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This Week's Citation Classic

Evans H J & Sorger G J. Role of mineral elements with emphasis on the univalent cations. *Annu. Rev. Plant Physiol.* **17**:47-76, 1966. [Dept. Botany, Oregon State Univ., Corvallis, OR]

This review indicates that potassium plays its major role in living cells as a cofactor for enzymes that participate in the synthesis of protein and starch and many other metabolic processes. Univalent-cation activated enzymes usually require potassium concentrations of 0.03 to 0.15 M. The potassium concentration in normal cells is within this range. [The *SCI*® indicates that this paper has been cited over 185 times since 1966.]

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"As a student at Rutgers University around 1950, I was impressed by the emerging biochemical evidence indicating that trace elements such as copper, zinc, manganese, and iron played essential roles in cells as cofactors for enzymes. This explained the physiological role of elements that occurred in tissues at concentrations of less than 10 to a few hundred ppm. But it was frustrating to learn that plant biology texts in that period, and some 15 years later, presented no satisfying explanation for the role of potassium, which normally occurs in tissues at concentrations of 1 to over 3% of the dry matter. During the 1950s and 60s many plant science texts included general statements indicating that potassium was involved in the unique organization of protoplasm, and that it functioned in cellular osmotic processes.

"There seemed to be a reluctance to consider that an element such as potassium that normally is present in tissues at concentrations near 0.1 M could serve as a cofactor for enzymes. After reading papers by Boyer *et al.*[1] showing that pyruvic kinase from rabbit muscle was dependent upon a univalent cation, it became apparent that plant scientists had not realized that potassium, like the micronutrient elements, also may be essential for a series of enzyme catalyzed reactions. A series of students and I began to look for univalent-cation activated enzymes in plants. Gene Miller and I showed that pyruvic kinase from peas behaved like the enzyme from animals requiring univalent cations for activity.[2] A.J. Hiatt examined the acetic thiokinase from spinach leaves and arrived at a similar conclusion.[3] Ronald Nitsus demonstrated a specific requirement of potassium for the synthesis of nitrate reductase in *Neurospora* and also showed that potassium was essential for the starch synthetases from several plants.[4] The concentrations required for maximal enzyme activities were in the range of 0.03 to 0.1 M.

"In our review some of the metabolic consequences of potassium deficiency were listed. These include decreased starch contents of plants and lesions in the protein synthesizing machinery in bacteria, plants, and animals.

"Perhaps the reason why our review has been cited often is because it provided a long documented list of univalent-cation activated enzymes which served as a basis for the argument that potassium deficiency in plants and other organisms may be accounted for by an insufficiency of potassium for the normal functions of a whole series of important enzymes. Even though rubidium, ammonium, and sometimes cesium often activated enzymes *in vitro,* we concluded that potassium was the only non-toxic element that accumulated in cells in sufficient concentrations to fulfill the physiological role of a univalent cation activator for a large group of enzymes. More recent reviews on the subject have been prepared by Suelter and Evans and Wildes."[5,6]

1. **Boyer P D, Lardy H A & Phillips P H.** Further studies on the role of potassium and olher ions in the phosphorylation of the adenylic system. *J. Biol. Chem.* **149**:529-41. 1943.
2. **Miller G & Evans H J.** The influence of salts on pyruvate kinase from tissues of higher plants. *Plant Physiol.* **32**:346-54. 1957.
3. **Hiatt A J & Evans H J.** The influence of certain cations on the activity of acetic thiokinase from spinach leaves. *Plant Physiol.* **35**:673-7, 1960.
4. **Nitsus R E & Evans H J.** Effects of univalent cations on the activity of paniculate starch synthelase. *Plant Physiol.* **44**:1260-6. 1969.
5. **Sueller C H.** Enzymes activated by monovalenl cations. *Science* **168**:789-45. 1470.
6. **Evans H J & Wildes R A.** Potassium and its role in enzyme activation. *Proceedings of the 8th Colloquium of the Internationa! Potash Institute.* Berne. Switzerland: International Potash Institute. 1971. p. 1.V39.