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Mineral Element Changes in Pistachio Leaves[1]

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Abstract. **Concentrations of several mineral elements in leaflets of *Pistacia vera* L. cv. Kerman, did not differ significantly with leaflet position. Thus, leaflets may be used instead of whole leaves in leaf sampling. Analyses of leaflets indicated that N, P, and Zn concn were relatively high initially. They then dropped rapidly during leaf expansion, reaching a steady state in early summer. Manganese increased from an initially low level and then remained fairly constant. Potassium, Mg, Cl, and B behaved similarly to Mn, but reached constant levels later in the season. Leaves from bearing branches were lower in N and P, but higher in K than leaves from nonbearing branches. It is recommended, in determining mineral element status, that leaves from nonbearing branches be sampled during the month prior to harvest, as most elements are then at a steady state.**

Pistachio acreage in California has expanded over 10 times since 1970 to approximately 30,000 acres. This acreage, composed exclusively of the 'Kerman' (pistillate) and 'Peters' (staminate) cultivars, extends into widely different soil types; and mineral nutrition problems are likely to appear in the future.

Deficiency symptoms, critical levels of mineral elements in leaves, changes in levels during the growing season, and leaf sampling techniques have been established for many fruit and nut tree species (7). The pistachio has been grown commercially in several Middle Eastern countries for many years, but there is nothing in the literature concerning its nutritional requirements other than the fact that it responds "... to applications of nitrogen the same as most other trees" (13).

Materials and Methods

This study was made in 1970 on 'Kerman' grafted on *Pistacia atlantica* Desf. seedling rootstocks at the University of California Wolfskill Experimental Orchards (WEO) in Winters (Sacramento Valley) and the West Side Field Station (WSFS) at Five Points (San Joaquin Valley).

Leaves from the basal portions were used in the early part of the season while the shoots were elongating, as this growth was the most nearly mature. Leaf samples were collected at random from the shoots after shoot elongation had stopped and leaf expansion was completed in mid-May. Leaves were washed in a weak detergent solution, rinsed in tap water several times, given a final rinse in distilled water, dried in a forced-air dehydrator at about 65°C, and ground in a Wiley mill to pass a 40-mesh screen. Nitrogen was detemined by the Kjeldahl procedure, K, Ca, Mg, and Na by flame photometry, Mn and Zn by atomic absorption spectrophotometry. Cl by titrimetry, P by the amino naphthol sulfonic acid method (6), and B by the curcumin method (10).

Sampling. Pistachio leaves are imparipinnate, or occasionally spuriously paripinnate. Leaflets occupying different positions in the leaf were sampled separately to determine if a leaflet was as satisfactory for mineral analyses as an entire leaf. Each leaf held in abaxial (dorsal) view was divided into 4 parts, terminal leaflet, first subterminal leaflet on the right, first subterminal leaflet on the left, and the remaining leaflets (usually 2-4 small sized leaflets). Each sample consisted of leaflets from 30 leaves from nonbearing branches on each of 5 trees.

Seasonal levels. Seasonal levels of mineral nutrients were studied with 25-30 terminal leaflets per tree sampled at intervals from nonfruiting limbs. Five trees at WEO were sampled at 2- to 4-week intervals beginning April 17 when the leaves were about half expanded and continuing until leaf fall. The number of leaflets in each sample was recorded, and the weight was determined after drying. This was done to determine the actual weight of an element in each leaflet, in addition to its concn.

Sampling began May 14 at WSWF and was done infrequently throughout the summer. Eight trees were individually sampled on each date.

Bearing vs. nonbearing shoots. Terminal leaflet samples at WEO were taken from both bearing and nonbearing shoots on 2 trees with moderate crops. Sampling was done on the same dates as those in the study of seasonal levels.

Results and Discussion

Sampling. The pistachio leaf of 'Kerman' is large and bulky. A single leaf may have a dry wt of over 2 g, nearly enough for mineral analysis; however, more than one leaf should be used to assess the nutritional status of any tree. Many leaves could be included in each sample by sampling a single leaflet. The question is: Can any leaflet be used? There were no statistically significant differences in concn of the several minerals in leaflets from various positions of the leaf (Table 1). The nonsignificance was found whether the samples were taken early in the season (April 17), in late summer (August 25), or near leaf fall (Oct. 7). The terminal and the 2 oppositely positioned subterminal leaflets are of about equal size and would be convenient to sample; or just the 2 subterminal leaflets could be used if the terminal was missing.

Seasonal levels (concn basis). Changes in concn of the elements during the season (Fig. 1) were similar to those reported for peach (1) and apple (12). Levels of N, P, and Zn initially were high when leaves were about half expanded. Subsequently, the levels dropped very rapidly during further expansion. The levels reached steady states about the end of shoot elongation (mid-May), when the leaves were fully expanded. All other elements were at low levels in April, but increased steadily thereafter. Potassium, Mg, Cl, and B increased until the first of August, when they levelled off somewhat. Manganese reached a steady state much earlier, i.e., in June. In contrast, Ca in-

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Table 1. Mineral nutrient content in relation to leaflet position in 'Kerman' pistachio leaves at WEO[z].

Sampling date & leaflet position	Nutrient content (dry wt) N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (ppm)	B (ppm)	Zn (ppm)
April 17								
Terminal	4.20	.432	1.02	.28	.264	23	25	31
Right	4.13	.429	1.05	.28	.267	24	24	31
Left	4.22	.433	1.07	.27	.263	23	23	31
Remaining Basal	4.03	.438	1.10	.24	.263	24	25	30
April 29								
Terminal	3.56	.311	.81	.45	.391	25	33	27
Right	3.51	.312	.85	.45	.393	25	33	29
Left	3.57	.316	.85	.46	.398	25	33	29
Remaining Basal	3.51	.326	.82	.42	.392	26	34	29
August 25								
Terminal	2.34	.131	1.92	2.91	1.18	33	169	13
Right	2.48	.132	2.00	2.97	1.17	29	176	13
Left	2.41	.135	2.03	2.87	1.19	29	178	13
Remaining Basal	2.41	.134	2.11	2.88	1.21	28	189	14
Oct. 7								
Terminal	2.43	.132	1.98	3.51	1.17	32	188	11
Right	2.49	.129	1.89	3.61	1.36	31	197	11
Left	2.43	.132	1.98	3.45	1.34	31	184	11
Remaining Basal	2.47	.132	2.03	3.54	1.35	33	192	11

[z]There were no significant differences in columns within a sampling date.

creased at a uniform rate throughout the season. There were marked declines in concn of N and P just prior to leaf fall, indicating a backflow of these elements from leaves to stems. Similar curves were obtained for leaflets sampled at the WSFS.

Time of sampling is important in tissue analysis and in the establishment of critical levels of the various elements. Sampling is usually done during the period when the least change is occurring in the concn of an element. This period is in early to mid summer for most fruit trees (5). The pistachio appears to be a little different in this regard. The time at which the concn began to level out was different for each element, but the concn curves reached a plateau for most of the elements during August and September.

Pistachios are harvested usually in early to mid September. If leaf sampling is to be done once a year it should be done sometime during the 1-month period preceding harvest.

Seasonal levels (amounts per leaflet). Expressing levels of an element on a concn basis is helpful in the interpretation and use of leaf analyses. However, they were calculated as mg or μg per terminal leaflet to compare the actual amounts of elements present (Fig. 2).

Concn curves for K, Mg, Ca, Cl, B, and Mn indicated general increases during the season, as pointed out previously (Fig. 1). Curves representing the amounts of these elements per leaflet also indicate that they accumulate in leaflets with time (Fig. 2). However, the curves for N, P, and Zn varied, depending on the method by which the data were calculated. These elements were highest, in terms of concn (Fig. 1), on the first sampling date in April. Levels then dropped rapidly until reaching steady states in early June. The curve for amount of N per leaflet indicated an opposite trend (Fig. 2). There were 11 mg of N per terminal leaflet on the first sampling date in April and an accumulation in the leaflet to a maximum of 18 mg at the end of July, instead of a decrease, as in the case of concn. Maximum amounts of P and Zn, in contrast, had occurred 3 months earlier (May 1). These elements were present in near-maximum amounts on the first sampling date, when the leaves were about half size. Maximum amounts were attained on the second sampling date, before the leaves were full sized. This response was in sharp contrast to the other elements, which accumulated even

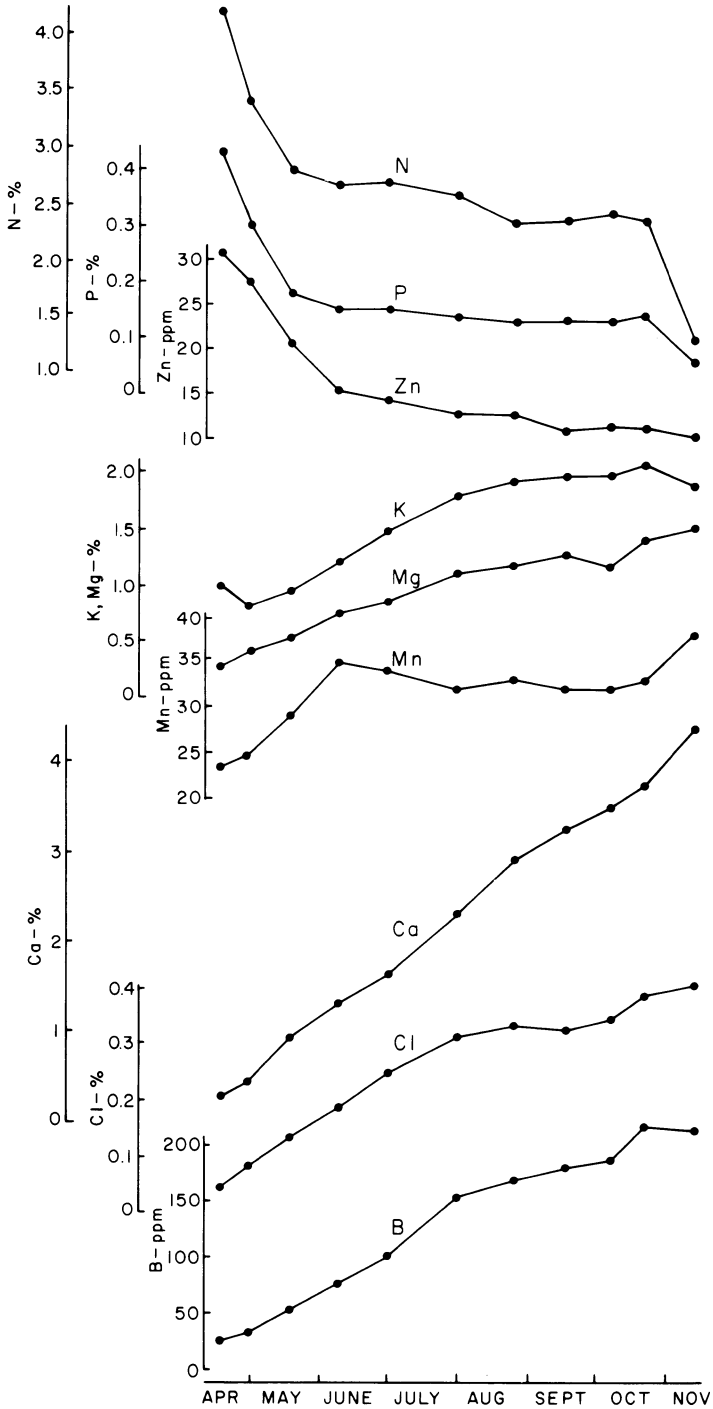

Fig. 1. Concn (% dry wt or ppm) of mineral elements in terminal leaflets of pistachio.

after the leaves were fully expanded.

Reductions in the amounts of P and Zn on May 18 indicated some movement of these elements out of the leaves about the time the leaves reached full size. Levels then remained stable until leaf senescence.

There was some movement of most elements out of the leaflets at leaf senescence in October, particularly of N, P, and K. Approximately 67% of the N, 75% of the P and 30% of the K had moved out of the leaflets from maximum levels earlier in the season to the final sampling date on November 13. These amounts of apparent "backflow" are comparable to those reported for apple (12) and peach (1).

Bearing vs. nonbearing shoots. Analysis of terminal leaflets from bearing and non-bearing shoots revealed no differences in

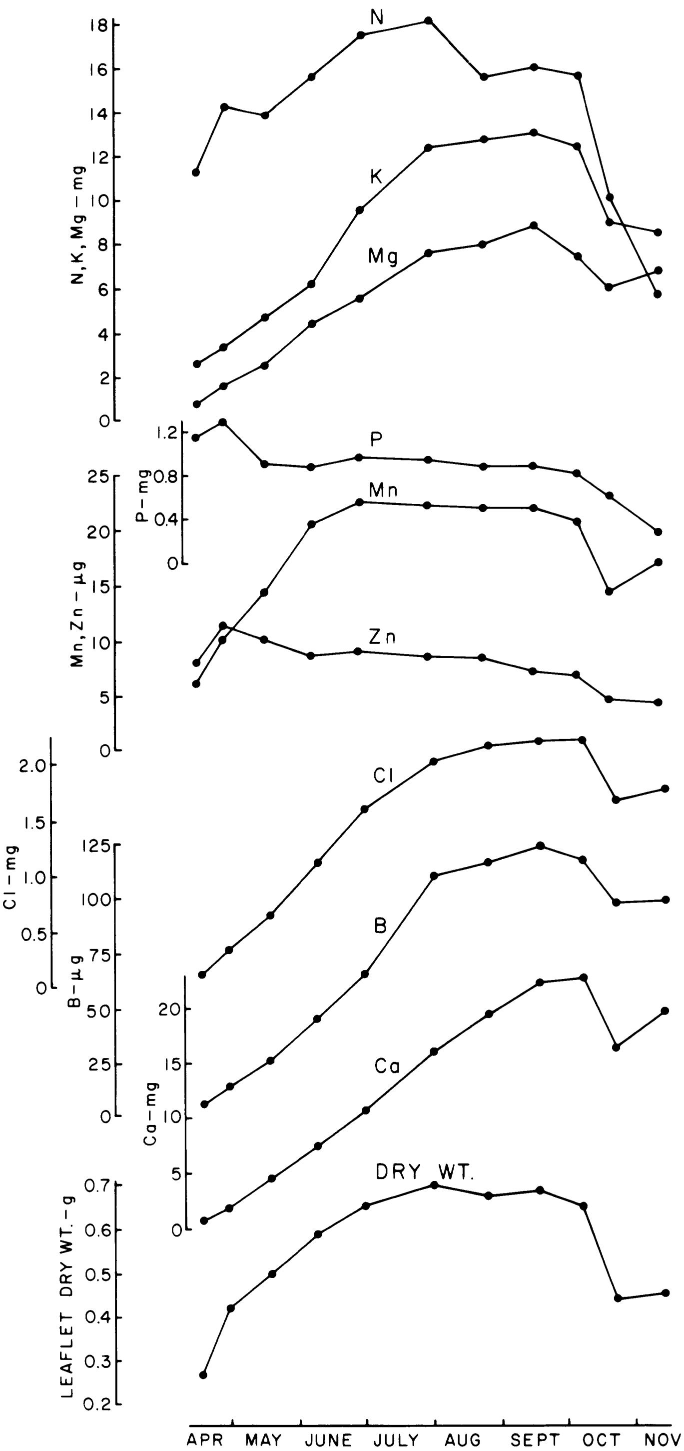

Fig. 2. Weight of mineral elements and dry matter per terminal leaflet of pistachio.

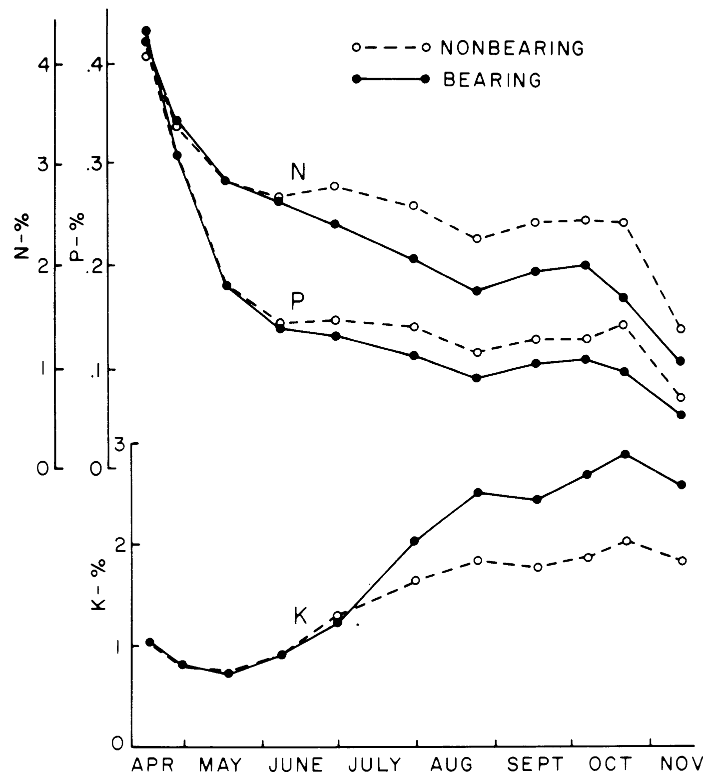

Fig. 3. Concn (% dry wt) of N, P, and K in terminal leaflets from bearing and nonbearing pistachio branches.

elemental levels except those of N, P, and K (Fig. 3). There were also no differences in levels of these elements in leaves at the first several sampling dates. However, levels of N and P were lower in leaves from bearing shoots than in leaves from nonbearing shoots by the first of July. This is the time at which the seeds begin rapid growth and development (8). It is assumed that the developing nuts are sufficiently strong sinks to deplete N and P in the leaflets. A similar situation exists in Douglas-fir, where foliage produced beyond the point of cone attachment to the branch is chlorotic and reduced in nitrogen content. This has been attributed to the ability of the developing seeds to attract nutrients from within the tree (11).

Potassium accumulated in the leaflets of bearing branches in much greater quantities than in those of nonbearing branches about a month after the differences in levels of N and P were detected. This was in contrast to other fruit species, in which leaves of heavy-cropping trees are usually lower in K concn than are leaves of light-cropping trees (2). However, an antagonistic effect between N and K has been observed in apple (3, 4) and peach (9); i.e., leaf K decreased as leaf N increased. An increase in K appeared subsequent to a decrease in N in bearing branches of pistachio. This may indicate that K accumulation was a consequence of low leaf N which resulted from presence of the crop of nuts.

We suggest that only leaflets from nonbearing branches be sampled for leaf analysis to eliminate the effect of variable crop level on mineral-element composition.

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Quantitative Genetic Analysis of Ten Characteristics in Sweet Corn (*Zea mays* L.)[1]

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Abstract. **Tassel date, silk date, plant height, ear height, shank length, husk extension, tip blanking, row number, ear length, and first ear weight were studied in a diallel involving 7 inbred sweet corn parents. Both general combining ability (GCA) and specific combining ability (SCA) were involved in the inheritance of all 10 characters. This was consistent for F_1 crosses in 2 years and for F_2 families. SCA variance (V_{SCA}) was larger than GCA variance (V_{GCA}) for ear length and first ear weight in the F_1 and ratios of V_{SCA}/V_{GCA} for these characters were slightly larger than 1.0. V_{GCA} was larger than V_{SCA} for all other characters in the F_1. Ratios of V_{SCA}/V_{GCA} ranged from .05 for row no. to .57 for plant height.**

Variance ratios for most characters decreased in the F_2. The failure of some ratios to decrease in the F_2 was attributed to either differential interactions of GCA and SCA with environment or inadequate sampling of F_2 families. Genotype × year interactions influenced the expression of most characters. A greater portion of the genotype × year interaction was contained in estimates of SCA than in estimates of GCA. Heritability estimates from parent-progeny regression were generally larger than those from variance components, although these estimates were generally in close agreement.

The quantitative genetics of *Zea mays* has been extensively studied, but primarily in field corn types. Additional information, obtained for sweet corn, would be useful for the following characters of interest to sweet corn breeders: length of time from planting to anthesis (tassel date), length of time from planting to silk emergence (silk date), plant ht, ear ht, shank length, husk extension beyond the tip of the ear, tip blanking, no. of kernel rows, ear length, and first ear wt. Variation in each of these characters is continuous and assumed to be under quantitative genetic control.

Three characters, tip blanking, husk extension, and shank length, were of primary interest in this study. Tip blanking, the failure of kernels to develop at the tip of the ear, can be intensified by unfavorable environment or improper plant nutrition. However, tip blanking is genetically controlled and is expressed by inferior genotypes even when environmental and nutritional conditions are optimum. No reports on the inheritance of tip blanking have been found in the literature. Husk extension has been associated with resistance to the corn earworm [*Heliothis zea* (Boddie)] and dusky sap beetle (*Carpophilus lugubris* Murr.) in sweet corn and field corn (15), and with resistance to bird damage in field corn (19). Inheritance of husk extension has been studied in limited populations of sweet and field corn (11, 15, 19). There have been no reported studies of the inheritance of length of the shank, the lateral branch that attaches the ear to the stalk.

The remaining characters have been studied extensively in field corn (1, 3, 5, 6, 11, 12, 14, 16, 17, 18, 20) but studies in sweet corn have been limited (2). They were included in this study to provide more information about inheritance in sweet corn germ plasm and to study their interrelationships with the characters of primary interest.

Our objectives were (1) to determine the relative importance of additive versus non-additive genetic variance for each of the 10 characters studied, (2) to compare the diallel analysis with covariance among relatives by comparing heritability estimates from variance components with those from parent-progeny regression, and (3) to determine the stability of types of genetic variance between years.

Materials and Methods

Diallel crosses among 7 sweet corn inbreds (Table 1) were made in 1973. F_2 seed was obtained by selfing the 21 F_1's in 1974.

The parents and F_1's were evaluated at Nampa, Idaho in 1974 using a randomized complete block design with 5 replications. They were reevaluated along with the 21 F_2's in 1975 using the same design but 4 replications. Each plot in 1974 consisted of a row 457 cm long with plants spaced 23 cm within the row. Rows were 81 cm apart. Plot rows in 1975 were 610 cm long and each F_2 plot consisted of two rows. In 1974 it became apparent that the inbred parents could not compete equally with the more vigorous F_1 hybrids when randomized with them in the same block. Thus, the parents were replicated in separate blocks adjacent to the interrandomized F_1's and F_2's in 1975.

Character measurements were made on 10 equally competitive

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