Identification of drought tolerant sweet potato (*Ipomoea batatas* (L.) Lam) cultivars

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Abstract

Pot experiments were conducted to screen fifteen sweet potato cultivars for drought tolerance. Two levels of water regimes were applied, control (maintained by regular watering at or close to field capacity) and water stressed plants (saturated then allowed to dry progressively to permanent wilting point). Plant biomass, main stem length, internode diameter, internode length, leaf number and area, and root weight all decreased in response to the water stress. Leaf water potential decreased significantly when water supply was withheld, however leaf water potential was not statistically different among cultivars in both control and water stressed treatments. The cultivar Lole showed more strongly developed drought resistant characters than all the other cultivars.

Media summary

Of 15 sweet potato cultivars evaluated, Lole showed the greatest drought tolerance

Key words

Sweet potato (*Ipomoea batatas* L.), drought tolerance

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is grown over a broad range of environments and cultural practices and is commonly grown in low-input agriculture systems (Prakash 1994). The plant is sensitive to water deficits, particularly during the establishment period including vine development and storage root initiation (Indira and Kabeerathumma 1988). Sweet potato is considered to be moderately drought tolerant (Valenzuela *et al* 2000). However, drought is often a major environmental constraint for sweet potato production in areas where it is grown under rain fed conditions (Anselmo *et al*. 1998). Different cultivars may respond differently to limited quantities of soil water. Selection for good cultivar performance (growth rate; tuber development) under drought conditions is considered to be of major importance. Experiments were therefore conducted, to identify sweet potato cultivars associated with superior drought tolerance.

Methods

A pot experiment to evaluate drought tolerance of 15 cultivars of sweet potato was conducted in a glasshouse at James Cook University, Townsville, North Queensland. A factorial experiment with a randomised complete design consisted of water stress treatments and normal water supply for 15 cultivars (Table 1). Each treatment was replicated 4 times. Sixty pots with 5-L volume were used to determine the amount of water at wilting point, and another 60 pots were watered normally. Tip cuttings (25 cm long) of each cultivar were planted after soaking for 2 days in water. The plants were watered to saturation after which water was permanently withheld in the stress treatment. While water stress was induced gradually by withholding water, the unstressed set of control plants was watered to field capacity every other day. Growth parameters were measured and analysed using analysis of variance (SPSS 10.0) at a significance level of 5% ($P<0.05$). When the effects of various treatments were significant, post hoc comparisons were carried out using Bonferroni’s method.

Results and Discussions

Table 1. Plant growth parameters of sweet potato cultivars as affected by soil water condition.

Cultivar	Dry biomass (g plant^{-1})		Main stem length (cm plant^{-1})		Internode length (cm plant^{-1})		Internode diameter (mm plant^{-1})		Root dry weight (g plant^{-1})	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
Beerwah Gold	37.6	10.0	98.0	76.0	3.6	3.5	3.8	2.9	4.6	1.4
Hawaii	26.2	9.4	118.0	101.8	5.8	5.8	2.5	2.0	3.6	1.1
Lole	22.9	6.9	70.6	60.5	2.5	2.5	2.8	2.5	3.4	1.1
Markham	36.7	10.3	200.5	165.4	7.7	7.6	3.4	3.0	5.5	1.7
Mariken	39.8	7.8	300.8	188.8	9.0	8.9	3.0	2.3	4.4	1.0
Wanmun	36.4	9.7	214.6	135.8	5.6	5.3	3.5	3.0	4.4	1.2
NG7570	31.5	8.3	160.8	127.8	6.3	6.0	2.3	2.0	3.9	1.2
LO323	39.4	9.0	162.0	109.8	7.1	6.8	2.9	2.0	3.7	1.2
L3	37.8	9.1	199.8	135.8	6.8	6.8	3.9	3.0	4.3	1.4
L11	32.4	9.7	172.8	148.4	7.2	7.0	3.7	2.8	4.8	1.2
L18	30.8	8.2	121.6	53.0	2.5	2.4	3.8	3.2	3.5	1.2
L46	32.7	9.4	163.1	111.3	5.4	5.0	3.8	3.1	4.4	1.4
L49	37.7	10.3	149.4	102.3	5.0	4.9	5.1	3.4	5.0	1.4
L131	24.4	8.8	197.0	149.8	6.1	5.9	3.0	2.0	4.5	1.3
L135	37.5	8.3	181.8	118.0	5.0	5.0	2.7	2.4	3.5	0.6

Table 2. Leaf growth parameters of sweet potato cultivars as affected by soil water condition.

Cultivar	Leaf weight (g plant^{-1})				Leaf area (cm^2 plant^{-1})		Leaf number/plant	
	Control		Stress					
	Fresh	Dry	Fresh	Dry	Control	Stress	Control	Stress
Beerwah Gold	89.4	12.6	11.8	4.3	3891	771	67	25
Hawaii	71.1	9.4	14.2	3.9	3216	839	62	31
Lole	51.8	9.2	13.9	3.4	2114	756	88	38
Markham	70.8	11.8	13.9	3.9	3716	889	54	20
Mariken	66.9	11.1	12.0	2.6	3524	771	46	18
Wanmun	71.8	12.1	12.7	2.9	3489	823	57	23
NG7570	77.4	11.8	14.7	2.6	4065	868	85	33
LO323	78.9	13.2	12.3	4.1	4160	851	50	25
L3	76.6	12.8	12.4	2.9	3871	818	54	22
L11	73.0	10.5	14.3	3.3	3682	819	43	20
L18	77.1	12.1	13.0	2.6	3609	762	93	52
L46	69.7	12.0	14.5	3.9	3809	842	38	18
L49	77.2	12.1	13.2	3.4	2972	814	51	24
L131	52.4	10.0	12.4	3.7	2348	824	53	30
L135	64.7	12.0	12.3	3.6	2773	798	46	23

Table 3. Morpho-physiology and water relations parameters of sweet potato cultivars as affected by soil water conditions.

Cultivar	Leaf dry matter content (g kg^{-1})		Specific leaf area (cm^2 g^{-1})		Leaf water potential at permanent wilting point (bar)		Final soil water content (g water pot^{-1})	Number of days to permanent wilting point
	Control	Stress	Control	Stress	Control	Stress		
Beerwah Gold	365.3	144.7	309	180	-2.4	-14.2	240	19
Hawaii	275.9	132.6	344	215	-1.9	-11.3	174	25
Lole	240.6	178.2	229	227	-2.3	-11.8	170	27
Markham	278.1	167.4	312	235	-2.3	-12.2	191	23
Mariken	200.3	166.1	317	296	-2.4	-12.5	179	21
Wanmun	228.2	168.3	289	286	-2.8	-12.3	163	21
NG7570	179.0	152.8	346	340	-2.3	-11.7	163	21
LO323	333.6	167.4	316	209	-2.8	-13.0	239	21
L3	215.9	167.9	305	294	-2.3	-12.2	199	21
L11	228.0	143.3	355	253	-2.3	-11.3	181	23
L18	199.7	157.2	298	297	-2.4	-12.0	158	23
L46	270.0	171.8	318	219	-2.2	-11.8	179	23
L49	243.7	156.3	245	244	-2.3	-11.4	174	23
L131	209.1	192.9	238	221	-2.2	-12.5	173	23
L135	249.2	184.8	233	226	-2.4	-11.5	172	23

There were significant interactions between water treatments and cultivars for most of the parameters observed except for root dry weight, suggesting that the general responses of the cultivars to the water treatments were statistically similar. All cultivars significantly responded to drought by a reduction in overall plant growth apart from the internode length (Table 1-3).

However, a number of cultivars showed differential growth responses to drought. Drought reduced the total plant dry weight from 31% to 46% with respect to the controls. The lowest biomass reduction was in cultivars L131, Hawaii, and Lole (Table 1). Although Lole had the lowest biomass weight, it produced the smallest reduction in the total dry biomass compared to other cultivars (Table 1). In all cultivars, stem length grew significantly slower after water was withheld (Table 1). The reduction of stem length varied from control to drought stress treatments. The greatest reduction in stem length was found in cultivar L18 (46.0%), while Lole showed the lowest reduction (16.1%; Table 1). Drought decreased internode diameter but not internode length in all cultivars. Internode diameter was slightly reduced in Lole (12%), whereas cultivars LO323, L49, and L131 produced the greatest reduction (45-50%; Table1). This reduction is in agreement with the findings of Kirnak *et al*. (2001) who showed that water stress reduced both stem height and internode diameter in eggplants by 46% and 51% under 40 % field capacity compared to the control (100% field capacity). Drought affected root dry weight irrespective of cultivars. The smallest reduction was in cultivars L18 (65.6%), followed by L3 (66.7%), LO323 (68.2%), Lole (68.6%), and L46 (68.7%; Table 1).

Leaf fresh weight was reduced from 60% to 80% among cultivars (Table 2). The lowest leaf fresh weight reduction was in Lole (73.2%; Table 2). When water was withheld, cultivar L18 produced the highest leaf dry weight reduction (78.9%), while the lowest reduction was in Hawaii (58.5%); leaf area was reduced from 80.2 % in Beerwah Gold to 64.2 % in Lole, and leaf number reduced significantly from 62% in Markham and Beerwah Gold to 50 % in Hawaii, L135, and LO323. The highest leaf area reduction was in Beerwah Gold, while Lole produced the lowest percentage of leaf area reduction. The reduction of leaf weight and area was strongly correlated with the reduction of leaf water potential (r^2= 0.89 and r^2= 0.91, respectively). Lole had the smallest leaf area, lowest specific leaf area, and greater drought tolerance characters; transpiration was therefore expected to be lower. Leaf size of sweet potato has been reported to have a negative correlation with apparent photosynthesis, suggesting that cultivars with small leaves have an advantage in the field (Bhagsari and Brown 1986).

Leaf dry matter reflects a fundamental trade off in plant functioning between a rapid production of biomass (high specific leaf area, low leaf dry matter content) and an efficient conservation of nutrients (low specific leaf area, high leaf dry matter content, Garnier *et al*. 2001). In the controls, cultivar Beerwah Gold produced the greatest leaf dry matter content, whereas cultivar L131 produced the highest leaf dry matter content in the water stressed treatment. NG7570 produced the greatest specific leaf area in both the control and water stressed conditions; Lole, on the other hand, produced the lowest specific leaf area in the controls.

In this trial, leaf water potential was not statistically different among cultivars. However, it progressively declined when water was withheld. The decrease in leaf water potential caused by water stress is well documented in other crop species; Siddique *et al*. (2000) found that leaf water potential of wheat cultivars decreased from –0.63 MPa in well watered plants to – 2.00 MPa in stressed plants, and as a consequence photosynthetic rate was extremely affected. In cassava, leaf wilting occurred at leaf water potential of less then –9 bars (Ike and Thurtell, 1981). Lole transpired less water than the other cultivars, and it was also withstood a prolonged dry period (Table 3). Plant growth usually decreased, as soil water availability becomes more limited due to turgor loss in expanded cells (Kirnak *et al*. 2001). Of the15 cultivars in this study, Lole was found to be relatively drought tolerant; its growth was less affected by drought, it delayed wilting, and it had higher leaf water content compared to the other cultivars. Lole used less water simply as a function of differences in leaf areas; therefore it has a greater capacity to retain moisture. This is in agreement with the results of Monneveux and Belhassen (1996) who showed that water loss at the plant level largely depends upon the size of the evaporating areas (leaves, stems).

Conclusion

Drought gradually leads to a decrease in soil water content and affected water relations and growth in all sweet potato cultivars. Among the 15 sweet potato cultivars evaluated Lole is considered to have the greatest tolerance to water stress. Drought tolerance in Lole is associated with the lowest percentage of growth reduction, less water consumption, higher leaf water potential, and delayed wilting under imposed drought stress conditions.

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