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Growing on a Parasitic *P. californicum* and Its Host, *Cercidium floridum***

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MINERAL CONCENTRATIONS IN AN AUTOPARASITIC PHORADENDRON CALIFORNICUM GROWING ON A PARASITIC P. CALIFORNICUM AND ITS HOST, CERCIDIUM FLORIDUM¹

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ABSTRACT

Tissue concentrations of 12 mineral elements (Al, Ca, Cu, Fe, K, Mg, Mn, amino-N, Na, P, Si, and Zn) were measured in an autoparasitic mistletoe (*Phoradendron californicum*), the parasitic mistletoe on which it was growing (*Phoradendron californicum*), and the host tree (*Cercidium floridum*). Mineral concentrations in the autoparasite were typically 1.1-1.3 times higher than in the parasite. Mineral concentrations of all elements except Ca, Fe, Mg, Mn, and Si were higher in the parasitic mistletoe than its host. Mineral concentration differences are discussed relative to accumulation via the transpiration stream and translocation within the host via the phloem.

XYLEM-TAPPING MISTLETOES are hemiparasitic and reported to have higher tissue concentrations of certain elements than their hosts. Potassium concentrations that are severalfold higher have been noted for a number of mistletoe species (Wolff, 1880; Nicoloff, 1923; Boresch, 1935; Lamont and Southall, 1982; Lamont, 1983). Similarly, the concentrations of Cu, Mg, Na, and Zn were higher in mistletoes when compared to their hosts (Lamont and Southall, 1982). In contrast, N and Ca concentrations of mistletoe tissues may be either similar to or higher than those of the host tissues (Nicoloff, 1923; Boresch, 1935; Lamont and Southall, 1982; Schulze and Ehleringer, 1984).

The higher tissue concentrations of these elements appear to be the product of passive accumulation from xylem water, resulting from the lack of any phloem connections for retranslocation of these elements out of mistletoe tissues (Leonard and Hull, 1965) and from transpiration rates that are up to severalfold higher in the mistletoe than in the host (Kamerling, 1910; Härtel, 1937; Hellmuth, 1971; Glatzel, 1983; Schulze, Turner and Glatzel, 1984). Tissue water potentials are more negative in mistletoes than in the host tissues (Scholander et al., 1965), and this is undoubtedly a result of

the higher transpiration rates (Schulze et al., 1984).

Mistletoes can be epiparasitized by other mistletoes (even by members of the same species = autoparasitism) (Kuijt, 1969). However, epiparasitism occurs infrequently, and little other than taxonomy is known about epiparasitic plants. One question of interest because of its nutritional and water-relations implications would be to know what, if any, differences existed in tissue nutrient composition between the parasite and its epiparasite. If the epiparasitic mistletoe transpired at a rate higher than that of its parasitic host, then its tissue nutrient concentrations should be proportionally higher than those of its parasitic mistletoe host. In turn, the parasitic mistletoe should have higher tissue nutrient concentrations than those of its nonparasitic host for the same reason. In this paper, we present nutrient composition data for autoparasitic mistletoes observed growing on another mistletoe, which was in turn growing on its host tree in the Sonoran Desert.

MATERIALS AND METHODS—The plants were located approximately 15 km south of Oatman, Arizona (lat. 34°57'N, long. 114°25'W, 540 m elevation) in a dry wash habitat. Thirty-four individuals of different age (up to 8 yr) of the mistletoe *Phoradendron californicum* were found autoparasitic on another *P. californicum*, which was in turn parasitic on the host tree *Cercidium floridum*. Most of the epiparasites were small enough in size that they were combined together in order to provide sufficient biomass for mineral analyses. Plants were

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sampled in October 1983, near the end of the growing season.

For all mistletoes (parasitic and autoparasitic), the entire plant was dissected and separated into 1-yr age classes as described previously by Schulze and Ehleringer (1984). The mineral composition was determined on single, homogenized subsamples from each mistletoe age class as well as from current leaf tissue of the *Cercidium* host tree. Amino-N was determined by microkjeldahl analysis (Lilivek, 1970). Al, Ca, Cu, Fe, K, Mg, Mn, Na, P, Si, and Zn concentrations were determined by inductively coupled argon plasma spectrometry (analyses were performed by the Department of Forestry, University of Montana).

RESULTS AND DISCUSSION—The tissue concentrations of 11 of the 12 minerals measured were higher in the autoparasitic mistletoes than in the parasitic mistletoe (Table 1). The remaining element, Cu, was present in concentrations similar to that of its parasitic host. For the vast majority of the minerals, this concentration increase was 10–30%. Since both parasite and autoparasite access the same xylem water and there was a similar increase in concentration for most elements, it would appear that the autoparasite utilized approximately 10–30% more water per increment growth than did its parasitic host. In view of the hypothesis that mistletoes transpire at a rate sufficient to gather the nitrogen necessary to meet their growth requirements (Schulze et al., 1984), it is interesting to note that the relative accumulation of N was the lowest of all the macronutrients.

Mineral concentrations in the parasitic mistletoe tissues were generally higher than in the *Cercidium* host (up to 2–3× higher for Al, K, P, and Zn), consistent with previous observations of mistletoe mineral composition and also with the notion that mistletoes have a relatively higher transpiration rate. However, unlike the other macronutrients, N was not accumulated and the concentrations of four minerals (Fe, Mg, Mn, and Si) were notably lower in the parasitic mistletoe than in its host. Translocation of minerals from one part of the host plant to leaf tissues via the phloem is a possibility for the *Cercidium* host, which these mistletoes would then not have access to (Leonard and Hull, 1965). Since many heavy minerals are known to be highly mobile in the phloem (Ziegler, 1975; Hocking and Pate, 1978), it is likely that the higher concentrations of these minerals in the host leaf tissues arose by translocation from other host tissues via the phloem. Similarly, it is known that K and P

TABLE 1. Mineral nutrient concentrations of autoparasitic *Phoradendron californicum* ($n = 6$, $\bar{x} \pm 1$ SE) growing on a parasitic *P. californicum* and its host *Cercidium floridum*. The samples are ranked by the percentage increase of mineral content of the autoparasite over that of the parasite, which is presented in parentheses next to the autoparasitic data. Also in parentheses next to the parasitic values is the percentage increase in the parasite over that of the host. All samples represent only current-year leaf tissues. Plants were sampled 15 km south of Oatman, Arizona in October 1983. Units are $\mu\text{g g}^{-1}$ for all elements except Ca, Mg, N, and P where units are mg g^{-1} .

Element	<i>Cercidium</i>	Parasitic <i>Phoradendron</i>	Autoparasitic <i>Phoradendron</i>
Al	13.0	43.0 (3.3×)	64.0 ± 26 (1.5×)
Na	106.0	115.0 (1.1×)	157.0 ± 11 (1.4×)
Mg	4.22	3.01 (0.7×)	3.94 ± 0.16 (1.3×)
Mn	55.4	13.1 (0.2×)	16.9 ± 1.1 (1.3×)
Fe	112.2	46.1 (0.4×)	56.5 ± 6.9 (1.2×)
K	11.0	27.6 (2.5×)	33.1 ± 1.5 (1.2×)
Ca	16.6	15.4 (0.9×)	18.4 ± 0.7 (1.2×)
Zn	13.1	25.4 (1.9×)	28.6 ± 2.9 (1.1×)
P	1.22	2.20 (1.8×)	2.49 ± 0.10 (1.1×)
N	24.8	28.0 (1.1×)	31.7 ± 1.8 (1.1×)
Si	280.0	189.0 (0.7×)	199.0 ± 19 (1.1×)
Cu	7.6	11.7 (1.5×)	10.7 ± 0.4 (0.9×)

are readily translocated out of leaf tissues to the roots via the phloem, and this most likely accounts for their relatively low concentration in leaf tissues (Ziegler, 1975). Following this same argument, it is likely that the extreme variations (high and low) in the ratios of mineral concentrations between parasitic mistletoe tissues and those of its host resulted from differential translocation of these elements within the host phloem.

It is noteworthy that even though the concentrations of Fe, Mg, Mn, and Si were lower in the parasitic mistletoe than its host, they were all present in higher concentrations (1.1–1.3×) in the autoparasite than in the parasite. These data show that although translocation of minerals both into and out of host leaf tissues may obscure the mineral ratio difference between host and parasite expected by simple transpiration stream accumulation, the mineral ratios were constant as expected when the same xylem water supply was tapped (as within parasite and autoparasite).

Mineral concentrations in the tissues of both autoparasite and parasite decreased with age (Fig. 1). Schulze and Ehleringer (1984) have shown that for *P. californicum* growing on adjacent *Acacia greggii* such decreases in tissue mineral concentration with age were a dilution effect resulting from increased woody growth and not because minerals were being leached or translocated from the tissues.

Phoradendron californicum on Ph. calif. on Cercidium floridum

Oatman, Arizona, October, 1983

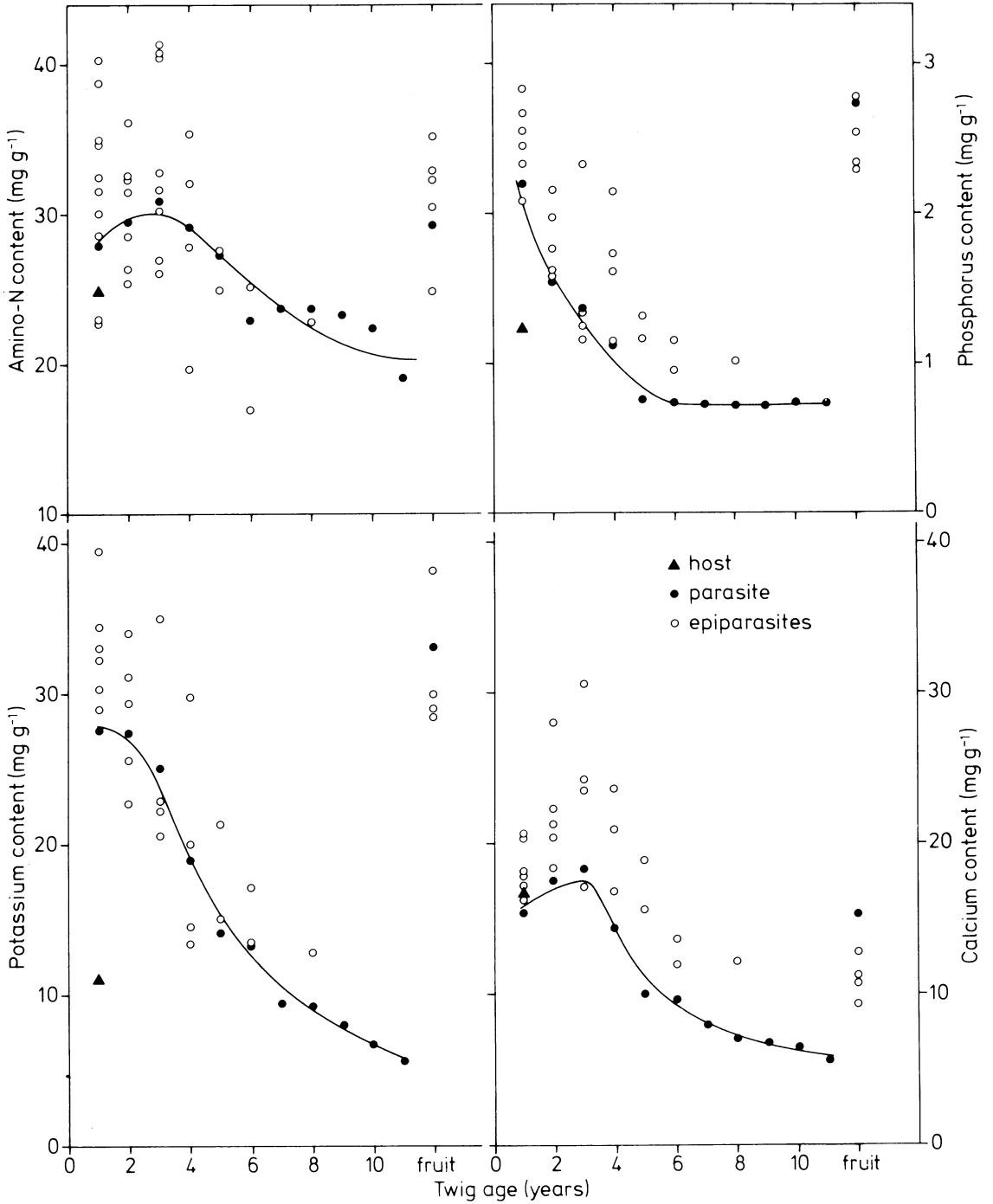


Fig. 1. Amino-N, P, K, and Ca contents of autoparasitic *Phoradendron californicum* (open circles) growing on *P. californicum* (closed circles), which is in turn growing on *Cercidium floridum* (closed triangles).

The absolute concentrations for nutrients in the tissues of the parasitic *Phoradendron* are similar to those previously reported by Lamont and Southall (1982) for *Amyema* growing on *Acacia* in Australia and by Schulze and Ehleringer (1984) for *Phoradendron* growing on *Acacia* in the Sonoran Desert. However, the nutrient concentrations of the autoparasite are very much higher, clearly indicating that the autoparasite accumulates more nutrients per increment biomass.

The observation that mineral concentrations of xylem mobile ions in the host leaf tissues are lower than those in the autoparasitic and parasitic mistletoes is consistent with the hypothesis that transpiration rates were greater in the mistletoes. Although transpiration rates were not measured, we can infer from the nutrient concentration differences that the autoparasitic transpiration rate was most likely greater than that of its parasitic host. The ratio of transpiration rates for autoparasite to parasite may have been of similar magnitude to the ratio of transpiration rates for the parasite to its nonparasitic host. Related to this, Schulze and Ehleringer (1984) measured $\delta^{13}\text{C}$ ratios (a measure of water use efficiency) in an autoparasite-parasite system involving the same species of mistletoe but with *Acacia greggii* as the host. In that study they found water use efficiency was highest in the host and lowest in the autoparasite and that the differences in water use efficiency between host and parasite and between parasite and autoparasite were of similar magnitude.

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