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This review summarizes the response of crop plants to deficiency of mineral nutrients and summarizes the physiological adaptations of wild plants that enable them to exploit habitats of differing soil fertilities. [The *SCI®* indicates that this paper has been cited in over 260 publications.]

A Search for Principles

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As I prepared for my first sabbatical leave in 1979, I tried to decide what I most needed to learn to proceed in my field of study, the mineral nutrition of wild plants. The more I thought about it, the more I realized that I didn't have a clue as to what the major physiological adaptations of wild plants to mineral nutrient deficiency were, despite having done research in this area for six years. I decided that the surest way to reach some conclusions about the subject was to write a review that described the major patterns of nutritional adaptation in plants. To ensure that I could not renege on this challenge, I persuaded the Guggenheim Foundation and *Annual Reviews* that such a review was needed and worthwhile. So armed, I went off first to Oxford University in England, where the person I had planned to do research with left for a new job just before I arrived. Six months later I went to Lincoln College in New Zealand, arriving just as all the university faculty left for summer vacation. These blessings in disguise left me with lots of time in excellent libraries.

The majority of nutritional work has been done on crop plants, so I began my review by summarizing the general conclusions about how an individual plant adjusts physiologically to an insufficient supply of mineral nutrients. These conclusions were well-established in the literature and gave no great surprises. When it came to the question of how plants have adapted evolutionarily to nutrient deficiency, the answers were not so clear. I began with the prejudice that plants adapted to infertile habitats should somehow be more efficient in getting nutrients, in using them for growth, or in minimizing nutrient loss. Several key papers[1,2] suggested that the situation was not so simple. I decided to read every paper I could find that had compared the nutritional response of plants adapted to different soil fertilities. Many of the more useful papers were in horticultural or regional journals that I would not normally have read.

The basic conclusion of my review was a surprise to me. Plants adapted to infertile soils are not more efficient in acquiring, using, or retaining nutrients than are plants adapted to high-fertility soils. This conclusion certainly did not conform to my teleological expectations of how a well-adjusted plant should behave. However, in my review, I tried to explain why the basic ecological constraints of low-fertility soils and the known interactions among physiological processes would logically lead to the observed patterns. It was only after many rounds of discussion, rethinking, and rewording that my editor-in-chief and wife (Melissa Chapin) could be convinced that these ideas had any validity. Perhaps it was the counterintuitive nature of the conclusions and the supporting evidence from many diverse ecosystems that have made this review useful. Many of these conclusions have been treated with skepticism and challenged in good experimental studies that have since greatly advanced our understanding of plant mineral nutrition.[3-5]

In general, I felt that my review showed many potential physiological adaptations that do *not* explain adaptation to infertile soils, but the positive physiological attributes of low-nutrient-adapted plants were less clear-cut. I now feel that effective growth in these soils requires a slow growth rate that results from trade-offs between rapid growth and alternative allocations to storage and defense against herbivores and pathogens.[5,6]

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2. **Rorison I H.** The response to phosphorus of some ecologically distinct plant species: I. Growth rates and phosphorus absorption. *New Phytol.* 67:913-23, 1968. (Cited 70 times.)
3. **Ingestad T.** Relative addition rate and external concentration; driving variables used in plant nutrition research. *Plant Cell Environ.* 5:443-53, 1982. (Cited 45 times.)
4. **Tilman D.** *Plant strategies and the dynamics and structure of plant communities.* Princeton, NJ: Princeton University Press, 1988. 360 p.
5. **Chapin F S, Groves R H & Evans L T.** Physiological determinants of growth rate in response to phosphorus supply in wild and cultivated *Hordeum* species. *Oecologia.* (In press.)
6. **Bloom A, Chapin F S & Mooney H A.** Resource limitation in plants—an economic analogy. *Annu. Rev. Ecol. Syst.* 16:363-92, 1985.