Effect of temperature, soil moisture content and type of cutting on establishment of sweet potato cuttings

T. Belehu* and P.S. Hammes
Department of Plant Production and Soil Science, University of Pretoria, Pretoria, 0002 Republic of South Africa

Accepted 22 October 2003

Effective rooting is essential for successful crop establishment from cuttings. The objective of this study was to determine the effect of temperature and soil water content on the root and shoot growth during the early establishment of sweet potato cuttings. Root growth and development were examined in a phytotron at four temperatures (20, 24, 28 and 32 °C constant) and with four types of cuttings (3 node cutting vertically planted, 3 node cutting planted upside down, 3 node cutting horizontally planted and 1 node cutting planted horizontally). The cuttings were allowed to establish and grow for three weeks. The highest total root length (3.59 m $plant^{-1}$) was recorded in the 24 °C growth chamber and was significantly longer than the roots from the other temperature treatments. The highest root dry mass (0.22 g $plant^{-1}$), shoot dry mass (1.7 g $plant^{-1}$), leaf area (578 cm^2) and total dry mass (2.0 g $plant^{-1}$) were also obtained from the 24 °C growth chamber. The three node cuttings planted vertically produced the longest total root length of 3.66 m $plant^{-1}$ which was significantly longer than those of the other cutting types. The highest root dry mass, shoot dry mass, leaf area, vine length, leaf number, and total dry mass were also obtained from the vertically planted three node cuttings. To determine the response to soil moisture content, cuttings were sealed and allowed to establish and grow in plastic bags containing sandy soil at 100, 80, 60 and 40% of field water capacity. After 12 and 20 days in a growth chamber at 28 °C the plants were harvested. The 80% of field capacity moisture regime was found to be the optimum soil moisture content for sweet potato root growth. With the soil water content at field capacity and at 40% of field capacity root development was somewhat suppressed. The results illustrated the capacity of sweet potato cuttings to establish successfully under a range of ambient temperatures and soil moisture contents.

Key words: *Ipomoea batatas*, root dry mass, soil moisture regimes, sweet potato, temperature

*To whom correspondence should be addressed (E-mail: terefeb2001@yahoo.com).

Introduction

Establishment of sweet potato cuttings can be quite variable depending on environmental conditions. Of particular importance in affecting the establishment of cuttings are the environmental conditions during early growth. Environmental factors that determine the rate at which cuttings establish are major factors governing growth and establishment. Identification of environmental conditions that affect establishment and early growth is necessary.

Sweet potato (*Ipomoea batatas* (L) Lam.) is a herbaceous dicot widely grown throughout the tropics and warm temperate regions of the world between latitudes 40° N and 40° S, and at altitudes as high as 2,300 m (Shukla, 1976; Hahn, 1977; Bourke, 1982; Jana, 1982). The thermal optimum is reported to be above 24 °C, compared to 25-30 °C for cassava and yam (Kay, 1973). Differences in thermal responsiveness would be expected among the wide range of sweet potato genotypes. Being a tropical crop, sweet potato is sensitive to low temperatures. Harter & Whitney (1962) reported that sweet potato could not survive temperatures of less than 12 °C, while at 15 °C plants were able to survive but did not grow, above 15 °C growth increased with increasing temperature up to 35 °C, and at 38 °C growth was somewhat depressed. Sark (1978) reported that sweet potato grown in a greenhouse at temperatures of 10 to 15 °C showed reduced vine growth compared to those grown at temperatures of 21 to 25 °C.

Gomes & Carr (2003) in Mozambique studied the effect of water availability and vine harvesting frequency on the productivity of sweet potato and suggested that the water requirement for the growing season is between 360 and 800 mm. Sweet potato is normally propagated from vine cuttings and the development of adventitious roots is expected to be sensitive to soil moisture deficits immediately after planting. An adequate moisture supply is probably essential for promoting rapid and uniform root development and good stand establishment. During vegetative development of plants even minor stresses can reduce the rate of leaf expansion and the leaf area at later stages of development (Gardner *et al.*, 1994). Although no published information on the effect of soil moisture content on cutting establishment could be found, various publications refer to the negative effect of water stress on growth and yield of sweet potato. During vegetative development the leaf area index increases with increase in soil moisture (Enyi, 1977; Indira & Ramanujam, 1985 as cited by Ravi & Indira, 1999; Chowdhury & Ravi, 1988). The storage root initiation period is the most sensitive to moisture deficit due to its effect on storage root number (Indira & Kabeerathumma, 1988; Nair & Nair, 1995; Ravi & Indira, 1996). Moisture deficits during the storage root initiation period induce lignification of adventitious root and hampers growth (Ravi & Indira, 1996).

Considering the lack of information on factors affecting early root growth and cutting establishment, two experiments were conducted to establish to what extent root and shoot growth of newly planted cuttings are affected by ambient temperature and soil moisture.

Material and methods

Temperature experiment

A pot experiment with four temperature treatments and four types of cuttings of cultivar Atacama was conducted during 2000 in a phytotron on the Experimental Farm of the University of Pretoria. Cuttings were obtained from sweet potato grown in a green house at 27/17 °C. Leaves were removed from the pot grown non-apical cuttings before planting. The experiment was carried out in four plant growth chambers with constant temperatures of 20 °C, 24 °C, 28 °C and 32 °C. The photoperiod was 12 h with an abrupt light/dark change. The four types of cuttings were: N1. Three-node cuttings vertically planted with one node under the soil surface; N2. Three-node cuttings planted upside down with one node under the soil surface; N3. Three-node cuttings planted horizontally with all the nodes 5-7 cm under the soil surface; N4. One-node cuttings planted horizontally 5-7 cm under the soil surface.

Pots were filled with fine sifted, heat-sterilised sand and cuttings were planted on 24 October 2000. Within the growth chambers, the pots were arranged randomly and watered once a day. All pots were harvested three weeks after planting. For each treatment five plants were sampled. The stem length, leaf number and leaf area were determined. The roots were carefully removed from the sand by submerging the pot in water to loosen the sand and minimise root breakage. After uprooting, the roots were washed to remove the remaining sand. Images of the roots were obtained by scanning the roots with an image analysing computer programme. The root length was measured using the "GS Root" programme. Roots and shoots were dried in a forced-ventilation oven at 60 °C for 48 hours. Dry matter partitioning was determined from the total dry mass of the shoots and the roots.

Treatments were arranged in a randomised complete block design. The experimental data were subjected to standard analyses of variance using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 1987) to determine the effect of main factors and the interaction between them. Differences at the $P \leq 0.05$ level were used as a test of significance and means were separated using Tukey's t-test.

Moisture experiment

A pot experiment with four soil-water content levels was conducted. The four moisture levels were field capacity (FC), 80% of field capacity, 60% of field capacity, and 40% of field capacity. The four moisture regimes were obtained by adding 70 ml, 56 ml, 42 ml, and 28 ml water respectively to 2 kg dry sand in plastic bags. After adding the water, the sand in each bag was thoroughly mixed to achieve an even distribution of moisture, and sealed in polyethylene bags to reach equilibrium. After two days, three cuttings of identical fresh mass and length were planted vertically through small slits in each bag on 6 September 2000. After planting, the containers were placed in a growth chamber at 28 °C and a photoperiod of 12 hours. The conditions under which the mother plants were grown were similar to those of the temperature experiment.

Two harvests were made, the first 12 days after planting (12 DAP) and the second 20 days after planting (20 DAP). At the first harvest three replicates of each treatment were sampled, while four replications were measured at the second harvest. The harvesting procedure, data recorded and statistical procedures were similar to those described for the temperature experiment.

Results

Temperature experiment

Root lengths and root dry mass results are presented in Table 1. An increase in air temperature from 20 °C to 24 °C increased the root length and root dry mass per plant. The highest total root length of 3.95 m per plant was obtained from plants exposed to a 24 °C growing temperature. As the temperature increased from 24 to 32 °C the root length decreased to 1.62 m per plant. The highest root dry mass was obtained from the plants exposed to a 24 °C growing temperature and the lowest from the plants exposed to 20 °C. The largest proportion (13.6%) of the total biomass was partitioned to roots in the 32 °C treatment and the lowest (9.5%) at 28 °C.

Table 1 Effect of temperature and orientation of cuttings on sweet potato root development

Treatment		Per plant		
		Root length (m)	Root dry mass (g)	% dry mass partitioned to roots
Temperature	20 °C	2.51	0.08	10.9
	24 °C	3.95	0.22	11.0
	28 °C	2.92	0.17	9.5
	32 °C	1.62	0.15	13.6
	LSD_T	0.75	0.05	1.6
Cutting type	N1	3.66	0.22	12.0
	N2	2.32	0.13	9.7
	N3	2.86	0.18	12.3
	N4	2.16	0.08	11.0
	LSD_T	0.75	0.05	1.6
Mean		2.75	0.16	11.3
CV%		43.2	55.00	22.2

Table 2 Effect of temperature and orientation of cuttings on sweet potato shoot development

Treatment		Vine length cm	Leaf number	Leaf area cm^2	Shoot dry mass g plt^{-1}	Total dry mass g plt^{-1}
Temperature	20 °C	14.1	7.2	187.5	0.61	0.7
	24 °C	25.6	13.7	578.2	1.75	2.0
	28 °C	26.7	14.4	519.0	1.50	1.7
	32 °C	20.9	11.7	246.5	1.00	1.1
	LSD_T	3.2	2.3	107.3	0.40	0.4
Cutting type	N1	24.1	13.8	510.4	1.59	1.8
	N2	22.7	12.7	375.8	1.21	1.3
	N3	22.9	12.8	425.3	1.34	1.5
	N4	17.6	7.7	219.7	0.70	0.8
	LSD_T	3.2	2.3	107.3	0.40	0.4
Mean		21.8	11.8	382.8	1.21	1.35
CV%		23.1	30.6	44.3	47.6	47.8

Table 3 Effect of soil water content on the top and root growth of sweet potato 12 days after planting

Soil water content (%FC)	Root length in (m)	Root dry mass g $plant^{-1}$	Shoot dry mass g $plant^{-1}$	Total dry mass g $plant^{-1}$	% DM partitioned to shoot
100	2.10	0.011	0.067	0.078	85.47
80	3.46	0.015	0.093	0.108	86.53
60	2.46	0.013	0.050	0.063	78.26
40	1.53	0.010	0.034	0.044	75.35
LSD_T	1.86	0.010	0.044	0.053	10.51
Mean	2.39	0.0123	0.061	0.073	81.40
C.V. (%)	41.37	41.53	38.31	38.10	6.86

The effect of temperature on shoot growth is presented in Table 2. In general shoot characteristics did not differ significantly between the 24°C and 28° C temperatures, but exposure to 20° C or 32° C negatively affected shoot growth. The highest vine length of 26.7 cm $plant^{-1}$ was obtained from the plants exposed to a 28 °C growing temperature, and the shortest vine length of 14.1 cm $plant^{-1}$ was obtained from plants exposed to 20 °C. The highest leaf number (14) $plant^{-1}$ was obtained from the plants grown at 28 °C, and the lowest temperature of 20 °C produced the smallest number of leaves (7) $plant^{-1}$. The highest shoot dry mass of 1.8 g $plant^{-1}$ was obtained from the plants exposed to 24 °C and the lowest shoot dry mass (0.6 g plant-1) was from the plants grown at 20 °C. The largest leaf area of 578 cm^2 was produced by the plants grown in the 24 °C growth chamber and the smallest leaf area (188 cm^2) was obtained from plants grown at 20 °C.

The effects of type of cutting on root length, root dry mass and fraction of the mass partitioned to roots are presented in Table 1. The highest root length of 3.66 m per plant was obtained from the three node cuttings oriented vertically, and the shortest (2.16 m) from the one node cutting oriented horizontally. The three node cuttings planted vertically produced the highest root dry mass of 0.22 g $plant^{-1}$, and the one node cutting planted horizontally produced the lowest (0.08g $plant^{-1}$). The three node cuttings planted horizontally partitioned the highest fraction of dry mass (12.3%) to the roots while the three-node cuttings planted upside down partitioned the lowest.

Results of the effect of type of cutting on vine length, leaf number, shoot dry mass production and partitioning and leaf area are presented in Table 2. The vine length, leaf number and shoot dry mass from the three node cuttings were similar, whether planted vertically, horizontally or even upside down. The leaf area from the three node cuttings was similar, whether planted horizontally or vertically. It is interesting that even when planted upside down, sweet potato cuttings retain the ability to establish vigorous root and shoot growth.

Moisture experiment

The effect of soil water content 12 days after planting on root development is summarised in Table 3. The longest total root length (3.46 m) was obtained from cuttings grown in soil at 80% of field capacity. As the soil water content decreased from 80 to 40% of field capacity, the root length decreased to 1.5 m $plant^{-1}$. Differences in shoot and total dry mass per plant and percentage dry matter partitioned to the shoot were significant. The largest proportion (86.5%) of the total biomass was partitioned to stems, the highest shoot dry mass of 0.09 g $plant^{-1}$, and the highest total dry mass of 0.11 g $plant^{-1}$ were recorded from plants grown at 80% of field capacity, and the lowest at 40% of field capacity.

Results of the effect of soil water content 20 days after planting on root development are summarised in Table 4. Differences in root growth and root dry mass were not statistically significant, although roots in the 80% of field capacity treatment tended to be the longest. Differences in shoot dry mass per plant were not significant, while the influence of soil moisture regimes showed significant differences in dry matter partitioned to the shoots and total dry mass produced per plant. The largest proportion (90.9%) of the total biomass partitioned to the stems, and the highest total dry mass of 0.146 g produced plant^{-1}, were recorded from plants grown at 80% of field capacity.

Table 4 Effect of soil water content on the top and root growth of sweet potato 20 days after planting

Soil water content (%FC)	Root length in (m)	Root dry mass g plant^{-1}	Shoot dry mass g plant^{-1}	Total dry Mass g plant^{-1}	%DM partitioned to shoot
100	2.40	0.009	0.086	0.095	90.26
80	3.80	0.012	0.118	0.146	90.92
60	3.21	0.010	0.094	0.103	90.83
40	3.02	0.015	0.083	0.098	85.27
LSD_T	1.66	0.006	0.040	0.039	3.72
Mean	3.11	0.012	0.095	0.111	89.32
C.V. (%)	37.72	32.61	27.24	23.10	2.70

In this study the 80% of field capacity moisture regime was found to be the optimum soil moisture content for root and shoot development. Lower or higher moisture regimes resulted in less root growth, but it is interesting to note that even at an initial moisture content of 40% of field capacity, substantial root development occurred. This is an indication that soil water content is not critical during the establishment of cuttings, provided that the soil is neither too wet nor too dry.

Discussion

The increase in root length and root dry mass per plant with increasing temperature from 20 to 24 °C, and a decrease in root length and root dry mass with increase in temperature from 28 to 32 °C suggests that 24 °C was the optimum temperature for root growth and development. The increase in leaf number and vine length per plant with increasing temperature from 20 to 28 °C, and decrease in vine length and leaf number with increase in temperature from 28 to 32 °C, indicate that the optimum temperature for shoot growth was approximately 28 °C. The results suggest that temperature ranging from 24 to 28 °C is the most suitable for early root and shoot growth. No published information is available on the effect of temperature on early root growth and development of sweet potato cuttings. Spence & Humphries (1971) conducted experiments on root differentiation using fully expanded leaves of two sweet potato cultivars, which were cut from the plant at the base of the petiole. The leaf cuttings were planted in 10 cm pots of sand and roots emerged from the petiole two weeks after planting. Rooted leaves of cultivar A16/15 were exposed to root temperatures of 30, 25, 15 and 10 °C, while rooted leaves of cultivar C9/9 were exposed to root temperatures of 35, 25, 20 and 15 °C. At 15 °C no roots developed into storage roots but there were more fibrous roots than at 25 and 30 °C.

Despite the relative large coefficient of variation, a reasonably clear picture emerged from the experiments regarding the effect of temperature and soil moisture content on early root development. Better root growth was achieved 12 and 20 days after planting from cuttings planted at 80% of field capacity. Using two sweet potato cultivars Bok (1998) conducted a pot experiment where cuttings were planted in soil at 100%, 70%, 50%, and 30% of field capacity. He reported that 35 days after planting the cultivars performed similarly under different soil water regimes, with respect to root length and root dry mass production. The 70% of field capacity moisture regime was found to be the optimum soil moisture content for root development of the cultivars. These results are similar to our data, which indicated that the 80% of field capacity moisture regime was the most favorable for root development. An explanation for the somewhat depressed root growth at field capacity reported by Bok (1998), and observed in our experiment, is not clear. The possibility of partly anaerobic conditions in the polyethylene bags containing the sandy substrate cannot be excluded, and should be investigated.

The results confirm the capacity of sweet potato cuttings to successfully establish under a range of soil moisture conditions and ambient temperatures. This is one of the features of sweet potato cuttings contributing to its suitability as propagating material, even under relatively unfavorable environmental conditions.

References

BOK, I., 1998. Response of sweet potato to different soil moisture regimes. MSc. Thesis, University of Pretoria, Pretoria, South Africa.

BOURKE, R.M., 1982. Sweet potato in Papua New Guinea. In: R.L. Villarreal & Griggs, T.D (ed.). *Proceedings of the International symposium on sweet potato*, Taiwan, China, p.45-47.

CHOWDHURY, S.R. & RAVI, V., 1988. Physiology of tuberization in sweet potato with reference to moisture stress and seasonal influence. In: *Ann. Rept.* Central Tuber Crops Res. Inst., Trivandrum, India, pp. 89-90.

ENYI, B.A.C., 1977. Analysis of growth and tuber yield in sweet potato (*Ipomoea batatas*) cultivars. *J. Agr. Sci.* 88, 421-428.

GARDNER, F.K., PEARCE, R.B. & MITCHELL, R.L., 1994. Physiology of crop plants, 3rd edn, Iowa State University Press, Ames, Iowa.

GOMES, F. & CARR, M. K. V., 2003. Effect of water availability and vine harvesting frequency on the productivity of sweet potato in Southern Mozambique. II. Crop water use. *J. Expl. Agric.* 39, 39-54.

HAHN, S.K., 1977. Sweet potato. In: *Ecophysiology of tropical crops.* Edited by R.T. Alvim & T.T. Kozilowski. New York, Academic Press, p. 237-248.

HARTER, L.L. & WHITNEY, W.A., 1962. Influence of soil temperature and soil moisture on the infection of sweet potato by the black rot fungus. *J. Agric. Res*. 32, 1153.

INDIRA, P. & KABEERATHUMMA, S., 1988. Physiological response of sweet potato under water stress: 1. Effect of water stress during different phases of tuberization. *J. Root Crops* 14, 37-40.

JANA, R.A., 1982. Status of sweet potato cultivation in East Africa and its future. In: R.L. Villarreal & Griggs, T.D. (eds.). *Proceedings of the International symposium on sweet potato.* AVRDC, Taiwan, China, P. 63-76.

KAY, D.E., 1973. *Root Crops product digest 2: Root Crops.* Tropical Product Institute, London.

NAIR, G.M. & NAIR, V.M., 1995. Influence of irrigation and fertilizers on the growth attributes of sweet potato. *J. Root Crops* 21, 17-23.

RAVI, V. & INDIRA, P., 1996. Anatomical studies on tuberization in sweet potato under water deficit stress and stress free conditions. *J. Root Crops* 22, 105-111.

RAVI, V. & INDIRA, P., 1999. Crop physiology of sweet potato. *Hort. Reviews* 23, 277-316.

SARK, E.S.M., 1978. Effect of temperature on yield of sweet potato. *Proc. Am. Soc. Hort. Sci.* 42. 517

SAS Institute, 1987. SAS/STAT Guide for personal Computers, Version 6; SAS Institute: CARY, N.C.

SHUKLA, P.T., 1976. Stability performance of sweet potato (*Ipomoea batatas* L.) varieties in the medium altitude areas of Tanzania. *East Afr. Agr. Forest J.* 42, 198-200.

SPENCE, J.A. & HUMPHRIES, E.C., 1971. Effect of moisture supply, root temperature and growth regulators on photosynthesis of isolated rooted leaves of sweet potato (*Ipomoea batatas*) *Ann. Bot.* 36, 115-121.