Leaf Analysis as a Guide for Potassium Nutrition of Potato[1,2]

Kwok H. Fong and Albert Ulrich,
University of California, Berkeley

Abstract. "White Rose" potato plants were grown in modified Hoagland's solution at concentrations of 0 to 16 meq/l of K. After 32 days of growth, 16 plant parts were taken for analysis. The K status of the potato plant was reflected best by the second leaf below the flat top (Fig. 1). This leaf was the recently matured leaf of the plant, was relatively easy to sample, and did not differ greatly in K concentration from the first, third, and fourth leaves. The critical K value at a 10% reduction of growth was 2.3% for the petiole tissues and 1.1% for the blade tissues.

Introduction

Potato plants in the production of tubers remove a substantial amount of K from the soil. To insure a high yield of tubers, K must often be increased in the soil by the addition of K fertilizers. A leaf analysis program would be helpful to determine the most effective amount and time of fertilization. Such programs have been used successfully for many crops including potatoes (6). The objective of this paper is to develop the leaf sampling program for potatoes more fully and to estimate more precisely the critical level indicative of K deficiency at the time of sampling (8). The resulting information should serve as a better guide for the diagnosis of the K status of the potato plant (7).

Materials and Methods

Potato plants, *Solanum tuberosum*, L., were grown outdoors by the water culture technique (3). Vegetative growth, without tuber formation, was studied by pinching off the stolons as they developed (2). Plants were obtained from cut tubers of certified 'White Rose', sprouted in Alvolite (exploded volcanic sand) and watered daily with a minus K nutrient solution. After 3 weeks, uniform plants 7 to 10 inches in height, were selected at random for transplanting into pots containing 20 liters of culture solution of the following composition, expressed in millimoles per liter: 3.75 $Ca(NO_3)_2 \cdot 4H_2O$, 0.5 NaCl, 1.0 $NaH_2PO_4 \cdot H_2O$, 1.0 $MgSO_4 \cdot 7H_2O$ and 0.25 $Na_2SiO_3 \cdot 9H_2O$. Micro-elements in mg per liter were: 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 the ferric-sodium ethylenediamine tetraacetate complex (4). A second addition of these salts was added 12 days after transplanting. Potassium was supplied as K_2SO_4 in 9 treatments ranging from 0 to 16 meq/l (Table 1), i.e., 0 to 12.51 g/pot (Table 2).

After 32 days of growth, the plants were harvested on July 7. Five categories of leaves were taken from the main shoot for tissue analysis. The immature leaf was the oldest leaf on the flat top. Using this leaf as a reference and going down the main axis, the first, second, third, and fourth leaves were identified and selected (Fig. 1). Each leaf was separated into three parts: terminal blade, lateral blades, and petiole-rachis which has been designated as the petiole. The fibrous roots were rinsed in distilled water, wrapped in cheese cloth, and centrifuged for 5 min at 39 × g to remove excess water.

The plant parts were dried in a forced draft oven at 80°C, weighed and then ground in a Wiley mill to pass a 40 mesh screen. Samples weighing less than 200 mg were ground in an oscillatory ball mill (Wig-L Bug Triturator, Crescent Dental Manufacturing Co., Chicago, Illinois). The plant samples were ashed by the sulfuric acid procedure (5). Potassium was determined by flame photometry.

Statistical analyses were performed with the computer (CDC 6400) using "Biomedical Computer Programs" (1). BMDO7V (Multiple Range Tests) and Duncan's values at the 5% level of significance were used for the separation of means. BMDO2R (Stepwise Regression) was used for the calculation of linear regressions and correlations.

Results and Discussion

At the time of transplanting, the seedlings appeared to be slightly K deficient. After transplanting into the culture solution, all seedlings grew well until the K supply became limiting at the lower treatments. Thereafter, the symptoms appeared progressively on the plants at

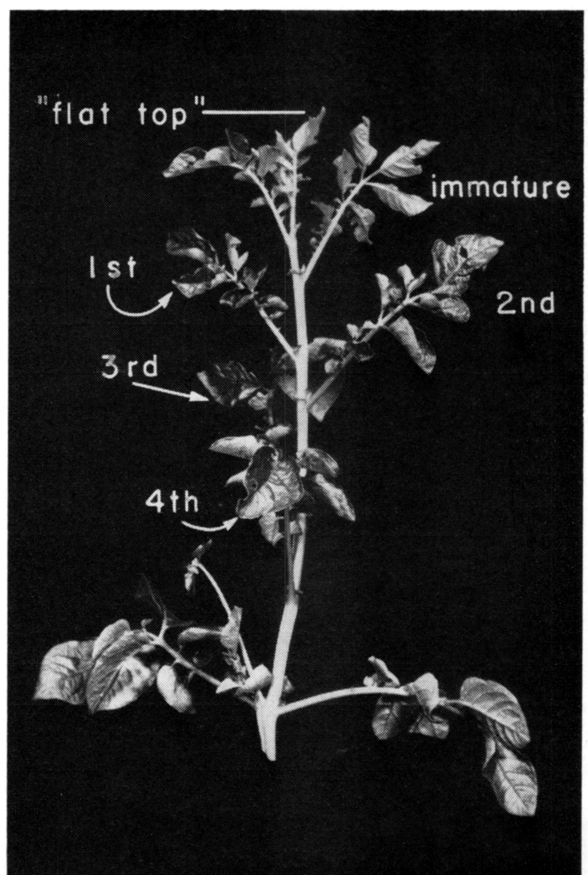

Fig. 1. Potato leaf sample identification. The immature leaf is the oldest leaf on the flat top. The second leaf is referred to as the recently matured leaf.

[1]Received for publication August 27, 1968. Department of Soils and Plant Nutrition.
[2]We gratefully acknowledge the Grant-in-Aid from the American Potash Institute.

approximately one treatment per 5 day interval. After 32 days of growth, treatment one showed very severe symptoms of K deficiency, treatments 2 and 3 showed severe symptoms, treatment 4 showed moderate symptoms, treatment 5 showed mild symptoms, and the last 4 treatments were without symptoms.

The effects of K supply on the growth of the potato plant are given in Table 1. The fresh and dry weights were small when K was a limiting factor and these values increased up to treatment 6 with increased K supply. The corresponding ratios of tops to roots followed the same pattern. But, the dry weight percentages of tops were higher at the lower levels of K supply, which agrees with the visual fact that these plants contained leaf scorch typical of K deficiency. However, the dry weight percentages of the fibrous roots were not affected.

The results of the K analysis for the leaves and roots are given in Tables 2 and 3. Potassium percentages increased in the tissues with increased K supply. The

Table 1. Effect of potassium supply on fresh weight and dry weight of potato tops and roots.[x, y]

Treatment no.	K (meq/1)	Fresh weight			Dry weight				
		Tops (g)	Roots (g)	Tops/roots	Tops (g)	Roots (g)	Tops/roots	Tops (%)	Roots (%)
1........	0.00	184	92	1.99	30	5.0	5.87a	16.1	5.43a
2........	0.25	369	159	2.32	52	7.7	6.79ab	14.1a	4.83b
3........	0.5	499	191	2.64	65	9.7a	6.84ab	13.1ab	5.08ab
4........	1.0	626	214a	2.92a	77	10.7a	7.24b	12.3b	4.99ab
5........	2.0	738	230a	3.21b	94	12.2b	7.70b	12.6b	5.30a
6........	4.0	860a	264b	3.26b	103a	13.4bc	7.70b	12.0b	5.08ab
7........	6.0	849a	272b	3.13ab	108a	14.7c	7.52b	12.8b	5.37a
8........	8.0	892a	270b	3.31b	107a	14.2c	7.58b	12.0b	5.25ab
9........	16.0	885a	281b	3.15ab	108a	14.0c	7.79b	12.3b	4.98ab

[x]All values are means of 5 replications.
[y]Means with a common letter are homogeneous subsets at the 5% level.

highest K percentage obtained was 9.8% in the petiole tissues and 4.6% in the blade tissues. A constant K percentage of about 0.4% remained in the petiole and blade tissues when the leaves showed the most severe symptoms. When the plants were K deficient, the younger leaf tissues contained a higher K concentration than the

Table 2. Potassium (%) in potato petiole and root tissues.[x, y]

Treatment no.	K (g/Pot)	Petiole					Fibrous roots
		Immature leaf	First leaf	Second leaf	Third leaf	Fourth leaf	
1............	0.00	0.50a	0.37a	0.35a	0.32a	0.35a	0.55a
2............	0.20	0.75ab	0.39a	0.32a	0.30a	0.33a	0.63a
3............	0.39	1.13b	0.64a	0.44a	0.38a	0.38a	0.54a
4............	0.78	2.43c	1.68b	1.15	0.80	0.76a	0.54a
5............	1.56	2.88c	2.08b	1.84	1.67	1.79	0.53a
6............	3.13	3.72	3.36	3.26	3.42	3.78	0.83a
7............	4.69	4.81	5.14	5.56	5.81	6.04	1.79
8............	6.26	6.25	7.00	7.29	7.36	7.42	4.23
9............	12.51	7.26	8.09	8.50	8.64	8.31	6.10

[x]All values are means of 5 replications on the dry weight basis.
[y]Means with a common letter are homogeneous subsets at the 5% level.

Table 3. Potassium (%) in potato terminal and lateral blade tissues.[x, y]

Treatment no.	Terminal blade					Lateral blade				
	Immature leaf	First leaf	Second leaf	Third leaf	Fourth leaf	Immature leaf	First leaf	Second leaf	Third leaf	Fourth leaf
1......	0.40a	0.32a	0.29a	0.32a	0.33a	0.48a	0.36a	0.30a	0.32a	0.30a
2......	0.47a	0.33a	0.28a	0.31a	0.31a	0.61ab	0.39a	0.32a	0.33a	0.30a
3......	0.53a	0.42ab	0.35a	0.36a	0.33a	0.74b	0.50a	0.41ab	0.38a	0.33a
4......	0.80b	0.58b	0.53a	0.52a	0.52a	1.16	0.82b	0.64bc	0.56a	0.52a
5......	1.00b	0.88	0.94	0.96	1.01	1.36	1.05b	0.90c	0.88	0.85
6......	1.42	1.60	1.75	2.00	2.27	1.57	1.55	1.70	1.89	2.04
7......	2.00	2.36	2.89	3.08	3.45	1.89	2.17	2.84	3.12	3.35
8......	2.44c	2.91c	3.25	3.51	4.02b	2.26c	2.84c	3.34	3.70	3.98
9......	2.60c	3.08c	3.57	3.90	4.19b	2.40c	2.96c	3.77	4.23	4.31

[x]All values are means of 5 replications on the dry weight basis.
[y]Means with a common letter are homogeneous subsets at the 5% level.

older leaves, hence, K decreased with age. This was in direct opposition to the plants with sufficient K in which K increased with age. The youngest leaves in both instances were without deficiency symptoms.

Potassium deficient roots contained a constant K percentage of about 0.6%. In non-deficient roots, K percentage increased up to 6.1% with increased K supply. A sharp break in K concentration occurred between deficient and non-deficient roots, with a critical K value of about 0.7%. The results in Tables 1 and 2 showed that the plants in treatments 1–5 are K deficient while those in treatments 6–9 have sufficient K, which corresponded to the visual observations.

The relationship of growth to K percentage in the leaf tissues can be seen from the schematic diagrams in Fig. 2, 3 and 4, which are composites of detailed plottings, such as in Fig. 5 and 6. These relationships are shown in Fig. 2, 3 and 4 for the petiole, terminal blade, and lateral blade tissues, respectively. The immature and first leaves below the flat top contained a higher K percentage when the plants were K deficient than the second, third, and

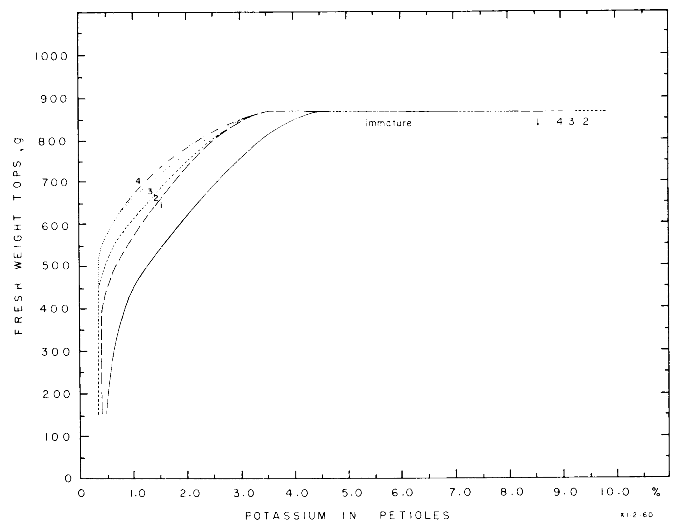

Fig. 2. Relationship of fresh weight of potato tops to K percentage (dry basis) of the petiole tissues of 5 leaf ages.

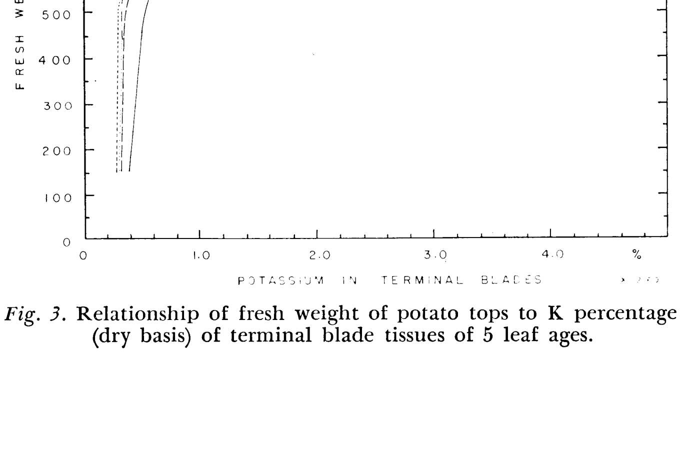

Fig. 3. Relationship of fresh weight of potato tops to K percentage (dry basis) of terminal blade tissues of 5 leaf ages.

fourth leaves, which were essentially the same in K percentage. A comparison of Fig. 3 and 4 shows that the terminal blade and the lateral blades of the second, third and fourth leaves were also essentially the same in K percentage.

The K percentages of the 16 plant parts were evaluated mathematically by regression lines and correlation coefficients (Table 4). Good correlations of 0.836 to 0.996 were obtained when the 3 plant parts of the second leaf were compared with the other plant parts. This indicates that one plant part may be substituted for another for K analysis. When the slopes (regression coefficients) are approximately 1.0, this indicates that one plant part may be substituted for another without correction. Thus, the K values for the first, second, third, and fourth petioles and those of the terminal blade and lateral blades of the second and possibly the first and third leaves may be substituted for one another within a plant part.

The second leaf sampled was referred to as the recently matured leaf (Fig. 1). The results for the petioles from

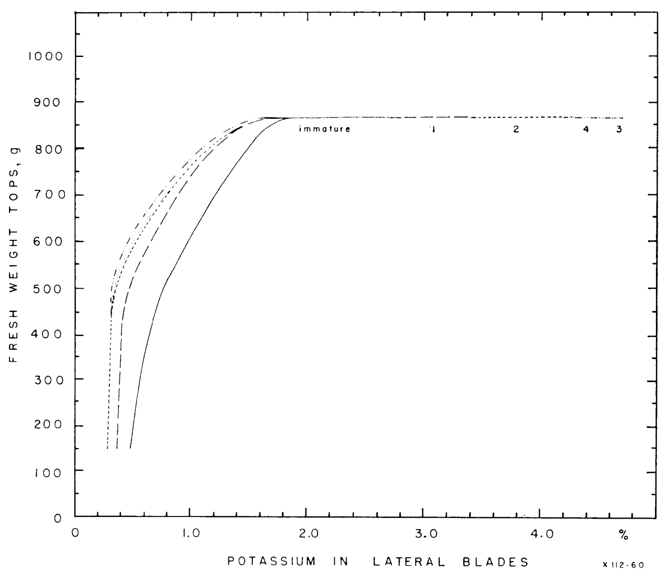

Fig. 4. Relationship of fresh weight of potato tops to K percentage (dry basis) of lateral blade tissues of 5 leaf ages.

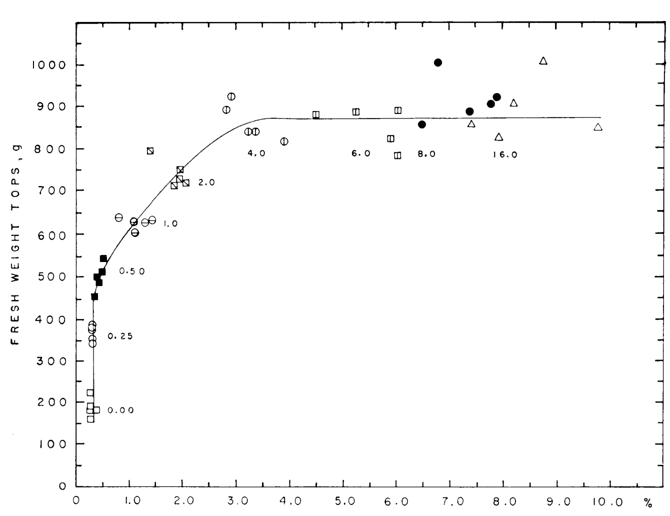

Fig. 5. Relationship of fresh weight of potato tops to K percentage (dry basis) in petiole tissues of second leaf. The numbers in the graph refer to meq/1. K added as K_2SO_4. The critical K level is about 2.3% K at 10% reduction of growth.

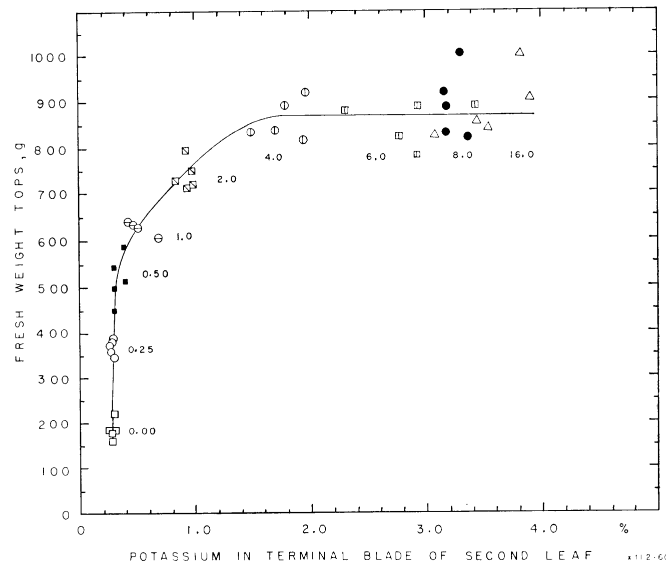

Fig. 6. Relationship of fresh weight of potato tops to K percentage (dry basis) in terminal blade of second leaf. The numbers in the graph refer to meq/1. K added as K_2SO_4. The critical K level is about 1.1% K at a 10% reduction of growth.

Table 4. Regression and correlation of K percentages in petiole, terminal blade, lateral blade, and fibrous root tissues.

Variable X	Petiole Second leaf			Terminal blade Second leaf			Lateral blade Second leaf		
	a	b	r	a	b	r	a	b	r
Petiole									
Immature	−1.00	1.27	0.970	−0.25	0.54	0.964	−0.26	0.56	0.969
First	−0.22	1.07	0.987	0.10	0.45	0.970	0.10	0.46	0.975
Second	0.00	1.00	1.000	0.19	0.42	0.981	0.20	0.43	0.984
Third	0.11	0.97	0.995	0.22	0.41	0.988	0.24	0.42	0.990
Fourth	0.05	0.97	0.990	0.19	0.42	0.993	0.20	0.43	0.994
Terminal blade									
Immature	−1.43	3.57	0.976	−0.46	1.54	0.984	−0.47	1.58	0.985
First	−0.60	2.74	0.978	−0.12	1.19	0.994	−0.11	1.22	0.991
Second	−0.32	2.29	0.981	0.00	1.00	1.000	0.02	1.02	0.996
Third	−0.29	2.10	0.977	0.02	0.92	0.996	0.03	0.93	0.992
Fourth	−0.19	1.86	0.973	0.05	0.81	0.994	0.07	0.83	0.998
Lateral blade									
Immature	−2.68	4.24	0.950	−0.98	1.82	0.948	−0.99	1.86	0.949
First	−0.98	2.97	0.971	−0.26	1.28	0.977	−0.26	1.31	0.979
Second	−0.36	2.24	0.984	−0.002	0.97	0.996	0.00	1.00	1.000
Third	−0.21	1.98	0.983	0.07	0.86	0.992	0.08	0.88	0.991
Fourth	−0.10	1.85	0.981	0.10	0.81	0.995	0.12	0.82	0.993
Fibrous roots	0.80	1.37	0.891	0.57	0.55	0.836	0.57	0.58	0.857

[a]Intercept of the Y axis when X = 0 of Y = a + bX.
[b]Regression coefficient (slope of the regression equation).
[r]Correlation coefficient.

Table 5. Critical K value in petiole, terminal blade, and lateral blade tissues.

Plant part	At 10% reduction of growth
Petiole	
Immature	3.2%
First	2.3%
Second	2.3%
Third	2.2%
Fourth	2.0%
Terminal blade	
Immature	1.1%
First	1.0%
Second	1.0%
Third	1.0%
Fourth	1.0%
Lateral blade	
Immature	1.4%
First	1.1%
Second	1.1%
Third	1.1%
Fourth	1.0%

Precision Planting of Lettuce[1]

O. D. McCoy, F. E. Robinson, H. Johnson, Jr., R. G. Curley, C. Brooks, G. Giannini, F. LeBaron,[2]
University of California, Riverside and Davis

Abstract. Experiments were conducted to evaluate precision planting of single uncoated and spherically (clay) coated single seeds at 2 (uncoated only), 3, 4, 6, and 12 inches in the row. Three planters were used and compared to the conventional Planet Junior at accepted seeding rates. Sprinklers were compared with furrow irrigation. Seed emergence was superior with sprinkler irrigation. Coated seed and 6-inch spacing was not satisfactory with furrow irrigation, but was considered comparable to commercial stands with the sprinkler method (87.5% stand). In planting to a stand with a single seed every 12 inches (thus eliminating the thinning requirement), 84.4% of the desired stand was obtained with uncoated seed and sprinklers. Commercial stands most often range from 80 to 90% of the theoretical 12-inch spacing. Theoretical machine thinning of 3-inch plantings resulted in 8.6 single plants/10 ft of row indicating promise for this innovation.

this leaf did not differ greatly from those of the first, third and fourth leaves as indicated by the regression analysis. Accordingly, the second leaf has been taken as the standard leaf for sampling. Detailed plottings of the results for the second leaf are presented for the petiole and blade tissues in Fig. 5 and 6. Fig. 5 shows the relationship between the fresh weight of tops to the percentages of K in the petiole tissues and Fig. 6 for the terminal blade tissues.

The critical K values for the various tissues are given in Table 5. The values are essentially consistent except for the immature tissues which are slightly higher. The critical K concentration can be set approximately at 2.3% for the petiole tissues and 1.1% for the blade tissues when determined at a 10% reduction of growth. These values give a good estimate of the K status of the potato plant relative to vegetative growth where stolons are removed. Additional experimentation is required to determine the effect of tuber development on the critical level (9).

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Introduction

Mechanization of vegetable culture has undergone an increasing amount of study as a means of achieving efficiencies.

Nearly one-half (43% or 22.5 hr) of the labor used prior to harvesting lettuce may be for thinning (1, 3). Theoretically 24,890 single plants/acre 12 inches apart result from thinning 2-row beds on 42-inch centers (6). In practice stands are 10–20% lower due to effects of environment or losses in the hand thinning process. Twenty-four to 50 times the amount of seed needed is planted to insure a stand (5). This practice has remained unchanged for 40 years (5, 6, 10).

Experiments (8, 9) have shown that changing from furrow to sprinkler irrigation will remove surface salt, provide better soil-air conditions, and permit light seeding rates. This paper presents the results of 3 studies with 3 precision planters dropping single seeds at intervals of 2, 3, 4, 6, and 12 inches to determine the interval that would require removing the fewest excess plants and yet insure an economic stand. Synchronous mechanical thinning would require plants at least 2 inches apart (2). Planting to a stand (12 inches apart) eliminates the thinning requirement. Theoretical "synchronous" thinning was performed in one study.

Methods and Procedure

Experiments 1, 2, and 3 had split plot design, half of the plots receiving sprinkler irrigation and the other half furrow irrigation. Water was not a limiting factor as adequate amounts were applied. The initial irrigations were applied on October 29, 1964, October 21, 1965, and March 21, 1966.

Experiment 1. Precision planting was performed with a Clow Vac Jet (Clow Seed Company, Salinas, California) planter utilizing a continuous vacuum pump and small hollow tubes to pick up and drop seeds at 2-inch intervals, using uncoated seeds. Planet Junior planters were used for comparison at 0.7 and 3.0 lb./acre. Three replications were used for seeding in individual 3-bed plots 65 feet long. Data were obtained on loss of stand.

Experiment 2. Seed were dropped singly at 3-inch intervals on 2-bed plots having 2 seed rows per bed. Individual plots were 130 ft long. Planter No. 1 was a modified (University of California, Curley-Brooks) International Harvester 188, utilizing clay coated (Filcoat Process Full-Coat) seed. Planter No. 2 was the George Giannini-University of California precision vacuum needle planter for uncoated seed (4). Seed row covering of vermiculite (agricultural grade #3; 56 ft^3 per acre stabilized with 1:5 solution of polyvinyl acetate at 100 gal/A) was compared with soil. Eight replications were used for seeding treatments.

Sprinkler irrigation was effected with #14 rainbirds, 3/32-inch nozzles, 30 × 40 ft spacing, 40 psi.

[1]Received for publication September 5, 1968.
[2]The authors gratefully acknowledge assistance and materials from California Zonolite Co., Clow Seed Co., Filcoat Division Germains Seed Co., Henning Produce Co., Neuman Seed Co., Perma Rain Irrigation Co., Rain for Rent Riverside, Redi Rain Manufacturing Co., and Western Rain Bird Sales.