by the relatively low fat content of the latter, and led to the elimination of excess fat by skin glands, as indicated by the oily condition of the skin in rats supplied with choline.

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Calcium Deficiency in Serpentine Soils as Revealed by Adsorbent Technique

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The Conejo soil series near Morgan Hill, California, is derived from outwash material of a serpentine rock area. The soil is deep, and rich in clay. The pH of the surface is 7.2. Conejo clay contains about 5.5 milliequivalents of exchangeable calcium/100 gm of soil. In comparison with many productive soils, this value is not low.

Conejo soil was brought to Berkeley and placed in pots containing 1,600 gm of soil. In the check pots romaine lettuce made little growth. Additions of nitrogen, phosphorus, and potash increased plant growth significantly, seemingly supporting the idea of Gordon and Lipman (*1*) that serpentine soils are unproductive because of deficiencies in nitrate, phosphate, and potassium.

After two to four weeks the lettuce plants on the fertilized soil developed a rosette disease. The young, inner leaves curled and became extremely stunted. Intense light enhanced these symptoms. Rosette, in various degrees, was also observed on serpentine soils of the Henecke and Venado series and on Maxwell and Dublin soils.

Following a suggestion by Robinson, *et al.* (*4*) that chromium and nickel, and perhaps cobalt, are the dominant causes of infertility in serpentine soils, normal lettuce plants grown on a productive soil and abnormal plants (rosette) from Conejo soil were analyzed spectrographically by A. P. Vanselow at the University of California Citrus Experiment Station. No consistent differences in Cr, Ni, and Co content could be observed. Adding these elements to good Yolo soil or spraying normal lettuce leaves with the soluble salts did not produce rosette disease.

After having initiated a great variety of treatments, we observed that gypsum and, to some extent, lime would combat the disease. Since serpentine soils are notoriously high in magnesium, these observations seemed to agree with Loew's (*2*) old theory of the Ca-Mg-proportions.

The question whether rosette disease is conditioned by magnesium excess or calcium deficiency, either absolute or relative, was elucidated with the aid of adsorbent technique, using cation amberlites as ionic carriers. Amberlites saturated with Ca, Mg, Sr, and K were added to fertilized Conejo soils and Yolo soils, the latter being a productive soil. The results were as follows:

(1) Ca-amberlite added to Yolo soil did not retard the excellent growth of the plants. Apparently the amberlite anion itself, in the amounts used, had no injurious effect on lettuce plants. Ca-amberlite added to Conejo soil overcame the disease and produced normal plants, comparable in weight and appearance with the plants grown on Yolo soil.

(2) Mg-amberlite added to Yolo soil produced characteristic rosette disease symptoms. When Mg-amberlite was added to Conejo soil, the extent of the disease was enhanced.

Experiments 1 and 2 rule out Cr, Ni, and Co as disease-producing agents.

(3) K-amberlite incorporated in Yolo soil produced lettuce rosette, and it emphasized the disease in Conejo soil. This experiment rules out magnesium as the primary factor. In the case of Yolo soil, it also eliminates the absolute level of exchangeable calcium (Moser's hypothesis, *3*) as the causal element.

Experiments 1, 2, and 3 suggest that the degree of saturation of exchangeable calcium is a prime contributing factor in the origin of lettuce rosette.

(4) Sr-amberlite added to Yolo soil in the same amount as Mg- and K-amberlite did not produce the disease. In Conejo soil it improved plant growth slightly but did not appreciably reduce the disease. The behavior of Sr-amberlite suggests a partial substitution of Sr for Ca in the growth of romaine lettuce.

While these experiments established the cause of rosette disease with the aid of soil studies and adsorbed ion technique, the crucial aspects could also be demonstrated with water culture experiments. Thus, the disease was produced in nutrient solutions as a result of calcium deficiency, in absence of significant amounts of cobalt, chromium, and nickel.

Similar results have been obtained with barley plants, which exhibit their own specific symptoms. A more detailed report will be published elsewhere.

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