POTASSIUM REQUIREMENT OF TARO IN RELATIONSHIP TO GROWTH, FOLIAR ANALYSIS, YIELD, AND QUALITY AS GROWN IN SOLUTION CULTURE

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SUMMARY

Small plantlets were grown on half-Hoagland and various potassium-deficient solutions which changed weekly. KNO_3 was added daily to the solutions. Extensive data, analysed by computer is tabulated and highlights discussed. Growth measures could often be fitted to ln-ln functions. Leaf K measured at 91 days can be correlated with yield. Corms from plants grown in solution culture were usually rich in N, P, K and nitrate. The Mg content was significantly higher in Lowthan Complete– K treatments. Taste testing revealed poor panel discrimination with large differences in assessment between coded replicate samples. However, there was generally preference indicated for baked over steamped corms and for the Low-K grown corms.

RESUME

Des plantules sont cultivées sur sol semi-"Hoag" et des solutions déficientes en potassium qui changent chaque semaine. Chaque jour on ajoute du KNO_3 aux solutions. Des données détaillées, analysées à l'ordinateur sont classifiées et les éléments discutés. Souvent les mesures de croissance peuvent correspondre aux fonctions ln-ln. La feuille K mesurée a 91 jours peut correspondre au rendement. Les tiges souterraines bulbleuses des plantes cultivées en solution de culture sont habituellement riches en N, P, K, et en nitrate. La teneur en Mg est nettement plus élevée avec les traitements bas K qu'avec les traitements de K complet. Lorsqu'on teste le goût il se révèle que le panneau de discrimination est pauvre avec des écarts sensibles dans l'évaluation des échantillons de replicas codés. Toutefois les tiges bulbleuses cuites au feu ou ayant une quantité basse de K sont généralement préférées à celles qui sont cuites à la vapeur.

RESUMEN

Se cultivaron pequiñas plántulas en solución un medio-Hoagland y en varias soluciones deficientes en potasio las cuales se cambiaron semanalmente. Se añadió KNO_3 diariamente a las soluciones. Se tabulan datos extensivos, analizados por computadora y se discuten los puntos mas sobresalientes. Las medidas de crecimiento pudieron ser frecuentemente ajustadas a functiones ln-ln. Se pueden correlacionar el potasio foliar medido a los 91 dias, con el rendimiento. Los cormos de las plantas que crecieron en soluciones nutritivas, fueron generalmente ricos en N, P, K y nitratos. El contenido de Mg fue significativamente mas rico en los tratamientos de bajo K que en los que el K estaba completo. Las pruebas de palatabilidad revelaron una baja capacidad de discriminacion de parte del jurado con grandes diferencias de opinión sobre muestras repetidas, codificadas previamente. Hubo, sin embargo, preferencia generalizada pro cormos porneados sobre los procesados al vapor y por los cultivados con bajo potasio.

INTRODUCTION

At alafua, W. Samoa, soil N was low, K was also deficient[2] and there were frequently symptoms of marginal scorch and interveinal chlorosis on taro like those described for *Xanthosoma* sp.[18]. Most taro is planted in lowland and foothill gardens under rainfed culture in Samoa on soil which is highly leached and on which K is usually limiting to production.

On the Dala series soils of Malaita Island (Solomon Islands) Gollifer has reported responses to K fertilizer in taro[7]. Foliar analysis of samples collected on a field study there confirmed K deficiency[1]. Samples for foliar analysis from Keravat, New Britain, P&NG indicated K deficiency and this was associated with excess Mg concentrations. Response to K and P occurred on soils of Moorea I., Society Islands[12].

When high concentrations of K are in petioles and leaf blades[14,15] this is associated with highest total yields of sucker and main corms. The high K requirement of taro is traditionally met by the usual practice in Pacific islands of planting taro after a tree fallow which would return K to the surface by leaf fall. Such

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areas are seldom replanted to taro but are returned to bush fallow after less demanding crops have followed taro. K is perhaps the most common limiting element in the nutrition of taro.

MATERIALS AND METHODS

Buds of taro cultivar Niue, which is the most popular cultivar in Samoa, were obtained from corms at harvest. These were used for propagating in vermiculite watered with one-tenth Hoagland solution without micronutrients[10]. Plantlets having one and two leaves were transferred after 1½ months to 1-gallon jars and watered with half-Hoagland solution with modified micro-nutrients[8]. The plantlets were supported in these containers on nylon mesh with polyester fiberfill. On 11 January 1972, 16 plantlets were transferred to plastic buckets for treatment with different levels of K and other nutrients (Table 1). The plants were supported in black polycans from which the bottoms had been removed. These were surrounded by wide rubber mesh so that the plants could be suspended over buckets of aerated nutrient solution with just their roots submerged. Later, support was provided for the top heavy plants by means of wires suspended from the ceiling of the plant house.

To facilitate changing the root solutions each week, and to make additions from time to time, an ordered arrangement within the plant house was adopted with two rows of 8 plants oriented north-south and fans giving air movement from west to east. Weekly changes of position were made to randomize position effects within replicates. Spacing within rows averaged 0.404 m. and between two rows 1.16 m.

Complete half-Hoagland solution, solutions with graded levels of K-deficiency were provided (Table 1). Micronutrients were supplied at levels 0.54 ppm B, 0.55 Mn, 0.065 Zn, 0.064 Cu, 0.048 Mo, 2.3 Na and 4.4 ppm Cl. Solution samples were taken, at first daily, later twice weekly for analysis by atomic absorbtion spectrophotometer or flame photometer. Cs was added to compensate when K was below 10 ppm. Use of nitrate electrode indicated when KNO_3 additions were required.

Analysis of P by ascorbic acid reduction[9] indicated rapid uptake in some cases, necessitating a mid-weekly addition of KH_2PO_4. Ca and Mg were more than sufficient. Mn was nearly completely taken up and was quadrupled to 2.2 ppm in three steps, while Fe sequestrene was reduced from 0.5 to 0.1 ppm.

The dry matter content of fallen leaves was determined. Number of leaves and dimensions for estimating area were also taken. The lengths of fallen petioles and the fourth and final leaf samples, by cutting, were measured as well as all fresh weights. Suckers were cut and counted, or removed when possible. Where this stimulated further suckering and this could be identified, the secondary suckers were not counted. Deionized water was added daily to replace transpiration and guttation loss. K-use was calculated from K added and change in solution from the nominal values. pH was determined twice weekly and $Ca(PH)_2$ was added as required to maintain it about 6.0.

The first sample was taken after 91 days when there was considered to be sufficient growth that the removal of a leaf would not greatly affect photosynthetic rate. Successive samples were taken only after all the cut petioles had fallen away. At harvest corms and roots were sampled. Foliar samples were oven dried for one day at 85° C, weighed, ground to 40 mesh, and bottled samples redried at 70° C for one day before taking one gram samples for dry ashing at 550° C overnight. After cooling they were wetted and heated with 5 ml. 5N Hc1, filtered and made up to 25 ml. for micronutrient analysis. Dilutions were made for P and K, and with 0.5% La to compensate for Ca and Mg. Nitrogen was determined on a separate sample by the Kjeldahl modification for auto-analyzer[19].

Corm cores were taken for analysis. The remainder of corms were divided for cooking tests. One half was baked at 325° for 1.5 – 2 hours and the other steamed 1.5 hours to 200–210° F internal temperature for ½ hour.

Difference and preference tests[11] had been previously tried using Hawaiian taros on a panel of Pacific Islanders and Caucasians. The earlier questionnaire was modified to include colour, smell, taste, flavour, fibrousness and hardness.

Data were analyzed as though the treatments had been given in a complete randomized design. Means were compared by Duncan's multiple range test[5]. Linear and some multiple regression analyses were carried out using a Wang 700 calculator. The University of Hawaii Computer Center's programme for multiple regression with transgeneration[4] was used, checking F values for significance. Analysis of co-variance[3] was applied to growth data with weekly change.

RESULTS AND DISCUSSION

Growth measurements

Total K uptake could be described on the basis of a ln-ln relationship with number of changes of solution (Fig. 1a). K 'use' per week taken over the first 14 changes, gave highly significant fit to a ln-ln exponential function. Early uptake from the high-K treatment was similar to that from the 'complete' solution, later decreased to a rate similar to that with the medium-K treatment but fially overtook the latter near the end of the treatment period (Fig. 1b).

A double reciprocal function relating total K-use with mean weekly (K^+) produced a significant 'fit' occurring during growth (Fig. 2). Half maximal uptake was calculated on the basis of such relationship to be 0.021 meg./l.

Number of leaves accounted for about 85 percent of the variation Total AA (as indexed at leaf area). Leaf area increased almost linearly with time until the 28th change of solution. Petiole length was significantly associated with the amount of $Ca(OH)_2$ added to the nutrient solution.

Nutrient levels in foliar samples

Leaf K was significantly correlated with leaf nitrate and leaf P over all sampling dates. This may be explained on the basis of K being as either KNO_3 or KH_2PO_4.

Data are presented in Table 3, for example; leaf Ca and Mg were significantly correlated at every sampling date. Leaf Mn was significantly correlated with dry matter.

Leaf K decreased from Complete through High and Medium to Low K when K was sampled at 91 days or 206 days (Table 3). Leaf nitrate decreased from Complete to High to Low K treatment at 91 days, but increased from High to Medium and Low K at 135 days. Leaf P decreased from Low to Medium, High and Complete at 91 days, but increased from Low to Medium and Complete at harvest. Ca decreased from Low to Complete K at 91 days. Leaf total N, Mg and Cu did not differ significantly between K treatments.

Leaf number and area

Leaf number at harvest was significantly affected by K-treatments and related to the concentrations of other nutrients except %P and nitrate.

Leaf area was significantly correlated with dry matter, but accounted for only about 38 percent of the variation in the latter. Petiole fresh weights were significantly correlated with leaf area.

Roots and corm samples

Root Mg was significantly greater for the Low-K and Medium-K than for Complete nutrient treatment. Root K and Ca were highly correlated both with each other and with NO_3. Corm Mg was also significantly higher for low than High and Complete K treatments (Table 2). Concentrations of N, P and K in corms in this experiment were about twice those found by de la Pena and Plucknett[14].

Corm weight was correlated significantly with the Total AA measure of leaf area at changes 12 and 20, but accounted for less than half of the variation. Yield was only significantly correlated with leaf %K at the first sampling date (Fig. 3), but better correlation was obtained for $(yield)^2$ with K.

The specific gravity of corms was highly correlated with corm nitrate, root fresh weight and corm percent dry matter.

Totals

Table 4 presents data on cumulative totals over all sampling occasions of all the measured parameters for the four different K-treatments.

Fig. 1a. Mean Total K-Use to Change 12

Fig. 1b. Mean Total K-Use for the Rest of the Changes for K treatments.

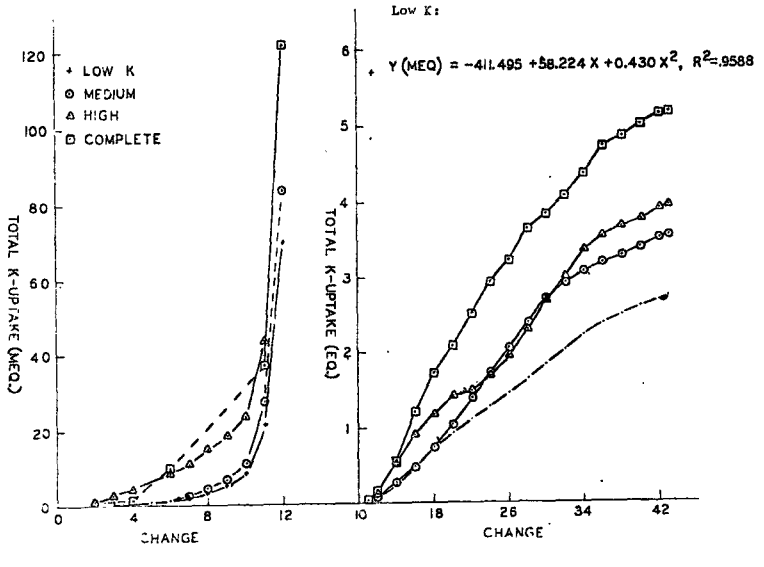


Figure 2. Double Reciprocal Graph of K-Uptake and Solution-K for Replicate 4 of K-Treatments from Changes 12 to 15.

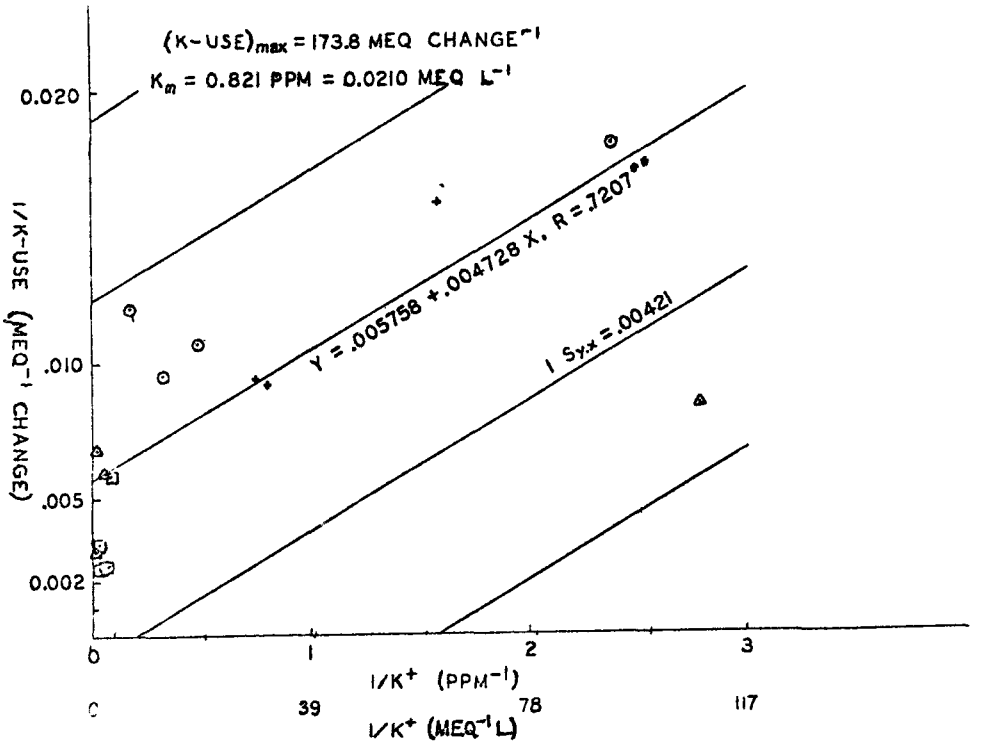
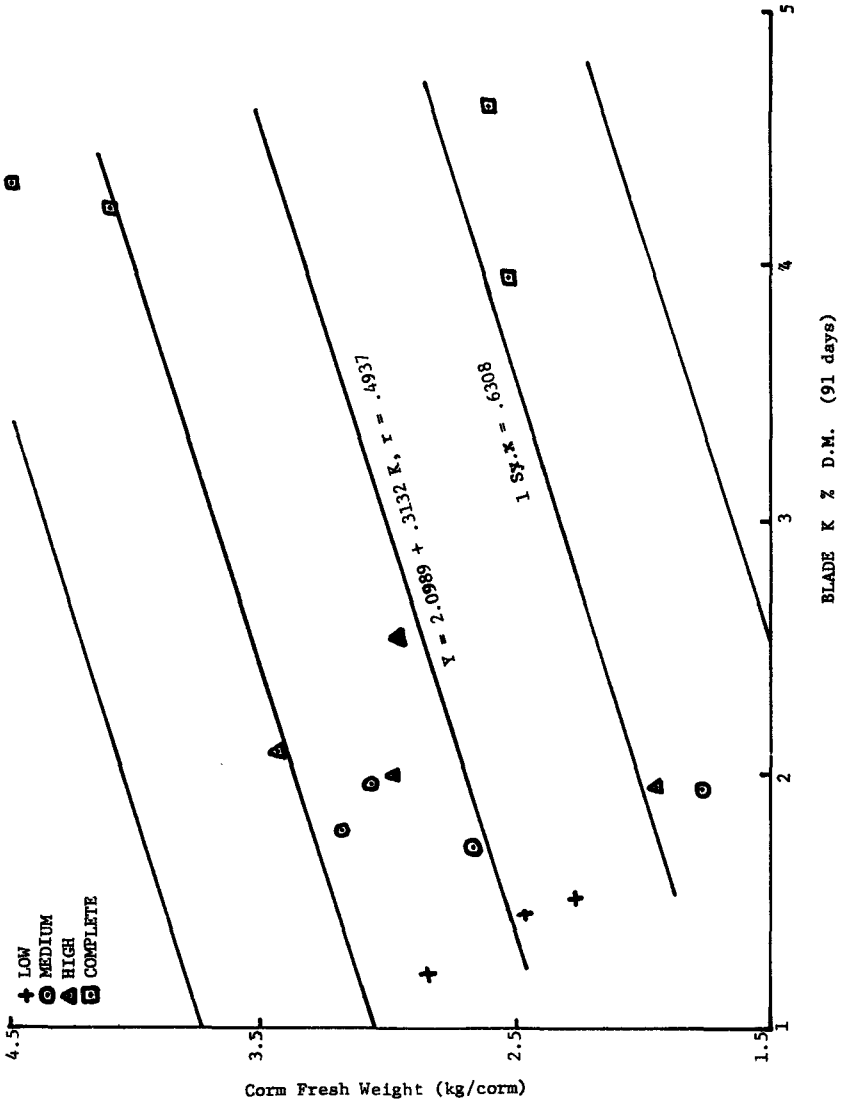


Fig. 3. Corm Fresh Weight with Leaf Blade K % D.M. at 91 days.



Taste testing

Differences were generally as great for coded replicates of corms from complete K treatment as among other treatments either steamed or baked, indicating differences within corms or failure of the tasters adequately to discriminate differences. However, Complete-K (coded but unknown) baked samples were given better colour but poorer taste scores than standard samples, and conversely Low-K baked corms were generally preferred to Complete-K samples. As a steamed food, the Medium-K samples were generally preferred to either Low- or High-K. High-K baked corms may have had better smell but poorer taste than standards.

REFERENCES

1. Cable, W.J. (1973) Report of a field study on taro research in the S. Pacific. I. Cultural factors. SPRCTA, Alafua, W. Samoa.
2. – – – – – (1971) Results of some taro (*C. esculenta* L. Schott) trials. Res. Paper Series No. 9, SPRCTA, Alafua, W. Samoa.
3. Dixon, W.J. (1969) *Biomedical Computer Programs.* X-series supplement. UCLA publications on Automatic Computation No. 3.
4. – – – – – (1970) *Biomedical Computer Programs.* 2nd Ed. revised, UCLA Publications in Automatic Computation, No. 2.
5. Duncan, D.B. (1955) Multiple range and multiple F test. *Biometrics* 11, 1–40.
6. Epstein, E.E. (1966) Dual pattern of ion absorption by plant cells and by plants. *Nature* 212, 1324–7.
7. Gollifer, D.E. (1972) Effect of applications of potassium on annual crops grown on soils of the Dala series in Malaita, Br. Solomon Is. *Trop. Agr., Trin.* 49, 261 f.
8. Hewitt, E.J. (1966) *Sand and water culture methods used in the study of plant nutrition.* 2nd Ed.
9. John, M.K. (1970) Colorimetric determination of phosphate in soil and plant materials with ascrobic acid. *Soil Sci.* 109, 214–20.
10. Kikuta, K and Parris, G.K. (1971) Propagating taro by the normally dormant buds present on hull and corms. *Prog. Notes.* No. 21. HAES.
11. Merck Tech. Bull. (1963) An introduction to taste testing of goods. Fd. Prods. Dept., Merck Chem. Div., Merck & Co., Inc., Rahway, N.J.
12. Millaud, R. (1971) *Taro.* SPC Info. Circ. No. 34.
13. Orion Res. Inc. (1969) Determination of nitrate in plant tissue. *Applications Bull.* Applic. Bull. No. 7.
14. Pena, R.S. de la and Plucknett, D.L. (1967) The response of taro (*C. esculenta* (L.) Schott) to N, P and K fertilization under upland and lowland conditions in Hawaii. Proc. Int. Symp. Trop. Root Crops, Trin. 1(2), 70–85.
15. Plucknett, D.L. and Pena, R.S. de la (1971) Taro production in Hawaii. *World Crops.* 23, 244–9.
16. Reddy, V.B. *et al.* (1968) Note on the relationship between corm yield and certain leaf measurements of taro (*C. esculenta* L. Schott). *Trop. Agr. Trin.* 45, 243–5.
17. Snedecor, G.W. and Cochran, W.G. (1967) *Statistical Methods.* 6th Ed.
18. Spence, J.A. and Ahmad, N. (1967) Plant nutrient deficiencies and related tissue composition of tannia (*Xanthosoma sagittifolium*) Proc. Int. Symp. Trop. Root Crops Trin., 1(2), 61–7.
19. Warner, M.H. and Jones, J.B. (1970) A rapid method for N determination in plant tissue. *Soil Sci. and Plant Anal.* 1(2), 109–14.

TABLE 1

K Treatments

Nutrient Ion	Solution Complete	K Low	Medium	High
NO_3^-	7.5	5.0+.02	+.06	+.20 meq/l
$H_2PO_4^-$	0.5	0.5	0.5	0.5
K^+	3.0	.02	.06	.20
Ca^{++}	2.5	2.75	2.75	2.75
Mg^{++}, $SO_4^=$ each	1.0	1.0	1.0	1.0
	15.5	10.25 meq./l		

TABLE 2

Corm Macro-elements % D.M. at harvest

K	%N	NO_3^-	P	K	Ca	Mg
Low	1.74	.34	.33	1.84	.128	$.100^a$
Medium	1.68	.32	.30	1.94	.055	$.080^{ab}$
High	1.80	.35	.32	2.20	.070	$.074^b$
Complete	1.70	.41	.30	2.30	.053	$.064^b$
	±.42ns	±.40ns	±.24ns	± .5ns	±.16ns	$.025^{*1}$

*1 means significantly different beyond the 5% level throughout this paper; values with the same letter in the superscript are not significantly different (ns).

TABLE 3

Third leaf element concentrations in dry matter at all sampling dates for K treatments

Days		%N	$\%NO_3^-$	%P	%K	%Ca	%Mg	ppm Fe	Mn	Cu	Zn	%SO4-S
91	Low	3.45	.212^{c}	.69^{a}	1.43^{b}	3.2^{x}	.65	87^{bc}	124^{a}	7.3	56^{x}	.135^{x}
	Medium	3.76	.31^{bc}	.40^{b}	1.82^{b}	2.3^{xy}	.50	82^{c}	141^{a}	6.9	51^{xy}	.098^{y}
	High	3.80	.41^{b}	.42^{b}	1.98^{b}	2.2^{xy}	.43	103^{a}	65^{b}	6.2	35^{y}	.091^{y}
	Complete	3.80	.60^{a}	.30^{b}	4.28^{a}	1.4^{y}	.27	95^{ab}	134^{a}	5.8	36^{y}	.066^{z}
		+.67ns	±.19*	±.23*	± .65*	±1.4*	±.32ns	±12*	± 42	±1.7ns	±17*	±.017*
		3.70^{c}	.38^{ab}	.45	2.38^{c}	2.3^{a}	.46	92	116^{a}	6.6	44	.098
135	Low	3.92	.55^{a}	.44	4.3	1.01	.103	69	38	6.1	30^{b}	
	Medium	4.40	.56^{a}	.44	4.0	1.06	.106	65	43	5.9	68^{ab}	
	High	3.96	.26^{b}	.33	4.0	1.05	.098	53	36	6.2	95^{a}	
	Complete	4.46	.51^{ab}	.43	4.8	.84	.087	108	43	6.1	43^{b}	
		+.74ns	±.26*	±.12ns	± .88ns	± .65ns	±.062ns	±46ns	±32ns	±2.0ns	±39*	
		4.18^{b}	.47^{a}	.42	4.2^{a}	0.99^{b}	.098^{d}	74	40^{b}	6.1	59	
206	Low	4.09	.35	.36^{ab}	3.0^{b}	1.14	.117	83	45	7.4	37^{ab}	
	Medium	4.17	.39	137^{ab}	3.8^{ab}	.95	.102	85	45	7.1	31^{b}	
	High	4.05	.44	.34^{b}	3.7^{ab}	.94	.102	71	45	7.6	32^{b}	
	Complete	4.16	.53	.48^{a}	4.5^{a}	1.03	.114	74	43	6.8	47^{a}	
		+.94ns	±.29ns	±.13*	±1.3*	± .50ns	±.046ns	±20ns	±21ns	±2.7ns	±11*	
		4.12	.43	.39	3.8^{ab}	1.02^{b}	.109^{cd}	78	44^{b}	7.2	37	
								±46ns	±61*	±1.4ns	±55ns	
259	Low	4.27	.20	.45	3.8	2.6	.32					
	Medium	4.10	.21	.44	4.1	2.4	.23					
	High	4.36	.32	.50	5.0	1.8	.24					
	Complete	4.56	.31	.44	5.1	2.1	.26					
		+.80ns	±.19ns	±.08ns	±2.1ns	±.6ns	±.17ns					
		4.32	.26	.46	4.5^{a}	2.2^{a}	.28^{b}					
301-4	Low	4.62	.208	.51^{a}	3.2	2.12	.28					
	Medium	6.90	.160	.37^{a}	2.7	1.66	.25					
	High	4.88	.224	.36^{ab}	2.9	1.49	.21					
	Complete	4.88	.125	.31^{b}	2.6	1.12	.22					
		+.60ns	±.093ns	±.06*	±1.4ns	± .15ns	±.15ns					
		4.82^{a}	.18^{b}	.36	2.8^{bc}	1.6^{ab}	.24					
		±.36*	±.22*	±.16ns	±1.4*	± .81*	.14*					

TABLE 4

Totals of K treatments

Total	Low K	Medium K	High K	Complete K	LDs
Leaf weight, kg/plant	0.506	.63	.492	.45	ns
Petiole weight, kg/plant	2.53	2.77	2.24	2.14	ns
Sett weight, kg/plant	2.18	2.80	2.31	2.15	±.77ns
Root weight, kg/plant	0.90	.76	.67	.56	ns
Corm weight, kg/plant	2.38	2.69	2.85	3.4	±1.6ns
Total weight, kg/plant	8.50	9.6	8.56	8.8	ns
Ratio (top/corm)	2.66	2.09	2.14	1.63	±1.7ns
% Corm	28.4	28.1	30	39.4	ns
Leaf D.M., g/plant	459	467	479	510	±190ns
L.A.I.	2.57^{ab}	3.47^{a}	2.60^{ab}	1.99^{b}	±1.1*
Leaf production,days/leaf	7.34	7.16	6.99	7.07	±.40ns
Number of petioles	39	38.5	41	42	±9.3ns
Suckers	30.8	36.2	46	64	±41ns
Corm D.M., g.	540	620	570	640	ns
Water, L.	810	840	800	890	±290ns
Water use, l./kg	345^{y}	320^{xy}	287^{xy}	264^{x}	±59*DMRT
K-use, g./plant	106^{c}	136^{bc}	157^{b}	204^{a}	±34*
Nitrate-use, g./plant	64.8^{b}	74.2^{ab}	74.9^{ab}	89.7^{a}	$\pm 8.4^{**}$
P-uptake, g./plant	8.4^{b}	9.1^{b}	7.8^{b}	12.7^{a}	3.1*
% leaves	5.92	6.67	5.72	5.15	ns
% petioles	29.7	28.7	26.1	24.1	ns
% sett weight	25.7	29.4	26.9	24.9	ns
%roots	9.2	7.93	7.9	6.4	ns
Corm % D.M.	22.4	22.7	1919	19.3	ns
Sp.Gr.	.902	.888	.893	.881	ns