Table 5. Snapbean and tomato plant growth and Mn composition as affected by $MnSO_4$ and MnEDTA band treatments, Experiment 4.

Mn rate in band	Source	Bean Mn content	Bean Dry weight	Tomato Mn content	Tomato Dry weight
mg/ft		ppm	mg	ppm	mg
0		39	928	38	438
10	MnEDTA	52	1088	35	385
10	$MnSO_4$	65	1068	46	412
20	MnEDTA	62	562	30	358
20	$MnSO_4$	85	1015	54	378
40	MnEDTA	68	370	60	178
40	$MnSO_4$	78	1000	45	382
LSD p = 5%			233		72

the range of rates that did not affect the tomato growth was not as effective a source of Mn as was $MnSO_4$.

In the several experiments reported which were run over a period of one year in the greenhouse, manganese treatments were evaluated on a soil that in the field caused beans to exhibit moderate to severe deficiency symptoms. The general recommendations for correcting deficiency are 10 to 20 lb. available Mn/A as $MnSO_4$ or 1 to 2 lb. available Mn/A as MnEDTA or Rayplex-Mn. These recommendations would correspond to the band rates of 100 to 200 mg Mn/ft of row as $MnSO_4$ or 10 to 20 mg Mn/ft of row as MnEDTA or Rayplex-Mn. According to the experiments reported here, the $MnSO_4$ would be much more effective at these relative rates than the organic Mn sources. Mn was not absorbed from MnEDTA at the general recommended rate in Experiment 1 and so the rate was increased in Experiment 2 in an attempt to determine if the Mn was available to the plant from the MnEDTA source. Rates above 25 mg Mn/ft of row as MnEDTA did not increase Mn content of the plant and were toxic to the point of being lethal to the plant. The toxicity appeared to be due to EDTA since $MnSO_4 + Na_2EDTA$ caused the same effect whereas plants that received $MnSO_4$ alone were healthy.

The inorganic and organic carriers, $MnSO_4$ and Rayplex-Mn, released Mn to the plant with equal effectiveness such that there does not appear to be any justification for the general recommendation of a 10 to 1 available metal bias in favor of the organic carriers.

Literature Cited

1. DeKock, P. C., and R. L. Mitchell. 1967. Uptake of chelated metals by plants. *Soil Sci.* 84:55–62.
2. Fiskel, J. G., and G. A. Mourkides. 1955. A comparison of manganese sources using tomato plants grown on marl, peat and sand soils. *Plant and Soil.* 6:313–331.
3. Nylund, R. E. 1952. The response of onions to soil and foliar applications of manganese and to soil applications of other trace elements. *Proc. Amer. Soc. Hort. Sci.* 60:283–285.
4. Rumpel, J., A. Kozakiewicz, B. Ellis, G. Lessman, and J. Davis. 1967. Field and laboratory studies with manganese fertilization of soybeans and onions. *Mich. Agr. Exp. Sta. Quart. Bul.* 50:4–11.
5. Shepherd, L., K. Lawton, and J. F. Davis. 1960. The effectiveness of various manganese materials in supplying manganese to crops. *Soil Sci. Soc. Amer. Proc.* 24:211–218.
6. Wallace, A. 1962. A decade of synthetic chelating agents in inorganic plant nutrition. Edwards Brothers. Ann Arbor, Michigan.

Effects of Potassium Nutrition on Growth and Cation Content of Potato Leaves and Tubers Relative to Plant Analysis[1]

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Abstract. Potato plants were grown outdoors in pots containing Alvolite, a low K material, under low and high K conditions. The blades of recently matured leaves were relatively constant in K concentration, whereas the petioles changed rapidly with growth and K supply. Sodium was largely excluded from the leaf tissue while Ca and Mg were higher with low K supply. Tubers under high and low K nutrition changed only from about 2.0 to 1.3% K, respectively, and the values of Na, Ca, and Mg were very low, ranging from only 0.06 to 0.30%. Therefore, an analysis of tubers is not useful in plant analysis.

The degree of K deficiency can be estimated by following the rate of K decline in reference to the K critical level of 2.3% for the petiole and 1.1% for the blade tissues as illustrated by present results and of a field experiment.

Introduction

A plant physiologist often uses the water-culture technique to determine the nutrient requirements of plants (1, 2), whereas a horticulturist often uses the results of field tests for the same purpose (5). Quite often there is difficulty in reconciling results from nutrient solutions with field usage. In these instances, an intermediate study may be useful, such as a controlled pot test, to bridge the gap between water-culture results and those of the field.

Fong and Ulrich (2) determined the critical K level of potato plants to be 2.3% for the petiole and 1.3% for the blade tissues of a recently matured leaf for plants grown in water culture with stolon and tubers removed. In the present study, tubers were retained in an open pot solution culture experiment, using Alvolite, a low K material, and the daily watering with nutrient solutions. Results for a low and high-K series, relative to plant analysis concepts, are reported in this paper.

Materials and Methods

Potato plants, *Solanum tuberosum*, L. var. 'White Rose,' were grown outdoors in 5-gal pots containing Alvolite. Four plants, 4–6 inches tall, were transplanted to each of 24 pots on May 9. Thereafter, 12 pots were watered daily with a minus K solution of the following composition in millimoles per liter: 3.75 $Ca(NO_3)_2 \cdot 4H_2O$; 0.5 NaCl; 1.0 $NaH_2PO_4 \cdot H_2O$ and 1.0 $MgSO_4 \cdot 7H_2O$. Another 12 pots were watered daily with a high K solution of the following composition in millimoles per liter: 2.5 $Ca(NO_3)_2 \cdot 4H_2O$; 0.5 KH_2PO_4; 2.5 KNO_3; 1.0 $MgSO_4 \cdot 7H_2O$ and 0.5 NaCl. Both solutions contained microelements in mg per liter; 0.25 B, 0.25 Mn, 0.025 Zn, 0.01 Cu, and 0.005 Mo. Iron (2.5 mg per liter) was added as ferric-sodium ethylenediamine tetraacetate complex (3).

Leaf samples from only 2 of the 12 pots of each treat-

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ment were collected successively in rotation at approximately weekly intervals starting 17 days after transplanting. The second leaf below the flat top, also referred to as a recently matured leaf, was selected and separated into the blade and petiole-rachis tissues, with the latter designated as the petiole (1, 2). When the plants were relatively small, the leaf samples were taken from the main shoot. One leaf from each of the 4 plants in a pot was collected and combined to form a single blade or petiole sample. When the plants were too large to identify the main shoot, leaf samples were taken from the axillary shoots. Starting with the 66th day, 8 leaves from a pot of a treatment were taken and combined to form a single petiole or blade sample. The plants were harvested on September 13, 127 days after transplanting. All samples were dried at 70°C. The potato tubers were classified according to size, diced and dried at 70°. All plant material after drying was ground in a Wiley Mill to pass a 40 mesh screen.

The leaf and tuber samples were ashed by the alcoholic sulfuric acid method (4). Potassium, Na and Ca were analyzed by flame photometry. Magnesium was analyzed by atomic absorption. Strontium chloride was added to all solutions at 2200 ppm to eliminate interference.

Results

The results of the leaf analyses for the second leaf below the flat top are given in Tables 1 and 2 for the blade and petiole tissues, respectively. The K concentrations of the leaf tissues in relation to time and K supply are given in Fig. 1. With high K supply, both the petiole and blade tissues are well above the corresponding critical K value, 2.3% for the petioles and 1.1% for the blades (1,2). During the growth period, the K concentrations in the blades are relatively constant in comparison with the petioles. The blades remained at about 3.0% K after declining from 4.0% while the petioles varied from 7.5% to 5.5% after declining from about 10%. Thus, it appears, that petioles vary more in K concentration than the blades and therefore may serve as a sensitive indicator of the K status of the plant.

When the pots were watered with a minus K solution, the plants became K deficient after about 3 weeks of growth. This indicates that the K provided by the seed piece and the Alvolite was not enough for normal plant growth. The leaf analyses indicated that the plants were K deficient starting with the samples taken after the 24th day, at which time, both the petiole and blade tissues were below their critical K value. On the 73rd day there was a rise in K concentration, and this was associated with the taking of leaf samples primarily from the lateral shoots because the main shoot could not be identified easily. These leaves were not as deficient in K because of probable retranslocation of K to the laterals from the dying main shoot. However, this increase was followed quickly by a decrease to the earlier K value of about 0.5%. Thereafter, K remained at this value until

Table 1. Cations in blade tissues of the second leaf.

Days after transplant	High potassium[a]				Low potassium[a]			
	K %	Na %	Ca %	Mg %	K %	Na %	Ca %	Mg %
17	3.65	0.07	2.21	0.54	0.95	0.04	3.23	0.65
24	3.95	0.07	2.14	0.56	0.77	0.03	3.14	0.96
31	2.78	0.04	1.57	0.52	0.71	0.04	2.69	1.05
38	2.64	0.03	1.55	0.57	0.72	0.05	3.03	0.89
44	2.73	0.04	1.57	0.63	0.58	0.03	2.93	0.90
52	2.71	0.06	1.85	0.68	0.51	0.05	2.95	0.97
66	2.82	0.05	1.82	0.67	0.53	0.02	2.31	0.85
73	3.30	0.03	2.03	0.68	1.20	0.01	2.06	0.87
80	3.00	0.04	2.40	0.71	0.89	0.02	2.46	0.90
87	2.95	0.03	1.70	0.67	0.67	0.02	2.57	0.86
94	2.95	0.02	1.85	0.82	0.67	0.02	2.13	0.83
104	3.05	0.03	2.29	0.96	0.59	0.02	2.36	0.85
112	3.00	0.04	2.18	0.99	0.41	0.03	2.46	0.85
127	2.93	0.08	2.64	0.91	0.44	0.05	2.74	0.99

[a]All values are mean of 2 replications except at 127 days which consists of 11 replications (dry weight basis).

Table 2. Cations in petiole tissues of the second leaf.

Days after transplant	High potassium[a]				Low potassium[a]			
	K %	Na %	Ca %	Mg %	K %	Na %	Ca %	Mg %
17	8,70	0.15	2.25	0.54	2.67	0.10	3.29	1.22
24	10.00	0.10	2.04	0.53	2.00	0.07	3.38	1.56
31	8.60	0.16	1.75	0.52	1.85	0.07	3.29	1.67
38	6.90	0.10	1.67	0.55	1.25	0.10	3.59	1.71
44	6.10	0.06	1.67	0.68	0.92	0.06	3.08	1.57
52	6.70	0.12	1.75	0.54	0.68	0.04	3.09	1.81
66	6.80	0.11	1.67	0.66	0.60	0.03	2.84	1.78
73	8.00	0.14	2.00	0.49	1.66	0.02	2.67	1.94
80	7.50	0.07	1.59	0.55	1.88	0.03	3.09	1.49
87	7.20	0.08	1.25	0.31	1.06	0.03	3.00	1.51
94	6.80	0.13	1.00	0.28	0.75	0.02	2.71	1.44
104	6.30	0.09	1.01	0.40	0.53	0.03	2.25	1.30
112	5.37	0.13	0.81	0.40	0.61	0.03	2.79	1.53
127	5.51	0.11	1.11	0.80	0.53	0.03	2.28	1.58

[a]All values are means of 2 replications except at 127 days which consists of 11 replications (dry weight basis).

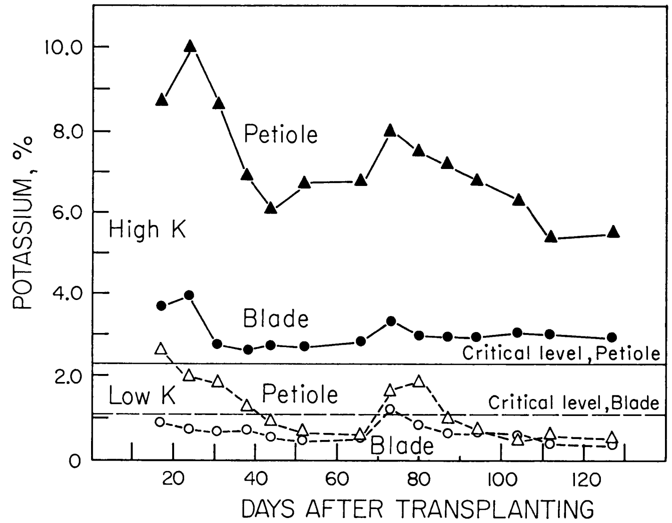

Fig. 1. Effect of K nutrition on petiole and blade K percentages (dry basis) for the recently matured leaf. Leaf samples were taken at approximately weekly intervals from 17 days after transplanting to 127 days at harvest.

Fig. 2. Comparison of potato plants from low K (at left) and high K treatments (at right). The leaves for the low K plants are bronzed and are dying prematurely. The plants with high K are still green and growing.

Table 3. Cations, specific gravity and dry weight in potato tubers.

Tuber size[b] g	High potassium[a] K %	Na %	Ca %	Mg %	Specific gravity	Dry weight %	Low potassium[a] K %	Na %	Ca %	Mg %	Specific gravity	Dry weight %
0–10	2.23	0.11	0.30	0.11	1.043	13.7	1.24	0.10	0.23	0.09	1.039	12.2
11–20	2.23	0.10	0.20	0.11	1.040	12.8	1.21	0.09	0.18	0.08	1.041	12.8
21–30	2.32	0.11	0.19	0.13	1.039	14.7	1.25	0.08	0.15	0.08	1.043	13.0
31–40	2.16	0.08	0.15	0.10	1.051	15.9	1.35	0.09	0.16	0.08	1.043	13.1
41–60	2.01	0.07	0.13	0.09	1.050	14.5	1.36	0.09	0.14	0.08	1.045	12.7
61–80	1.88	0.06	0.11	0.09	1.056	15.1	1.27	0.08	0.12	0.07	1.044	13.7
81–100	1.88	0.07	0.11	0.08	1.056	14.8	1.30	0.05	0.15	0.07	1.045	13.9
101–140	1.80	0.07	0.11	0.08	1.053	14.1						
141–180	1.78	0.07	0.10	0.08	1.057	15.0						
181–220	1.94	0.07	0.11	0.09	1.053	14.7						
221–260	1.96	0.07	0.12	0.09	1.052	14.6						
261–300	2.01	0.07	0.12	0.10	1.052	14.3						
301–340	2.04	0.07	0.13	0.09	1.053	15.0						
341–380	1.85	0.08	0.12	0.09	1.057	15.5						
381–460	1.90	0.06	0.12	0.09	1.056	14.9						
461–540	1.80	0.07	0.10	0.10	1.059	16.2						
r	−0.56	−0.52	−0.52	−0.28	0.65	0.52	0.46	−0.83	−0.73	−0.90	0.85	0.88

[a]All values are means of 12 replications.
[b]Not all sizes are present in each pot.
[r]Correlation coefficient.

the end of the growth period, at which time all leaves were dying and turning brown except for some young leaves on the flat top. In contrast, the leaves on the high K plants remained green, although there were some signs of deterioration (Fig. 2).

Sodium in the blade and petiole tissues was in all cases very low in concentration and, thus, mainly excluded from the potato leaves. Calcium concentration was high in all cases but especially high with low K supply. Magnesium was moderately high in all cases, being only slightly higher in low K blades and much higher in the corresponding low K petioles. These values are considerably above their critical levels and indicate that some cation interactions have taken place. This is a case in which when the monovalent cations are low, divalent cations tend to be higher.

The results of specific gravity, dry weight, and cation analysis for the tubers are given in Table 3. No large differences were observed in specific gravity and dry weight. Potassium concentration in the high K tubers was about 2.0% while in the low K tubers it was about 1.3%. Sodium, Ca and Mg were low in all cases, ranging from 0.06 to 0.30%, with the highest values occurring in the very small immature tubers of the high K plants. These low values and small differences indicate that tuber analyses are not useful diagnostically in plant analysis.

The tuber yield in the low K pots was only 494 g/pot while in the high K pots the yield was 3450 g/pot (Table 4 and Fig. 2, 3). Tubers for the low K plants were under 100 g each while some of the tubers for the high K plants were as large as 514 g (Fig. 3). The K values for the leaves indicated that a drastic reduction in yield was to be expected for low K plants since the leaves were K deficient for almost the entire growth period (Fig. 1). The fresh and dry weights of the tops with low K supply were decreased to one half and the tubers to one-seventh of high K supply. Hence the potato tuber yield was affected much more than top growth.

Table 4. Harvest yield – 127 days after transplanting.[a]

Treatment no.	Fresh[b] weight top, g	Dry[b] weight top, g	Dry[b] weight top, %	Fresh weight tubers, g
High K	1770	318	18.0	3540
Low K	920	188	20.5	494
	*	*	NS	*

[a]All values are means of 12 replications.
[b]Leaves sampled or lost during growth period were not included.
*Significance at 5% level.
NS No significance.

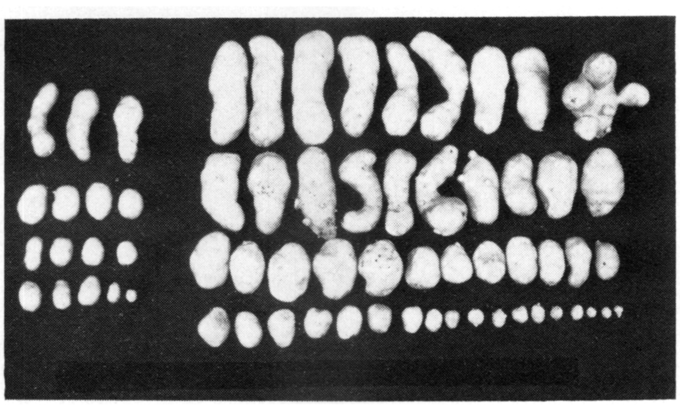

Fig. 3. Comparison of tubers from plants with low K (at left) and high K treatments (at right). The shape of the tubers was abnormal with high K due to over-crowding in the 5-gal pots.

Discussion

Sampling petioles at weekly intervals gives the K status of the potato plant at the time of sampling. When these

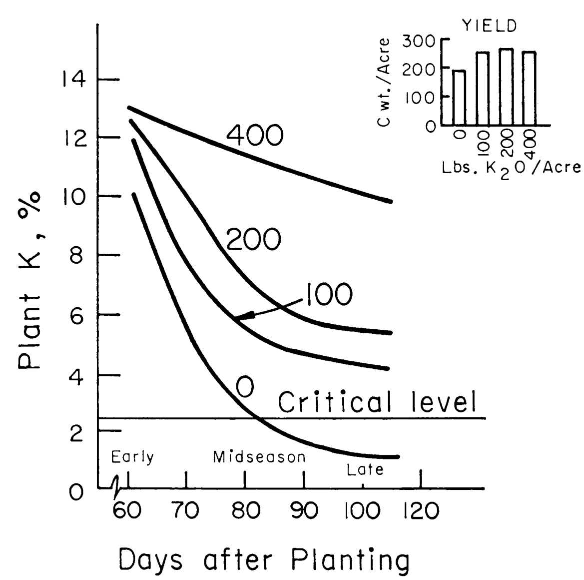

Fig. 4. Petiole K levels and tuber yields of 'White Rose' potatoes fertilized with 4 rates of K. Redrawn of field experiments from Tyler, Lorenz and Fullmer (5).

results are compared to the critical concentration, the relative degree of deficiency for the crop can be estimated for the growing season just completed. Fig. 4 gives an application of this concept to the field experiments of Tyler *et al.* (5). They found that when no fertilizer was applied, the potato plants were K deficient at about 85 days after planting and hence the tuber yield was decreased. With the application of K in the field, all petiole values were above the critical level and hence no yield differences were observed.

In the use of plant analysis as a guide to crop production, Tyler *et al.* (5) recommended a declining critical level instead of a constant reference critical concentration (6). Their declining critical level concept can be illustrated from their field plot study where all the fertilizers were applied at the beginning of the season and only one sample is to be collected at early midseason for analysis from the growing crop. The results of this sampling anticipate the K supply to the plants and the yield of potato tubers at harvest. The accuracy with which this sampling anticipates the K value at harvest depends on the time of sampling and the rate of change of K in the plant to harvest. This rate of change of K in the plant to harvest depends on the weather and soil type, which cannot be predicted accurately by present technology. The average effects of climate can, however, be established by taking a series of plant samples from many fields for a reasonable number of seasons in a cropping area. If cropping practices, climate and soils are relatively constant, then a single sampling will have a high predicative value, but in non-uniform areas, the declining slope of critical values will change from season to season and from soil type to soil type and more samplings will therefore be necessary to establish the nutrient trends of the crop for the growing season. In essence, the 2 sampling programs are compatible and compliment each other.

Literature Cited

1. Fong, K. H. 1962. Potassium nutrition of White Rose potato in relation to growth and to potassium, calcium, magnesium and sodium in leaf and root tissues. M.S. thesis University of California, Berkeley, Calif.
2. Fong, K. H., and A. Ulrich. 1969. Leaf analysis as a guide for potassium nutrition of potato. *J. Amer. Soc. Hort. Sci.* 94:341–343.
3. Jacobson, L. 1951. Maintenance of iron supply in nutrient solutions by a single addition of ferric potassium ethylenediamine tetraacetate. Plant Physiol. 26:411–413.
4. Johnson, C. M., and A. Ulrich. 1959. Analytical methods for use in plant analysis. *Calif. Agr. Exp. Sta. Bul.* 766.
5. Tyler, K. B., O. A. Lorenz, and F. S. Fullmer. 1961. Plant and soil analysis as guides in potato nutrition. *Calif. Agr. Exp. Sta. Bul.* 781.
6. Ulrich, A., and F. J. Hills. 1967. Principles and practices of plant analysis. In: Soil testing and plant analysis. Part II. Plant analysis. SSSA Special Publication No. 2. Soil Science Society of America, Inc., Madison, Wisconsin.

Staking and Pruning Young *Myoporum laetum* Trees

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Abstract. The ability of young *Myoporum laetum,* Forst. f. trees to stand by themselves was improved by neither staking nor pruning them during their first 2 years in the landscape. Omitting these practices resulted in: 1) larger trunks at the ground, 2) trunks with greater taper, and 3) shorter tops. Taper of the trunks increased as the trees became older.

Introduction

Since young trees in the landscape are often slow in being able to stand upright and are frequently deformed by wind, almost all young trees in California urban plantings are staked. However, staking appears to create as many problems as it overcomes. Trunk and limbs may be injured and made unattractive by rubbing against the stake, tree ties may girdle the trunk, and the entire top may be lost if the stake or ties break.

Leiser and Kemper (5) have shown that the stress per unit cross-sectional area of the trunk increases as the height of staking rises from the ground level to within 12–18 inches of the tree top. The main leader may be severely deformed as a young tree grows above the top of the stake.

Restricting the tree tops from swaying greatly impaired the ability of Monterey pine, *Pinus radiata,* to withstand the elements. Jacobs (3) guyed the trunks of 2 trees in each of 74 matched 3-tree sets of 16-year-old Monterey pine. In the first year after guying, trunk diameter increased 83% as much in guyed trees as in trees which were free to sway. By the fifteenth year, the guyed trees had made only 52% as much trunk growth as the free-swaying trees but grew taller. In the first wind after the guy wires were removed, all trees that had been guyed broke or blew over. None of the other trees was lost.

Leaving branches along the trunk has been recommended by many (1, 4, 7) to protect and speed development of the trunk.

Young landscape trees might withstand the elements and other hazards better if grown without staking or pruning. The response of an evergreen tree species to certain staking and pruning practices is reported here.

Materials and Methods

The experiment was located at a future park site in Fremont in the San Francisco Bay Area. During March through September, the prevailing winds average 9 to 10 mph from the west and north-west. Afternoon wind velocities of 15 to 25 mph are common.

The soil is described as Yolo clay loam to Yolo clay. It is compact, inclined to crack, and high in alkali. To provide surface drainage for planting, the soil was graded into 2′-high gentle-sloping ridges. Forty trees of *Myoporum laetum,* Forst. f. were planted on the ridges 20 ft apart in May 1965.

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