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EFFECT OF POTASSIUM NUTRITION ON CONTENTS OF CHEMICAL CONSTITUENTS IN SWEET POTATO PLANTS

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Root crops especially have a high potassium requirement, and root or tuber enlargement is depressed relatively more than leaf development when potassium is in short supply. This growth response has indicated that potassium may have an essential role in photosynthesis and respiration of higher plants[1]. The previous works on the respiration in sweet potato plants[2,3,4], taro plants[5], broad bean plants[6], and barley[6] have inferred that a critical point of potassium deficiency resulting in a higher respiration rate than its normal status may be in the range of 1/2 to 1/3. This work was undertaken in an attempt to prepare a profitable material for investigations into the effect of potassium nutrition on the respiration in sweet potato roots, and presents some supplemental data on the previous report[7].

Table 1. Composition of nutrient solution

Nutrient level		Salts used
N	40 ppm	$(NH_4)_2SO_4$ or $NaNO_3$
P_2O_5	40	$NaH_2PO_4 \cdot 2H_2O$
K_2O	40	K_2SO_4
CaO	15	$CaCl_2 \cdot 2H_2O$
MgO	10	$MgSO_4 \cdot 7H_2O$
Fe_2O_3	2	$FeCl_3 \cdot 6H_2O$
pH of nutrient solution — 6.5		

Materials and Methods

The shoot end, 25 cm long and with 8 nodes, was cut out of sweet potato plants var. "Kohkei-

Table 2. Effects of potassium nutrition on yields of sweet potato plants grown at varying nitrogen source

N-source		NH_4-N		NO_3-N		NH_4-N		NO_3-N	
K-application		+K	−K	+K	−K	+K	−K	+K	−K
plant part	Culture period, weeks	Fresh weight, g/plant				Dry weight, % of fresh weight			
2nd leaf	0	0.94				20.58			
	1	1.03	1.08	1.24	1.10	18.49	18.66	19.13	18.89
	2	1.19	1.14	1.36	1.22	17.23	17.75	16.25	18.30
	3	1.13	1.09	1.40	1.24	17.05	17.59	16.19	18.12
4th leaf	0	0.37				21.87			
	1	0.60	0.54	0.65	0.55	17.97	18.11	19.84	19.35
	2	1.00	0.87	1.10	0.89	15.23	16.70	14.96	18.41
	3	1.12	0.98	1.23	0.99	14.81	16.11	14.44	17.70
2nd petiole	0	0.58				10.11			
	1	0.77	0.73	0.89	0.71	9.88	10.01	9.76	10.05
	2	0.86	0.82	0.96	0.81	8.57	9.50	8.44	9.94
	3	0.88	0.84	0.99	0.83	8.47	9.26	8.32	9.47
4th petiole	0	0.26				12.59			
	1	0.48	0.40	0.60	0.47	9.43	9.99	9.10	10.44
	2	0.55	0.50	0.72	0.53	8.05	8.67	7.58	9.41
	3	0.76	0.71	0.88	0.72	7.13	8.00	6.62	8.15
Stem	0	4.16				12.09			
	1	4.40	4.36	4.49	4.34	12.22	12.03	12.31	12.17
	2	5.07	4.94	5.05	4.93	12.83	12.35	12.54	12.40
	3	5.93	5.61	6.37	5.71	13.07	12.84	12.85	12.77
Roots	0	—				—			
	1	1.71	1.56	1.95	1.67	5.69	5.41	5.52	5.33
	2	4.20	3.34	4.71	3.91	6.33	6.42	5.97	6.12
	3	6.60	5.35	7.31	5.88	7.01	7.55	6.59	7.15

* Laboratory of Plant Nutrition.

Table. 3. Effects or potassium nutrition on three major elements in sweet potato plants grown at varying nitrogen source

N-source		NH_4-N		NO_3-N		NH_4-K		NO_3-N		NH_4-N		NO_3-N	
K-application		+K	−K	+K	−K	+K	−K	+K	−K	+K	−K	+K	−K
plant part	Culture period, weeks	Total-N, % dry wt.				P_2O_5, % dry wt.				K_2O, % dry wt.			
2nd leaf	0	5.05				0.57				3.23			
	1	5.20	4.71	4.61	4.53	1.26	1.08	1.24	0.96	3.26	2.84	3.34	3.14
	2	4.75	4.46	4.99	4.05	0.91	0.85	0.95	0.68	3.16	2.44	3.09	2.58
	3	4.17	4.05	3.33	3.22	0.57	0.55	0.50	0.50	2.65	2.16	3.36	2.02
4th leaf	0	5.44				1.05				3.53			
	1	7.80	5.49	7.43	5.21	1.74	1.30	1.20	1.47	3.46	3.14	3.55	3.34
	2	4.71	4.41	4.69	4.32	1.25	1.06	0.97	1.14	3.22	2.88	3.28	2.69
	3	4.84	4.42	4.28	4.05	1.03	0.95	0.71	0.99	3.20	2.68	3.47	2.52
2nd petiole	0	3.80				0.52				5.29			
	1	3.47	2.72	2.87	2.27	0.89	0.88	0.77	0.66	5.16	3.37	4.71	3.56
	2	2.51	2.35	2.13	1.98	0.69	0.61	0.54	0.56	4.66	2.46	4.47	2.58
	3	1.44	1.22	1.65	1.35	0.49	0.50	0.44	0.42	3.89	2.32	3.92	2.37
4th petiole	0	4.18				0.73				7.95			
	1	2.93	1.84	3.39	2.73	1.72	1.20	1.80	1.11	7.71	6.98	8.22	6.89
	2	2.14	1.81	2.23	2.14	1.16	0.92	0.97	0.91	7.02	5.98	7.03	6.25
	3	1.90	1.63	2.05	1.71	0.81	0.88	0.76	0.75	5.38	4.87	5.67	4.72
Stem	0	2.88				0.74				3.85			
	1	3.45	2.40	3.19	2.93	0.82	0.73	0.86	0.80	4.15	3.77	3.76	3.21
	2	2.23	2.16	1.81	1.66	0.82	0.72	0.56	0.71	3.39	2.77	3.15	2.65
	3	1.76	1.09	1.21	0.99	0.66	0.68	0.55	0.62	2.80	2.02	2.72	2.37
Roots	0	—				—				—			
	1	6.04	5.54	6.24	5.66	1.70	1.48	1.74	1.44	5.64	5.22	6.50	6.10
	2	4.97	4.45	5.27	4.68	1.38	1.44	1.33	1.42	4.65	2.65	4.80	3.01
	3	3.35	3.13	4.07	3.90	1.10	1.21	0.97	1.13	3.41	1.71	3.62	1.96

14'' grown in a field culture. Three leaves near the cut of the shoot were removed before a 3 weeks' solution culture was started. Nutrient solutions as shown in Table 1 were renewed twice a week, and the tap water (pH 6.8) used for a preparation of nutrient solution contained 2 ppm K_2O, 10 ppm CaO, and 5 ppm MgO on the average. Samples were harvested at 10 a.m. on a given day.

After yield survey on fresh weight, the dried samples were used for analysis of several constituents. Total-N, phosphorus, and potassium were determined by submicro PUCHER's method, moylbdenum blue (HCl) method, and Kalignost reagent procedure, respectively. Amino-N fraction and sugars were extracted from the ground samples with 80 % ethanol, and determined by ROSEN's method and SOMOGYI's method, modified by MOYER and HOLGATE, respectively. The details of the analytical methods used have been described elsewhere[2,3,6].

Two centimeter segments of the root tip and the root base were dissected out of the roots with lateral roots. The respiratory assay was made by the standard Warburg manometric technique with 1/15 *M* Na-phosphate buffer at pH 7.0 at 30°C. Each vessel had in the main reservoir 10 segments of excised roots. Total volume of the reaction mixture was 3 ml. The oxygen uptake was expressed as $QO_2(F)$ for a value obtained during 30–90 minutes after the start of the assay. The other details of the assay have been described in the previous report[3].

Results and Discussion

Effects of potassium nutrition on yields of the 2nd leaf (the older leaf), the 4th leaf (the younger leaf), the 2nd petiole (the older petiole), the 4th petiole (the younger petiole), stem, and roots of sweet potato plants grown at varying nitrogen source for 3 weeks are summarized in Table 2. A 3 weeks' K-depletion of medium, especially under nitrate nutrition, decreased considerably the fresh weight of both tops and roots, and concomitantly increased the dry weight (% of the fresh weight) in all plant parts. A prolonged culture under ammonium application without aeration resulted in a more severe retardation of the growth and the development of the plants compared with the case under nitrate nutrition; the neoformed leaves (the 6th-10 or 11th) exhibited a faded color and the older roots were tinged with light brown.

Aging of the plants led to a reasonable dilution in the contents of nitrogenous, phosphorus, and potassium fractions (Table 3). A K-depletion of

Table 4. Effects of potassium nutrition on amino-N and sugars in sweet potato plants grown at varying nitrogen source

N-source		NH_4-N		NO_3-N		NH_4-N		NO_3-N		NH_4-N		NO_3-N	
K-application		+K	−K	+K	−K	+K	−K	+K	−K	+K	−K	+K	−K
plant part	Culture period, weeks	Amino-N % dry wt.				Total sugars, % dry wt.				Reducing sug., % dry wt.			
2nd leaf	0	0.182				3.24				3.02			
	1	0.081	0.102	0.052	0.058	4.25	5.15	4.46	5.53	2.55	3.74	3.79	4.45
	2	0.099	0.126	0.049	0.067	4.06	4.56	4.46	4.84	2.43	3.37	2.30	3.48
	3	0.073	0.083	0.023	0.032	1.92	2.88	2.08	2.72	1.41	2.42	1.75	2.21
4th leaf	0	0.202				4.13				3.71			
	1	0.143	0.170	0.052	0.067	5.12	5.68	5.86	5.27	4.04	4.91	3.89	4.66
	2	0.107	0.162	0.067	0.074	4.26	4.74	4.60	5.14	3.44	3.89	3.40	4.15
	3	0.138	0.193	0.044	0.051	2.87	4.33	3.11	4.38	2.08	3.19	2.56	2.99
2nd petiole	0	0.244				9.71				7.34			
	1	0.135	0.146	0.083	0.108	7.22	10.96	8.05	10.37	5.40	8.77	6.06	7.88
	2	0.139	0.150	0.043	0.059	9.63	11.66	10.40	11.60	7.62	9.00	8.71	9.29
	3	0.097	0.118	0.032	0.038	9.46	10.87	9.19	10.13	8.27	8.53	6.07	6.42
4th petiole	0	0.405				16.02				13.69			
	1	0.242	0.283	0.171	0.209	13.62	18.06	15.78	18.72	8.50	9.62	13.06	15.00
	2	0.221	0.251	0.147	0.164	14.70	16.86	13.88	16.42	10.44	13.59	10.77	14.56
	3	0.174	0.218	0.082	0.092	9.89	14.58	11.92	15.93	7.24	12.77	7.26	13.06
Stem	0	0.268				7.34				4.05			
	1	0.144	0.231	0.203	0.230	5.28	8.16	5.81	8.56	3.35	4.41	4.03	5.10
	2	0.227	0.240	0.131	0.133	7.70	9.00	7.63	8.21	4.94	5.71	4.36	5.79
	3	0.121	0.211	0.068	0.120	7.40	7.96	7.04	7.77	4.07	5.29	3.14	5.00
Roots	0	—				—				—			
	1	0.403	0.571	0.251	0.444	5.86	6.05	5.97	6.82	3.90	4.39	4.09	4.34
	2	0.391	0.415	0.242	0.264	5.03	4.91	5.20	5.51	3.04	3.37	3.50	3.80
	3	0.322	0.381	0.169	0.230	4.02	3.94	3.52	4.21	2.78	2.91	2.61	3.02

Table 5. The effect of potassium nutrition on the respiration (QO_2(F)) in excised roots

N-source	NH_4-N		NO_3-N	
K-application	+K	−K	+K	−K
Part of root	1 week's culture			
Tip	525	556	485	547
Base	378	402	370	404
	2 weeks' culture			
Tip	520	467	492	537
Base	285	328	303	336
	3 weeks' culture			
Tip	451	418	470	449
Base	237	222	278	265

medium decreased the nitrogenous levels in all plant parts as well as the potassium levels. The severity of K-deficiency was deeper in the roots than in the tops, which was marked under ammonium nutrition. The K-deficiency grades in roots became severe with time of culture; 2/3 of the normal status in the 2 weeks' culture dropped to 1/2 in the 3 weeks' culture.

Table 4 shows superior levels of amino-N and sugars in the younger tissues and in a shorter term culture. Amino-N contents were evidently higher in the ammonium nutrition, though sugars contents were unvaried between both N-sources. An increased grade in amino-N by K-deficiency diminished with a prolongation of culture term, whereas reducing sugars were increased by K-deficiency to a similar extent independently of the term of solution culture. It may be worthy of nothing that total sugars in the roots under ammonium nutrition were exceptionally decreased by K-deficiency.

Table 5 shows a variation in the effect of K-deficiency on the respiratory pattern with aging of the tissues and between both N-sources. In a week's culture, the respiratory activity in both parts of root was higher in the K-deficiency independently of N-source. In a 2 weeks' culture, the respiratory behavior of the root tip to K-deficiency was contradictory between both N-sources, though that of the root base was consistent. An appreciable diminution in the respiratory activity was encountered in a further prolonged culture (3 weeks' culture), and a K-depletion of medium resulted in inferior levels of the respiratory activity in both parts of root independenly of N-source compared with the normal status.

A 3 weeks' culture reduced the K-contents in

roots to a level at round 1/2 of the normal (Table 3), though the K-levels were lower under the ammonium nutrition. Such a grade of K-deficiency exceeded already a critical point of K-deficiency (probably 2/3 of the normal as observed in the 2 weeks' culture) resulting in a higher respiratory activity than its normal status. Although the pH of the nutrient solution containing sodium nitrate was practically unvaried during 3 weeks, an use of ammonium sulfate as a N-source lowered the pH to a greater extent in the later period of culture, for example by about 3.0 at the muximum. A depletion of aeration of medium may have enhanced a more severe derangement in the plant metabolism by the K-deficiency associated with the ammonium nutrition[8].

In conclusion, the data obtained suggest that the root samples from a 2 weeks' culture under nitrate nutrition seem to be one of the profitable materials for investigations into the effect of potassium nutrition on the respiration in plant roots.

Summary

In order to prepare a profitable material for investigations into the effect of potassium nutrition on the respiration in roots, shoot end of sweet potato plants var. "Kohkei-14", 25 cm long and with 5 leaves, was grown in solution culture without aeration for 3 weeks at varying potassium application and N-source. Yield survey and analysis of several constituents (total-N, phosphorus, potassium, amino-N, and sugars) were made on various plant parts. The effect of potassium nutrition on the respiration ($QO_2(F)$) in 2 cm segments of the root tip and the root base were examined by the standard Warburg manometric technique. Ammonia toxicity associated with an exclusion of aeration may have depressed the respiratory metabolism in roots. A K-depletion of medium lowered the K-levels in roots to 2/3 of the normal levels in the 2 weeks' culture and to 1/2 in the 3 weeks' culture. Such a K-deficiency grade in roots from the 3 weeks' culture exceeded a critical point of K-deficiency resulting in a higher respiration rate than its normal status. The results obtained suggest that root samples from a 2 weeks' culture under nitrate nutrition may be the desired material.

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