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Sweet Potato Agronomy Research in Ethiopia: Summary of Past Findings and Future Research Directions

Daniel Markos[1]
Gobeze Loha[2]
[1,2]Awassa Agricultural Research Center, Awassa, Ethiopia
(*Corresponding Author*)

Abstract

Sweet potato (*Ipomoea batatas* (L.) Lam) is economically important food crop in Ethiopia. Since its introduction, numerous agronomic research activities were carried out in agricultural research centers, non-governmental organizations and universities. The objective of this piece of work is to document available research findings in a usable manner and present it to first national sweet potato workshop held between 6-7 June 2013, SARI head quarter, Awassa, Ethiopia. Agronomic research has been carried out on preparation of planting materials, curing vine cuttings, planting methods, depth of planting, plant density, planting time, cropping systems, and etc. Results showed that sweet potato crop has a potential of 50 to 60 t/ha in Ethiopia and the length of vines to be used for planting shall be 30 to 40 cm. Weeding trials elaborated that weeding twice on 30-40DAS and 70DAS regardless of the study sites would suffice for the crop. Planting date experiments justified early planting with the onset of rainfall in non irrigated fields. However, the results of population density and fertilizer regimes varied across locations and varieties. Thus generation and promotion of site specific recommendations are of paramount importance for root crops like sweet potato.

Keywords: *Ipomoea batatas,* Ethiopia, Agronomy, Cultural practices, Varieties and research findings.

Contents

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1. Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is a herbaceous dicotyledonous plant with creeping, perennial vines and adventitious roots. It belongs to family *Convovulaceae* (morning glory flowers) and is hexaploid, and usually considered the only *Ipomoea* species of economic importance. It has large, starchy, sweet-tasting and tuberous roots. It adapts tropical and warm temperate regions. It is a highly heterozygous cross pollinated crop in which many of the triats show continuous variation. This crop is known for its resistance to drought, vigorous early growth and low input requirements. It also does well in areas of high rainfall and it requires very little labor and care compared to other crops. Because it readily produces adventitious roots and has trailing vines, sweet potato can colonize soils easily. Sweet potato is grown in several agro-ecological zones and usually plays significant roles in the farming and food systems. Sweet potato is commonly grown by farmers in complex, mixed cropping systems where they normally plant several varieties with different characteristics (yield, maturity, palatability, time to maturity, root size and shape, root colour, storability in the ground, pest and disease tolerance, drought tolerance, and sweetness) in a single plot. Farmers may use the vines left in the fields to improve soil fertility, and the crop is used in crop rotation. Since it has a short growing period, it stores well in the soil and performs well in marginal lands. It is recognized as ideal crop for food security. The yellow and orange-fleshed sweet potato varieties are also known as a good source of vitamin A that is frequently lacking in diets of most African farming communities. However, most varieties in sub-Saharan Africa are white-fleshed, low yielding and lacking beta-carotene, the precursor of vitamin A that was found vital to pregnant women and children. Also, sweet potato is widely used as animal feed (Assefa, et al. [1]; Engida, et al. [2]).

Globally, sweet potato is the seventh most important food crop and second most important tuber crop in the world after Irish potato. It ranks seventh among all food crops worldwide, with an annual production of 124 million tons. Among the root and root crops, it ranks third in acreage (9.1 million ha) behind Irish potato and cassava. In Africa, sweet potato is the second most important root crop after cassava and production is concentrated in the East African countries around Lake Victoria (Dantata, et al. [3]; Ndole, et al. [4]). Sweet potato productivity is limited by both abiotic and biotic constraints, leading to poor yields at farm level. They include low soil fertility and drought, shortage of improved varieties, shortage of planting materials, pests and diseases particularly viruses, post-harvest problems such as storage, and market availability and demand as well as low socioeconomic status in some communities. As a food security crop, it can be harvested piecemeal as needed, thus offering a flexible source of food and income to rural households that are mostly vulnerable to crop failure and consequently fluctuating cash income. In addition to being drought tolerant and having a wide ecological adaptation, it has a short maturity period of three to five months. Sweet potato has several advantages within the context of African cropping systems: i) it produces food in a relatively short time, ii) it gives reliable yields in sub-optimal growth conditions, iii) it requires lower labor inputs (appropriate for vulnerable households) than other staples, vi) it serves as an alternative food source for urban populations, facing increasing prices of cereals and v) it provides a potential option to reduce vitamin A deficiency (Andreas, et al. [5]; Getahun and Tenaw [6]). Sweet potato has a potential of giving over and above 50 to 60 tons/ha in Ethiopian conditions; however, yield obtained from farmer's field is by far lower than 6 to 8 tons. Thus the yields are ten times lower than the potential sought. This huge variation is attributed to biotic and abiotic stresses, lack of improved varieties, and weak attitude of people toward sweet potato, inefficient means of sweet potato technology transfer, inadequate, etc set of package recommendations.

1.1. Objectives

To summarize research findings in cultural practices, cropping systems and physiology of sweet potato in Ethiopia.

To recommend appropriate site specific management practices in sweet potato agronomy for future use

To set future research directions in sweet potato management

2. Materials and Methods

Identification of major growing areas in the country was carried out initially from secondary sources. Nextly available published and unpublished research findings and best practices were sought from universities, research centers and non-governmental organizations like Farm Africa, JICA and etc. working in major sweet potato growing areas like *Sidama, Wolaita, Harargie, Bako*, etc... Personal communication with growers, seed multipliers and researchers who made a research in the past was carried out to confirm their findings. Available information was assembled into categories of cultural practices and cropping systems by pictures, tables and summary notes. However, by no means the results are complete and exclusive of all observations and achievements in the country. Finally results were summarized in usable form by providing appropriate citation for future referencing.

3. Results and Discussion

3.1. Preparation of Vines for Planting

Results of various studies showed that sweet potatoes are propagated using seeds, vines and roots in Ethiopia. The use of seed is mainly for breeding purpose and not for commercial production. If the crop is to be grown from the root, then sets should be chosen from healthy robust marketable tubers. The most common method of planting sweet potatoes in commercial production is exclusively using vines mainly because vines are free from soil borne diseases, provide greater yield besides provision of uniform roots. The crop has a great deal of foliage; however, it has low multiplication rate compared to cereals. The vines are those parts of sweet potato that do not die after the roots are mature. However, there is shortage of preservation methods of these planting materials over the long dry season. Hence there is inability to meet large and regular demand for planting coming from governmental and non-governmental organization particularly in food insecure periods of the year. Preparation of planting material involves removing leaves, cutting the vines to appropriate size and curing them accordingly. These reduce moisture loss and bulkiness (Fig 1).

Fig-1. Preparation and packing of sweet potato planting materials

To compare and evaluate the yield performance different parts of the sweet potato vines used as planting material (top, middle and basal parts), experiments were conducted at Awassa and Areka. Although it was not statistically significant, the result indicated that top vine part gave higher root yield compared to the middle and basal portion of the vine cuttings. However, in case of low moisture conditions, the top portion easily wilts, as it is delicate. Top part is relatively free from weevil and other diseases compared to basal parts (CRCT (Crop Science Research Department) [7]). Therefore, it was recommended to plant top and middle portion of sweet potato compared to basal portion.

Vine pre rooting treatments were carried out to solve problem of establishment and yield obtained from vine parts. They have to be rooted under ideal condition before transferring to the field. Some farmers employ pre rooting to replace the dead vines in the field and minimize the time gap with the first planted crops (Geleta [8]).

Table-1. Mean tuber yield (tha^{-1}) of pre rooted vines tested for three years

Pre rooting time (days)	1990	1991	1992	Mean
0	4.5A	9.1B	8.8C	7.4B
3	4.5A	15.9A	12.2B	10.8A
6	4.2A	16.0A	15.8A	12.0A
9	4.9A	16.6A	14.5A	12.0A

Vine pre rooted for 6 and 9 days gave better root yield than 0 and 3 days. Both pre-rooting days were found to be consistent and better in root yield in all years (Table 1).

3.2. Curing of Vine Cuttings

An experiment was conducted at Awassa to compare establishment and root yield of sweet potato obtained from vine cuttings which were stored under shade for different length of time (0, 2, 4, 6, 8 and 10 days). The three years result of the experiment indicated that storing vines for two days could enhance better root initiation, increase vine establishment and root yield of sweet potato compared to others levels of vine curing. Vines stored for longer period dried off prior planting. Hence vine storage for two days before planting is recommended for better establishment and root yield (CRCT (Crop Science Research Department) [7]).

3.3. Length of Vine Cuttings

Based on the studies carried out a vine having 30 to 40 cm length with 3 to 4 buds on the cutting are preferred for better yield and ease of management in comparison to using whole vine.

3.4. Depth of Planting

Comparisons were made on depth of planting the vine cuttings. Results confirmed that burying two-third of the vine would suffice for better establishment and subsequent yield compared to other levels of burying the sweet potato cuttings.

3.5. Vine Treatment with Insecticides

The older sweet potato vines and roots harbor sweet potato weevil (*Cylas puncticollis*). Therefore it is recommended that all the cuttings should be dipped in the *Fentain* or *Fentrotion* insecticide solutions at the recommended rate just before planting in order to kill the egg or adult weevil (Endale, et al. [9]).

3.6. Land Preparation for Root Production

According to the studies carried out by national research coordination unit, land for sweet potato production should be ploughed thoroughly to 15-20 cm depth and could be prepared using either tractor drown implements, oxen drown plows or by hand tools. The land prepared could be flat as in *Wolaita* area and could be of ridges as in *Hararige*. In fact in research centers like that of Awassa, ridges are prepared by tractor drown implements. Series of studies has been carried out to explore the comparative advantage of these land preparation methods with consideration of different varieties. The researchers concluded that since the varieties had no significant response to methods of land preparation, any of the cost effective methods could be employed (Table 2 and 3). However, flat planting is beneficial in areas where the amount of rainfall is sufficient and the soil is more of sandy loam. In Areka, where the rainfall was higher and water-holding capacity of soil is good, flat planting produced significantly higher root yield of sweet potato. But, generally in moisture stressed areas, tie ridges are the most universally recommended methods of growing sweet potato (CRCT (Crop Science Research Department) [7]).

Table-2. Effects of land preparation methods on root yield (t/ha) of sweet potato varieties in Awassa

Land preparation methods	Koka -6				Koka-12			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Flat	15.7	16.2	12.9	14.9	17.3	14.7	7.1	13.0
Open ridge	14.8	16.7	12.9	14.8	18.1	17.2	8.2	14.5
Tied ridge	16.3	14.8	12.7	14.6	17.5	18.2	7.0	14.2

Source: Endale, et al. [9]

Table-3. Effects of land preparation methods on root yield (t/ha) of sweet potato varieties in Areka

Land preparation methods	Koka -6				Koka-12			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Flat	9.5	11.2	10.4	10.4	12.4	7.0	9.1	9.5
Open ridge	11.4	10.8	10.6	10.9	11.5	8.7	6.8	9.0
Tied ridge	9.3	9.5	11.4	10.1	9.9	18.2	6.7	11.6

Source: Endale, et al. [9]

3.7. Land Preparation Methods and Production of Herbage for Animal Feed

Research conducted at *Afar* (Melkaworer Agricultural Research Center) using Koka-12 variety consisted of three planting methods (ridge, flat, and sunken), and three vine harvesting times (45, 75 and 105 days after planting including one control treatment without vine harvesting). The experiment was laid out in a randomized complete block design in a factorial arrangement and replicated four times. The results revealed that planting sweet potato on ridges and harvesting the vines 105 days after planting (when about 60% of the growth phase of the plant was completed) led to optimum production of herbage for fodder without compromising yield of tuberous roots. Thus planting sweet potato on ridges and harvesting the vines when about 60% of the growth phase of the plant was completed enhanced the production of herbage for animal feed without compromising yield of tuberous roots to be used for human food. Therefore, pastoralists as well as sedentary smallholder farmers in Ethiopia who produce sweet potato using furrow irrigation should plant the crop on ridges and harvest the vines for animal feed at a later stage of growth by which time tuberous roots may have grown and bulked sufficiently. The farmers should also plant several adaptable cultivars having similar or different maturity times to spread vine harvests throughout the season for ensuring sustained availability of food for humans and fodder for animals (Mohammed, et al. [10]).

3.8. Ridge Height and Furrow Width

According to findings, ridge width and height happened to be researchable. Research recommendations showed that medium to high ridges (25 to 36 cm) are advantageous on poorly drained soils when there are heavy rains, and flat or low ridges are practiced where drainage is good and rainfall is not very high (Endale, et al. [9]). In tractor plown farms, furrows are spaced 75 cm apart and plants are placed 30cm away from one another.

3.9. Planting Date Studies

Planting date experiments were carried out in *Awassa*, *Areka* and *Bako* using varieties called Koka 6 and Koka 12. Results indicated that planting could be carried out between June 4 to July 7 in *Bako* areas. This holds true to similar agro ecologies to that of Bako [11]. In Awassa, early planting on 13 May 1987, 4 May 1988 and 16 May 1989 gave highest mean root yield of 28.4t/ha, 39.2t/ha and 30t/ha, respectively. Thus in Awassa and similar agro-ecological areas the onset of rainy season particularly mid may to early June was recommended as optimum unlike early June planting of Bako (CRCT (Crop Science Research Department) [7]).

3.10. Planting Positions

Studies on planting positions were carried in Areka and Awassa from 1987-1989 comparing inclined (slant), vertical, U-shaped and horizontal planting positions in relation to different varieties. Results indicated that none of the varieties responded significantly ($P<0.05$) to varying positions of planting both in Areka and Awassa (Table 4 and 5). At *Awassa*, planting cuttings at slant (inclined) position gave higher root yield compared to horizontal plantings. This was due to more vigorous establishment and better contact of soil and the planting material. However, in dry season horizontal planting is advantageous compared to slant planting. Similarly during wet seasons, slant planting is preferred compared to horizontal planting in Awassa. In *Harargie* vines are planted in inclined positions where plantings are done on ridges. In *Wolaita*, vine cuttings are buried horizontally in furrows when the land is prepared by oxen drown implements. In other parts of the country vertical and inclined positions predominate when planting is done on flat or ridges.

Table-4. Effects of planting positions on root yield (t/ha) of sweet potato varieties in Awassa

Planting Positions	Koka -6				Koka-12			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Inclined	22.2	18.7	15.9	18.9	28.3	15.5	15.9	16.6
Vertical	19.2	15.3	15.5	16.6	23.0	18.1	6.8	16.6
U-shaped	21.3	19.2	11.3	17.2	25.2	15.1	10.1	16.9
Horizontal	24.9	9.9	7.3	14.0	15.3	11.5	6.3	11.1

Source: Endale, et al. [9]

Table-5. Effects of planting positions on root yield (t/ha) of sweet potato varieties in Areka

Planting Positions	Koka -6				Koka-12			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Inclined	9.2	6.4	9.0	8.2	13.2	5.5	9.3	9.3
Vertical	10.3	6.0	7.6	7.9	12.4	6.8	8.8	9.3
U-shaped	9.7	6.0	9.7	8.5	13.3	5.1	9.5	9.3
Horizontal	7.5	5.8	6.6	6.6	15.5	1.3	6.8	7.8

Source: Endale, et al. [9]

3.11. Plant Density Experiments in Jido Combolcha

As shown in the table below (Table 6) values of total tuber yield of *Balella* variety with spacing 20 cm x 80 cm performed better (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.

Table-6. Result of mean and standard error comparison of Balella variety on farm in Jido Combolcha

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 column indicates non-significant difference among the treatments ($p<0.05$) (Teshome, et al. [12])

It is clear form Table 7 that the general yield performance of the Bareda (tubers horizontal vines spreading) variety was much lower than that of yield obtained by Balella (tubers vertical vines erect) in *Jido Combolcha* area. 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. Therefore, 20 cm x 60 cm between two consecutive plants and rows should be adopted regardless of tuber and vine orientation for those farmers involved in sweet potato production in *Jido Combolcha* and similar agro-ecologies (FRG [13]).

Table-7. Result of mean and standard error comparison of Bareda variety on farm in Jido Combolcha

Variable	Root Diameter (cm)	Root Length (cm)	Green Top (kg)	Marketable Root (q/ha)	Unmarketable Root (q/h)	Total Yield (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

(Teshome, et al. [14])

3.12. Plant Density Experiments in Bako Areas

The population study at Bako was carried out during 1978 to 1982 using a cultivar white star (Table 8). The row spacing employed were 80, 100 and 120 cm whereas plant spacing included 30, 40 and 50 cm with population ranging from 41, 700 to 16,700 in a hectare of land. The results indicated that marketable and total yield increased as plant densities were decreased where as unmarketable yield was higher due to either higher or lower plant densities. Unmarketablity was mainly due to oversized and undersized roots. Undersized roots increased as spacing between rows and plants decreases. An increase in oversized roots was observed with wider spacing. 100cm x 30 cm was recommended for the cultivar white star around Bako and similar area.

Table-8. Effects of plant density in mean root yield (q/ha) at Bako, 1978- 1982

Row x plant spacing (cm^2)	Number of plants/ha (1000)	Marketable root yield (kg/ha)	Total root yield (kg/ha)
80 x 30	41.7	206.28	319.54
80 x 40	31.3	193.15	309.19
80 x 50	25.0	187.70	299.16
100 x 30	33.3	209.80	322.12
100 x 40	25.0	174.59	289.94
100 x 50	20.0	157.39	272.62
120 x 30	28.6	188.79	302.25
120 x 40	21.4	158.81	269.28
120 x 50	16.7	157.84	265.53

3.13. Plant Density Experiments in Awassa and Areka Areas

Plant density recommendations varied in SARI mandate areas with variety and location (Table 9). In Areka, different varieties responded differently as shown in table below. However, at Awassa 60 cm x 30 cm recommendation was adopted after a three-year plant population experiment for a white fleshed variety called Awassa-83.

Table-9. Recommendations of plant density in SARI mandate areas

Variety	Location	Results
SP-1499	*Areka*	100 cm x 25 cm
SP-Koka 12	Areka	70 cm x 20 cm
SP-2498	Areka	100 cm x 20cm
Awassa-83	Awassa	60cm x 30 cm

Source: CRCT (Crop Science Research Department) [7]

3.14. Weeding

Weeding trials revealed that the crop is highly susceptible to weeds at early stage of growth as most other root and tuber crops. So a grower shall induce a weeding practice staring the 7^{th} day after planting. However, the crop starts suppressing annual broadleaved weeds starting 45^{th} day of planting. That is because the crop is known for its allelophatic effects at full growth. There was an increase in yield per unit area as plant density was increased from 5 to 10 plants m^{-2}. However, there was not significant variation in yield (kg/ha) due to 7 and 10, and 7 to 12.5 plants m^{-2} in *Tis* 1499 and Koka 6 (intermediate), respectively (Table 10). The yield of *Tis* 2498 did not show significant variation among plant densities despite the high yield from 10 plants m^{-2}. The results showed that a population of 10 plants m^{-2} produced significantly high tuber yield although it was not significantly different from 7 plants m^{-2}. Effect of weeding on tuber yield was dictated by variation in variety and plant density. Weeding of *Tis* 1499 (erect and early) and Koka 6 twice increased the yield by 22.5 and 23.9%, respectively, while weeding practice did not have a significant effect on tuber yield of *Tis* 2498 (long vine, spreading and early). Although weeding once and twice produced more as plant density was increased (up to 10 plants m^2), further increase reduced the yield. However, weeding twice increased tuber yield by 23.6, 18.2, 15.4, and 5.1% for the 5, 7, 10 and 12.5 plants m^{-2}, respectively, compared with weeding once. The variation in root yield was not statistically significant in both weeding practices due to the range of 7 to 12.5 plants m^{-2}. Generally speaking plant density of $25X10^3$ or less revealed poor ground cover percentages; Thus lower stand densities are of less value to the producers. Varieties with erect and intermediate growth habits can be weeded twice if high population is maintained. Growth with spreading canopy structure and plant density could be used as means to reduce weed infestation. This will save farmers time and labor and thus, breeders should focus in developing cultivars with spreading canopy structure with high yield.

Table-10. Weeding frequency x variety x plant density on tuber yield of sweet potato (tons/ha) at Areka

Variable	Weeding frequency	
	One time (30 - 40 DAS)	Two times (30 - 40 and 70 DAS)
Variety		
Tis 1499	16.96bc	20.78a
Koka - 12	6 15.45cd	19.15ab
Tis 2498	12.53de	11.82e
Plant density (no.ha^{-1})		
50 × 103	11.60c	14.34bc
70 × 103	16.19ab	19.14a
100 × 103	17.16ab	19.81a
125 × 103	14.96bc	15.72ab

(**Source:** Tenaw, et al. [15])

DAS = days after sprouting, same letter across a column and row for each factor shows no significant difference at 5% probability level

Sweet potato used to be grown without any fertilizer amendment despite its requirement and mining from the soil. However studies confirmed that use of either FYM or chemical fertilizers or both would increase yield. Fertilizer studies were carried out in sandy loam soils of Adami Tulu consisting of five levels of FYM (0, 5, 10, 15, 20 t ha^{-1}) and three levels of P (0, 90,180 kg P_2O_5 ha^{-1}). It was laid out as a Randomized Complete Block Design in a factorial arrangement, and replicated three times (Table 10). A sweet potato cultivar known in the area called Balella was used for the study. The result indicated that the main effect of FYM significantly ($P < 0.05$) affected total tuberous root yield, tuberous root dry weight, fresh total biomass and dry harvest index. However, the main effect of P had no significant influence on all parameters studied (Table 11). Moreover, the interaction effects of FYM and P significantly ($P< 0.05$) affected marketable root yield, specific gravity and total dry biomass yield. Combined application of 20 t farmyard manure ha^{-1} and 180 kg ha^{-1} P_2O_5 resulted in production of highest marketable yield (32.56 t ha^{-1}). The lowest marketable yield (8.8 t ha^{-1}) was obtained at the application of 0 t ha^{-1} FYM combined with 180 kg P_2O_5 ha^{-1}. Thus, most of the yield and yield estimate parameters were enhanced in response to the application of FYM. For the two commonly used sweet potato quality parameters (dry matter and specific gravity), dry matter was not significantly responsive to both FYM and P while the highest specific gravity (1.09) was obtained at the combined application of 10 t FYM ha^{-1} and 0 kg P_2O_5 ha^{-1}. Tuberous root dry weight was correlated negatively (r = -0.32*) with shoot dry weight and was statistically significant ($P < 0.05$). But it was correlated positively with yield and yield estimate parameters like tuberous root fresh weight (r=0.965**), marketable tuberous root weight (r = 0.842**), unmarketable tuberous root weight (r = 0.639**), average tuberous root number per plant (r = 0.582**) and average tuberous root length (r = 0.492**) at ($P<0.01$) indicating the existence of close associations among those parameters. Therefore, it could be concluded that tuberous root yield of sweet potato was significantly enhanced in response to the application of farmyard manure, indicating that enriching the soil of the area with organic matter through use of organic fertilizers holds the key for maximizing the yield of the sweet potato crop in the study area. These studies showed that higher nitrogen application would increase vine growth and suppress root growth.

Table-11. Farmyard manure x phosphorus effect on marketable tuberous root weight (t ha-1) of sweet potato

FYM (t ha^{-1})	P2O5 (kg ha^{-1})		
	0	**90**	**180**
0	15.89	12.41	8.80
5	19.01	22.65	9.72
10	18.67	9.01	32.04
15	14.20	11.17	12.47
20	24.72	22.07	32.56
F-test	*		
LSD (P*FYM)	15.41		
CV (%)	32.70		

*= Significant at P < 0.05probablity level; CV = Coefficient of Variation

According to sweet potato without FYM was not foreseeable around sandy loam soils of *Adami tulu* with chemical fertilizers alone. If a grower can have FYM as high as 5t/ha or 10t/ha then 90 kg ha^{-1} or 180 kg ha^{-1} would suffice to obtain agronomic optimum sweet potato root yield of 22.65 tha^{-1} and 32.04 tha^{-1} respectively (Table 11 and 12).

Table-12. Unmarketable and total root yield of sweet potato as affected by FYM and P application

Treatment	Unmarketable Tuberous Root Yield (tha^{-1})	Total Tuberous Root Yield (tha^{-1})
FYM(t ha^{-1})		
0	10.00	22.37b
5	9.70	26.83b
10	9.39	29.30b
15	10.75	23.30b
20	15.91	42.89a
F-test	NS	*
LSD	6.54	12.48
P2O5(kg ha^{-1})		
0	9.59	28.09
90	11.49	26.94
180	12.39	31.48
F-test	NS	NS
LSD	5.05	9.67
CV (%)	31.13	23.25

*=significant at p<0.05 probability levels; NS= non-significant; CV= Coefficient of variation; FYM=Farmyard manure

A study was undertaken to assess the effects of combined application of inorganic (NP) and organic (FYM) fertilizers on root and biomass yield of Sweet potato (*Ipomoea batatas (L.) Lam*). The field experiment was conducted from June-Dec. 2008 at Delbo Watershed, two N levels (23 and 46 kg/ha) and two P levels (20 and 40 kg/ha) were considered as inorganic fertilizers along with one unfertilized control treatment. The findings of this study clearly showed that yield and yield components of sweet potato at Delbo watershed can be enhanced by combining FYM and inorganic fertilizers. In this study the highest yield (24.12t/ha) was achieved using 46kg/ha N and 5t/ha FYM. Accordingly, the economic analysis showed that the highest net benefit of 37,880 Birr was obtained from 46kg/ha N and 5t/ha FYM. Considering the scarcity associated with inorganic fertilizer and limited amount of FYM, 23 N kg/ha and 2.5 t/ha FYM with a net benefit of 29,635 birr, could also alternatively be recommended for use by sweet potato producers in the area. Poor farmers who cannot afford fertilizer would be encouraged to use 2.5t/ha FYM (Gezahegn and Andergachew [16]). In fact, Horticulture development department of Ministry of Agriculture [17] recommended use of 100-200kg/ha DAP or equivalent animal manure in previous years. If ridges are to be made, it is recommended to apply farmyard manure prior ridging. In fact, at the level of Awassa Agricultural research center 50q FYM/ha was applied during ridging, 25kg /ha DAP was applied during planting and 50kg/ha Urea applied after a month of planting.

3.15. Irrigation Practices

Even though this crop is said to be drought tolerant, research results showed needs for sufficient moisture at early stage especially during the first six weeks to secure healthy stand establishment. This was mainly because sweet potato vines are succulent and fragile, and if no sufficient moisture is supplied it dries up soon. If there is no rain in early parts of planting, supplementary irrigation of 2mm of water per day is required even in the main rainy season. To meet this requirement, irrigating in alternative days is vital. Moisture stress during growth significantly reduces storage root yield. As a crop grows on, irrigating with 4-5mm water would suffice for a given week. Because sweet potato crop needs sandy and well-drained soil; and if the soil has high moisture content, planting in raised bed is preferable (MOARD [18]). With growing interest of sweet potato as emergency food security crop in the country, there were increased pressure from concerned bodies to supply sweet potato cuttings in off seasons. Obviously the production of vines under such situations required application of irrigation water pumped from springs, rivers or lakes (Fig 2). There was a practice of applying water to field capacity once in a week time in such cases in majority of sweet potato fields. Yield and quality of sweet potato in non-irrigated experiments were extremely low compared with that of irrigated experiments.

Fig-2. Furrow irrigation practices in sweet potato seed multiplication schemes

3.16. Intercropping

Three sweet potato cultivars (*Koka-12, Koka-14* and *Alemaya*) were grown under three sorghum varieties (Kobomash76, $76T_1$ No.23, hybrid sorghum) were tested under rainfed and irrigated conditions at Melkasa and Melka Werer, respectively. All pure sweet potato stands gave higher yield compared to intercrops. Sorghum grain yield of pure stands was lower when compared to intercrops. The results also indicated that Koka 12 and Kobomash 76 were relatively compatible (Sirak [11]). Results further depicted that sweet potato plants are sensitive to shade leading to low yields. The crop should be grown under full sunlight. Tesfa, et al. [19] also noted that maize intercropped with sweet potato showed reduced levels of leaf blight and common rust intensity when both crops were planted at the same time.

3.17. Relaying and Double Cropping

Therefore, it is only with erect leaved varieties that intercropping is recommended. However, all the varieties could be grown with relay crops, double crops or rotations with maize or sorghum (Table 13). Thus the crop can take advantage of residual moisture and fertility. Results showed that in areas where sweet potato was grown previously, long season maize varieties could be grown successfully.

Table-13. Double cropping of maize varieties after cereal, pulse and root crops at Awassa (1993, 1994 and 1996)

Precursor crop	Yield (q/ha) of katumani			Yield (q/ha) of A - 511		
	No fertilizer	46/46kgha^{-1}NP	Mean	No fertilizer	46/46kgha^{-1}NP	Mean
Katumani	-	-	-	25.00	26.04	25.52
A-511	5.52	5.52	5.10	-	-	-
Tef	10.83	10.83	5.52	18.75	19.79	19.27
Haricot bean (HB)	9.53	9.53	12.29	15.63	25.00	22.04
Irish potato (IP)	14.47	14.47	13.75	18.75	26.04	22.40
Sweet potato (SP)	7.08	7.08	6.65	17.71	26.04	21.88
	9.49	8.66	9.08	19.17	24.58	21.88

Source: (Tesfa, et al. [19])

A double cropping experiment of maize grown after different crops in the same year was executed from 1993 to 1996. The objective of the experiments was to properly utilize the available moisture, enhance productivity and fill food deficit periods. HB, IP and SP were found to be good precursors for A-511. Teff and Irish potato happened to be good pre cursors for Katumani under unfertilized conditions. Haricot bean would become good precursors only after fertilized plots. By double cropping the productivity of land was increased by 50 and 70% as compared to single crops under unfertilized and fertilized conditions (Table 12).

In another study carried out in Awassa by Tolesa, et al. [20] farmers were advised to grow either teff, haricot bean or sweet potato by harvesting at green ear or dry stage of maize. The land equivalent ratio analysis revealed that the advantage of relay cropping is higher, 71% when maize was harvested green and 54.9% when maize was harvested at dry grain stage. The researchers obtained the highest gross return of 8912 Br./ha when maize was harvested at green ear stage and 5683 Br./ha when maize harvested dry grain and when sweet potato was relayed into maize at 50% flowering. This manifested that harvesting maize for green ears and relaying sweet potato into maize are economically attractive. Thus the appropriate time of relay planting sweet potato is at 50% flowering of maize for both harvesting systems (Table 14 and 15).

Table-14. Effect of relay cropping sweet potato on maize green ear harvest and LER at Bako, 1990-1992

Treatments	Maize ears/ha	Sweet potato yield (q/ha)	Gross returnBr./ha	LER
Maize + 50% mf	36310.82	67.47	3911.99	1.27
Maize +SP 15 da 50% mf	36310.82	47.13	7372.81	1.16
Maize +SP 30 da 50% mf	40958.60	8.86	6480.39	1.07
Sole mz	-	-	5967.08	1.00

Mz-maize, sp- sweet potato, mf-mid flowering, da-days after

Table-15. Effects of relaying sweet potato after maize at Bako, 1990-1992

Treatments	Sp yield (q/ha)	Sp yield reduction relative to sole (%)
@ 50% mf	67.5	64.2
15 da 50% mf	47.1	75.0
30 da 50% mf	8.9	95.3
Sole sp	188.5	0
LSD5%	26.6	
LSD5%	37.3	
CV (%)	27.1	

3.18. Rotation Cropping

According to results of numerous year crop rotation study, maize, sweet potato and common bean coming in the sequence in the three year crop rotation scheme was productive compared to other cropping sequences.

3.19. Growing Sweet Potato near Shrub and Tree Crops

As leaves, barks, roots, twigs, exudates and branches release phenolic allello chemicals, eucalyptus spp. were generally recognized with their allelophatic effects on growth of various crops. This negative effect coupled with its fierce competition for sunlight, moisture and nutrients posed great threat to crop production and have been known as major court case in many places. However, driven by expansion of construction economy the reality of eucalyptus spp. expansion in most agro-ecologies of Ethiopia has become a reality. So serious studies were carried out to identify tolerant crops to the cumulative effect of eucalyptus and identify a mechanism for amelioration of the challenge. Results showed that a distance of some 5 meters should be left in lowlands to produce crops like teff, sweet potato and common beans; however, growing crops like wheat and barley is possible with Eucalyptus in highland areas where moisture is not limiting. In fact, cutting ditches was recommended to break root exudation and completion for moisture and nutrients (Fig 3).

Fig-3. Ditches dug between eucalyptus hedge row and adjacent farmland

There are also growing trends of growing sweet potato under other shrub crops like coffee and enset in some parts of the country. However, the production is maintained until canopy closure of coffee and enset, and is meant to fill food gaps of some forthcoming months.

4. Conclusion

Sweet potato that was once known as poor man's crop has become a food security crop all over the country with numerous potentials for income generation and export. Although it required low inputs, it matured in short period of time and provided reliable yield in Ethiopian conditions. Consequently the crop rightly obtained national focus due to the various organizations in the Ethiopian agricultural research system which contributed much to the generation of crop management options. Sweet potato crop has a potential of 50 to 60 t/ha in Ethiopia; however, farmers are obtaining 6 to 8 tons/ha only. The yield is ten times lower than the potential. This yield gap would be attributed to a number of factors like absence of high yielding improved and virus free planting materials, appropriate insect pest management and use of improved crop management options. Based on research findings to date, vines taken from upper or middle portion of the plant chosen for sweet potato planting should be of 30 to 40 cm length having 3 to 4 buds, shall be stored for two days under shade and should be buried in the soils until two-third of the cutting. The land prepared could be flat as in *Wolaita* area and could be of ridges as in *Hurarige* depending on soil texture, moisture regime and tillage implements. When planting dates are considered, in Awassa and similar agro-ecological areas the onset of rainy season particularly mid may to early June was recommended as optimum unlike early June planting of Bako. Planting position study confirmed that planting cuttings at slant (inclined) position gave higher root yield ($P<0.05$) compared to horizontal plantings in areas like Awassa. In *Harargie* vines are planted in inclined positions where plantings are done on ridges. In *Wolaita*, vine cuttings are buried horizontally in furrows when the land is prepared by oxen drown implements. Plant density experiments in *Jido Combolcha* revealed that net marketable yield of Balella variety 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. According to similar studies employing cultivar Whitestar 100cm x 30 cm plant spacing was recommended for the Bako and similar agro-ecologies. The plant density study at Areka showed that SP-1499 should be grown with 100 cm x 25 cm, SP-Koka 12 with 70 cm x 20 cm, and SP-2498 with 100 cm x 20cm. However, similar studies employing cultivar Awassa-83 ended up in recommending 60cm x 30 cm for Awassa and similar agro-ecologies. For a sweet potato crop grown with recommended plant density, varieties (eg. Tis 2498) with long spreading vines could be weeded once on 30-40DAS but varieties with erect vines (e.g.Tis 1499) should be weeded twice on 30-40DAS and 70DAS regardless of the study sites. In one fertilizer study carried out in *Adami tulu* combined application of 20t farmyard manure ha^{-1} and 180 kg ha^{-1} P_2O_5 resulted in production of highest marketable yield (32.56tha^{-1}). In another fertilizer study carried out at *Delbo* watershed, the highest root yield (24.12t/ha) was achieved using 46kg/ha N and 5t/ha FYM. If rains stop during early or late growth of sweet potato, supplementary irrigation of 2mm/day during planting (for a week or so) and 4-5mm/week during vegetative growth was recommended. In intercropping study carried out at *Melkasa* and *Melka worer* using three sweet potato varieties called Koka-12, Koka-14 and Alemaya and three sorghum varieties called Kobomash76, $76T_1$ No.23 and hybrid sorghum, sorghum grain yield of pure stands was lower when compared to intercrops and Koka 12 and Kobomash 76 were relatively compatible. Based on relay and double cropping trial carried out at Awassa, in places where sweet potato was grown previously, long season maize varieties could be grown successfully and sweet potato could act as precursor for maize varieties. Based on green ear and dry harvest analysis, best maize and sweet potato compatibility was seen when sweet potato was relay cropped at 50% flowering of maize. Whenever sweet potato is grown near Eucalyptus tree, ditches should be cut with 60 cm depth and 40 cm width to prevent root exudates of allelophatic effect. Totally there is a great deal of concern on production, research and technology dissemination; however, there is also a need to create sustainable and site specific integrated nutrient management options, appropriate irrigation schedules, generation of ways of conserving planting materials in dry seasons and development of compatible multiple cropping options for sweet potato in the country.

5. Future Research Directions

1. As we are in the era of global climate change and soil degradation, adopting and generating eco friendly site specific sustainable crop production technologies through well designed research projects is necessary
2. Information on productivity and on suitable soil fertility management practices for sustained crop production for the major soils of Ethiopia is still very limited. There are limited suitable options for improving soil fertility management (which is essential to increase crop and farm productivity) in a crop like sweet potato that is considered a low-input and subsistence crop and where there are few incentives to use labor and resource-intensive technologies. Sweet potato comprehensive integrated soil fertility management (ISFM) studies for early, medium and late maturing varieties preferred in seed multiplication and root production schemes for dominant soils found in major agro-ecologies is recommended as future research strategy.
3. Drought management is an important factor for increasing sweet potato productivity, given that sweet potato yields can be severely affected by limited water availability. So sweet potato irrigation studies aimed at economizing water use while optimizing vine and root production shall be sought in future.
4. Design and assessment of intercropping options and crop rotations that could extend the supply period.
5. Development of alternatives for conserving planting materials and for having planting material on a timely manner, particularly in drought prone areas.

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