

(I) INTRODUCTION

The determination of those nutrients in the soil which are usable by the plant is one of the problems which early engaged the attention of soil chemists. At first, chemical analysis of soils aimed at estimating the total amount of the various plant nutrients present, without any consideration of the degree to which they could be absorbed and utilised by the plant. Results obtained in this way proved to be of little practical importance in agriculture. This was soon realized by soil investigators, and they accordingly sought for a better means of determining the amount of nutrients in the soil of which the plant could make immediate use.

It had been noted as early as 1733 that roots have an acid sap. Philip Miller (gardener to the Society of Apothecaries) wrote:- "When the juice enters the root, it is earthy, watery, poor, and acid". He also speaks of "That tart liquor oozing from the root of the walnut tree when cut off in the month of May". Later, Sachs demonstrated the solvent action of seedling roots. He grew plants in sawdust on a polished marble slab and found that the rootlets etched the polished surface where they came in contact with it. It was therefore assumed that plant roots excrete organic acids which dissolve plant food in the immediate vicinity of the root hairs and render it capable of being absorbed by the plant. This view was developed by Dyer (1) who extracted the cell saps from the roots of a series of agricultural plants and titrated them with alkali. He found that a one percent solution of citric acid was approximately of the same acidity as the extracts. Thus a one percent solution of citric acid came to be used as an extracting agent for the determination of available phosphate and potash. Dyer, using this method, obtained results which were much more in accordance with field indications. Later investigators found no acid in the root-sap other than carbon dioxide; they showed that this substance could account for the acidity in and around the root-hairs, except in the case of lupins, whose great power to extract phosphate is

even now largely unexplained.

Dyer's method is still in general use, although his premise that plant-roots excrete organic acids appears to have been abandoned by plant physiologists. Investigators other than Dyer have used different acids at varying concentrations, but to the present day there has been no radical departure from the method originally proposed in 1894 by Dyer and used by him in his classical investigations at Rothamsted.

The matter of chemical estimation of "available" soil nutrients, that is, those which can be readily absorbed by the plant, was investigated at the University of California in a series of famous experiments carried out during the eight years prior to the publication in 1922 by Hoagland (2) of the detailed results obtained. Large tanks each containing about 1 ton of soil were employed. During the first season, all soils were cropped with barley. In subsequent years, only one soil of each series of replicates was cropped, the rest being left uncropped but otherwise treated similarly. Estimations of the total amount of the important plant nutrients were made on each soil, together with a determination of the amount of these elements which was soluble in concentrated hydrochloric acid (Hilgard's method) and in one percent citric acid. Water extracts from each of the soils were also examined at fortnightly intervals. Neither the total quantity of plant nutrients present in the soil, nor the amount soluble in concentrated hydrochloric acid, showed any relationship to the yield of barley. The citric acid extracts showed only slight but quite definite correlation. The water extracts, taken separately, had no significance, but collectively they exhibited a strong relationship to the yield obtained. This was particularly striking in the case of nitrate. Hoagland pointed out that the rate at which the soil solution is replenished with plant nutrients is of far greater importance than the total amount of these nutrients present in the soil at any one time. With regard to soil analysis he states:- "The point to be emphasized is that neither the analysis of the crop nor the analysis of the soil affords the essential information concerning availability of plant-food at various periods, and consequently such data cannot

"serve as a reliable guide to soil management".