrigated and irrigated), two types of NPK fertilizers (60:30:180, and 120:30:360), and three population densities (25,000, 33,333, and 50,000 cuttings ha $^{-1}$). Cuttings were planted with a spacing of 1.0 m between rows and 0.2, 0.3, and 0.4 m in the rows. They found that the highest density of 50,000 cuttings ha $^{-1}$ produced the highest root dry mass (10.3t ha $^{-1}$). This was followed in descending order by the 33,333 population yielding 9.3t ha $^{-1}$ and the 25,000 population producing 8.1t ha $^{-1}$, respectively. Bouwkamp & Scott (1980) conducted experiments using four cultivars (Redmar, Centennial, Nemagold, and MD 2262) and four planting densities (37,000, 28,000, 22,000, and 18,250 cuttings ha $^{-1}$). Cuttings were planted with a spacing of 0.9 m between rows and 0.3, 0.4, 0.5, and 0.6 m in the rows. Total yield and yield of roots measuring 5 to 9 cm diameter (no. 1 size) and 2.5 to 5 cm diameter (no. 2 size) were the highest for the highest planting density (37,000 cuttings ha $^{-1}$). The storage root yields reported in Table 8.1 are much higher than the yields obtained by Bouwkamp & Scott (1980) and Li & Yen (1988).

The effect of planting density on root dry mass is presented in Table 8.2. The root dry mass reflected the root fresh mass results. Total and marketable root dry mass increased as the plant population increased. The total root dry mass yield of 13.6t ha $^{-1}$ obtained from the 50,000 planting density (Table 8.2) was comparable to the 10.3t ha $^{-1}$ reported by Li & Yen (1988) for a plant population of 50,000. The 23.6t ha $^{-1}$ dry storage root yield obtained with the 100,000 population (Table 8.2) was twice as much as the maximum yield reported by Li & Yen (1988) for their highest population of 50, 000 cuttings per hectare.

The number and mass of storage roots per plant are presented in Tables 8.3 and 8.4, respectively. As the plant population increased from 50,000 to 100,000 plants ha $^{-1}$ the total storage root number per plant decreased from 5.1 to 3.8 (Table 8.3). Similar decreasing trends were observed for the marketable storage root number per plant. The total storage root mass per plant decreased from 1181g/plant to 812.3g/plant as the plant population increased from 55,555 to 100,000 plants ha $^{-1}$. Similar trends were observed for the marketable storage root mass per plant (Table 8.4).

An increase in plant population increased shoot fresh mass from 60.8 to 90t ha $^{-1}$ and the shoot dry mass from 8.2 to 12.9t ha $^{-1}$ (Table 8.1 & 8.2). The shoot dry mass of 9.9t ha $^{-1}$ obtained from the 50, 000 planting density (Table 8.2) was much higher than the 2.7t ha $^{-1}$ reported by Li & Yen (1988) for a population of 50,000. The 12.9t ha $^{-1}$ shoot dry mass obtained with a 100, 000 population (Table 8.2) was four times as much as the highest yield reported by Li & Yen (1988).

Table 8.1 Effect of cultivar and planting density on storage root yield and shoot fresh mass yield ha^{-1}

Treatment		Root yield t ha^{-1}					Shoot yield
		Total	Marketable	Small	Medium	Large	t ha^{-1}
Cultivar	**Falaha**	61.0	50.9	13.7	19.8	17.4	44.5
	Bareda	70.3	47.5	5.2	16.2	26.2	79.5
	Awasa-83	61.3	50.2	8.7	19.1	22.6	92.6
	LSD_T	12.4	7.8	2.3	2.2	6.8	23.1
Planting density	**50,000**	50.0	38.2	6.3	13.2	18.7	66.7
	55,555	61.6	42.7	8.4	14.3	20.6	60.8
	75,000	63.5	51.6	11.0	20.4	20.3	70.9
	100,000	81.6	65.6	11.1	25.7	28.9	90.4
	LSD_T	19.0	8.9	2.7	2.5	7.8	26.7
Mean		64.2	49.5	9.2	18.4	22.1	72.2
CV%		26.9	21.9	35.5	16.6	42.8	44.6

Table 8.2 Effect of cultivar and planting density on root and shoot dry mass yield in t ha^{-1}

Treatment		Root dry mass t ha^{-1}		Shoot Dry mass
		Total	Marketable	t ha^{-1}
Cultivar	**Falaha**	15.6	13.0	6.4
	Bareda	19.1	13.0	11.7
	Awasa-83	19.4	15.9	12.5
	LSD_T	3.5	2.5	2.9
Planting density	**50,000**	13.6	10.4	9.9
	55,555	16.8	11.8	8.2
	75,000	18.1	14.8	9.8
	100,000	23.6	18.9	12.9
	LSD_T	4.1	2.9	3.4
Mean		18.0	14.0	10.2
CV%		27.4	25.1	40.2

Table 8.3 Effect of cultivar and planting density on fresh storage root number on a per plant basis

Treatment		Number of storage roots per plant				
		Total	Marketable	Small	Medium	Large
Cultivar	Falaha	7.07	3.47	1.84	1.11	0.52
	Bareda	3.12	2.05	0.56	0.72	0.78
	Awasa-83	3.71	2.54	0.92	0.94	0.72
	LSD_T	0.97	0.46	0.33	0.15	0.19
Planting density	50,000	5.10	2.80	1.08	0.91	0.77
	55,555	5.09	2.81	1.20	0.86	0.77
	75,000	4.53	2.73	1.23	1.01	0.56
	100,000	3.82	2.42	0.91	0.91	0.60
	LSD_T	1.13	0.44	0.32	0.18	0.22
Mean		4.6	2.7	1.1	0.9	0.7
CV%		29.3	19.9	35.0	23.2	39.3

Table 8.4 Effect of cultivar and planting density on fresh storage root mass on a per plant basis

Treatment		Storage root mass g/per plant				
		Total	Marketable	Small	Medium	Large
Cultivar	Falaha	889.9	743.7	203.4	286.1	254.1
	Bareda	1092.5	672.9	73.4	223.9	378.9
	Awasa-83	898.1	745.8	124.2	276.9	344.7
	LSD_T	190.9	104.89	31.7	33.3	92.3
Planting density	50,000	1000.1	764.4	126.2	263.4	374.7
	55,555	1181.0	774.4	150.7	257.7	370.4
	75,000	847.5	688.2	146.9	271.5	269.8
	100,000	812.3	656.2	110.8	256.6	288.7
	LSD_T	220.4	121.1	36.59	38.51	106.63
Mean		960.2	720.8	133.70	262.32	325.9
CV%		27.7	20.3	33.0	17.7	39.5

Cultivars

The three cultivars (Falaha, Bareda, and Awasa-83) produced similar total and marketable yields of fresh storage roots, but differed in small, medium, and large storage root yields per hectare (Table 8.1). Falaha produced higher yields of small and medium storage roots than Bareda. Bareda produced a higher yield of large storage roots than Falaha. Cultivars differed in total and marketable root dry mass. Cultivar Awasa-83 produced the highest (19.4t ha^{-1}) total root dry mass, and Falaha the lowest 15.6t ha^{-1}. Awasa-83 also produced a higher marketable root dry mass than Falaha and Bareda (Table 8.2).

The cultivars produced similar marketable yields of fresh storage roots, but differed in total, small, medium, and large storage root yields per plant (Table 8.4). Bareda produced higher total and large storage root yields than Falaha. Falaha produced higher yields of small and medium roots per plant than Bareda.

The three cultivars differed in total, marketable, small, medium and large storage root numbers per plant (Table 8.3). Falaha produced more total, marketable, small and medium storage roots per plant. Bareda and Awasa-83 produced more large storage roots per plant than Falaha.

The cultivars differed in shoot fresh mass (Table 8.1) and shoot dry mass (Table 8.2). Cultivar Awasa-83 produced the highest shoot fresh and dry mass per hectare.

Cultivar x density interaction

None of the cultivar x planting density interactions were statistically significant indicating that for all the parameters evaluated the three cultivars reacted similarly and consistently to changes in plant population (data presented in appendix A8.5).

8.5 CONCLUSIONS

Although some differences occurred in yield and yield components between cultivars a similar and consistent increase in total storage root yield was observed as the plant population increased from 50,000 to 100,000 cuttings per hectare. This consistent increase in storage root yield with increasing plant population up to 100,000 cuttings per hectare clearly indicates the potential to increase storage root yield by increasing the plant population. This diverges from the lower plant populations (40,000 to 50,000 cuttings per hectare) often recommended for sweet potato production. With higher planting densities farmers will need to ensure that appropriate cultural practices are applied to reduce increased plant to plant competition. Cooperative on farm trials in Ethiopia to calibrate plant population recommendations are envisaged.

8.6 REFERENCE

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