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Colloidal Clay Culture for Refined Control of Nutritional Experiments with Vegetables[1]

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VEGETABLE fertilizer research has been woefully negligent up to the present time in studying the properties of soil as they affect the dietary quality of the vegetables produced. Attention to this aspect of vegetable research needs broadening as indicated by the voluminous amount of medical literature emphasizing the importance of the composition of the diet and its relation to the fitness of human beings. Probably the primary reason for our inattention to the soil characters as reflected in the nutritional value of vegetable crops has been the lack of a proper cultural medium for carrying out such investigations.

Colloidal clay can contribute to our knowledge of the chemical composition of vegetable crops in a manner to give greater significance to the data obtained than has heretofore been possible. It duplicates very closely the salient features of soil while permitting a complete chemical control of the medium upon which the vegetables are grown.

The Idealistic Medium

If one were to conceive a perfect medium upon which to grow vegetable crops for nutritional experiments, there are certain qualities which this medium would possess. The most important would be the potential ability of providing a large total supply of nutrient elements for plant utilization without effecting any great change, or an excessive total, in the osmotic pressure of the medium. Further, it would contain a high percentage of elements in an available form and thereby circumvent the common soil characteristic of low availability even though the total amount of elements present is high. It would permit an efficiency evaluation, or the determination of the percentage of the available supply of nutrients which are utilized by the plant. Such a Utopian medium would hold its pH constant while the nutrient elements vary widely and would also permit the reciprocal in which it maintains the nutrients constant while the pH is altered.

Another requirement, of which the importance has only recently been recognized, is the colloidal properties of the medium. This has been most forcefully brought to our attention by the work of Albrecht (3) and Jenny (6), who have shown that the colloids are powerful forces in the loss of nutrients from plant roots as well as in the delivery of nutrients to the plant. In many nutritional experiments, the physical structure of the media is of great importance. The perfect medium would permit a wide latitude in the use of nutrient elements with a minimum effect on the physical structure and at the same time permit the changing of the physical structure when this is desired.

To date, practically all of the vegetable nutritional investigations

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have been carried out with either sand, water or soil as the cultural medium. The disadvantages of these have limited the research work, at best, to comparatively crude chemical surveys. Colloidal clay possesses qualities which make it approach more closely the concept of the idealistic medium than any other cultural material previously used. It also affords the maximum in flexibility of the variables. At the same time, it permits such refinement of technique so as to make possible the study of the plant's production and manufacture of many of the more elusive dietary essentials.

Qualities of Colloidal Clay

It is possible with colloidal clay to vary greatly the total amount of nutrients available to the plant and still not even approach detrimental osmotic pressure, since the elements are absorbed on the surface of the colloid and at the same time are available for plant growth by exchange (5). The influence of such basic ions as calcium can be separated from the effects of the pH per se (2). This is done, for example, by taking advantage of the property of a hydrogen colloidal clay which permits its titration by basic solutions to any desired hydrogen ion concentration. If a low pH (high degree of acidity) is desired, each clay molecule delivers but little calcium and one needs only to vary the amounts of clay to vary accordingly the amount of calcium delivered at any degree of acidity. Larger delivery of calcium by more clay is without disturbance of the physical conditions of the medium. If a higher pH but a low (rather than a high) calcium delivery is wanted, then the excessive hydrogen ion may be replaced in part by some non-nutritional ion such as barium. The quantities of calcium, or other cations, desired and their degree of saturation on the clay thus make it possible to vary the nutrient at any pH figure desired. Since all of the ions are adsorbed, it is unnecessary to buffer the medium and therefore the osmotic pressure problem is of no consequence. Then further, since the clay is absorbed on the surface of sand and makes up only a small fraction of the total body, the physical properties of the sandy medium are unaffected.

The efficiency of the plant in absorbing the ions present can be studied very nicely through the use of colloidal clay. The nutrients in the medium are added in the exact chemical quantities, thus the total amount of each element present at the outset is known. Analyses of the medium and of the plants at the termination of the experiment permit in effect the balancing of a chemical equation and in that manner make the determination of the percentage of individual ions absorbed a mere mathematical procedure.

In preparing the colloidal clay, one can saturate a clay particle either wholly with one kind of ions or with definite quantities of each of the several different kinds of ions. This property affords a method of controlling and studying the effect of the degree of saturation of an ion upon the quantity absorbed by plants. Reiterating, colloidal clay approaches the visionary perfect medium since this substance permits a control of the degree of its saturation by any or several ions through hydrogen clay titration by them and likewise similar control of the total ions offered in terms of the amount of clay used, all at relatively constant physical conditions.

Importance of the Colloidal Fraction of the Soil

The use of colloidal clay as a medium for the growing of plants is well founded in fundamental reasoning. The silt and sand portions of soil are comparatively inactive chemically and over the brief periods of time required to mature vegetable crops only the more active, colloidal part of the soil can contribute significant amounts of nutrient ions for growth. Thus the source of nutrients in the soil is its colloidal fraction.

Not all clays are suited as a cultural medium for the growing of plants. The lateritic clays of the southern part of the United States do not have an appreciable exchange capacity. Weathering has taken place to the point where their aluminum silicate nucleus has broken to mainly aluminum and iron clays of an inactive colloidal nature. The clay fraction of the soils in Western United States has not reached chemical stability because of the small amount of weathering which they have undergone. If these clays are used, they keep constantly breaking down to less complex colloidal fractions and at the same time make available for plant use many basic ions originally on the internal structure of the colloidal particle and, therefore, previously unavailable to the plant. The conditions of weathering which the Beidellite clays have undergone make them admirably adapted as a cultural medium. Their weathering has reached a point where the clay has become stable in colloidal properties (4), but at the same time possesses a comparatively high exchange capacity.

Preparation of Colloidal Clay

In the preparation of colloidal clay, a subsoil which is high in percentage of Beidellite clay has been found to be an excellent source of material. This soil is taken and by sedimentation the finer clay fraction is separated from the remainder of the soil which is discarded. The clay fraction, separated to any desired fineness by the centrifuge, is electrodialized, replacing all of the cations with hydrogen ions. After the total exchange capacity has been determined, it is then possible to add the nutrient ions in the amount, ratio and to the pH desired. The clay is then mixed with leached white sand to furnish the desired cultural medium. For some investigations where large quantities of clay are needed, it is impractical to go to the lengths necessary for the preparation of the hydrogen clay. In this event, with some loss in the refinement of the medium, it is possible to place the desired nutrients directly on the original subsoil. The subsoil preparation can then be used in the same manner as are the hydrogen clay cultures. Care must be exercised in the choice of subsoils. It is desirable to select one with a high clay content or conversely one in which the silt and sand fractions are low. The original cations on the clay should preferably be unavailable for plant growth. The subsoil having the highest percentage of hydrogen ions on its clay particles has also the greatest capacity for the addition of the desired cations.

Suggested Uses for Hydrogen Clay

The majority of nutritional experiments on vegetable crops have justifiably been primarily concerned with ways and means of increasing the yield through the use of chemical fertilizers. Also, the quality or grade of vegetables has been usually determined by the external appearance and taste of the product. It would seem logical that there should be a decided increase in the amount of nutritional work carried on for the fundamental purpose of studying crop composition, so that the quality of vegetables can be judged not only by our fastidiousness but also by careful chemical analysis and other indices of the dietary value of the product.

It is well to bear in mind that fundamentally we must go to the plant for the synthesis of the many complex "food substances" which are essential for human life itself and which probably also determine the general health and efficiency of man. Albrecht has shown that nitrogen fixation does not take place with the soybean plant until a comparatively large amount of available calcium is present (1). This might indicate that nitrogen fixation is a synthesis which becomes a part of the plant process only when an adequate plane of nutrition is reached. The total tonnage of the soybean is not increased by the additional quantities of calcium which make nitrogen fixation possible. This information perhaps gives some justification to the hypothesis that vegetable plants will synthesize complex food essentials only if they are grown on soils which furnish a larger quantity of the necessary raw products than what is just essential for maximum vegetative growth by the plant. More specifically, this may mean that calcium, for example, should be added in quantities greater than that which gives profitable increased yields for the reason that the additional quantities of calcium may make possible the synthesis of desirable dietary essentials.

It would seem sensible at least, to study the comparatively few components which go together to make up a plant so that by exercising judicious control over them, the development and chemical composition of the plant can be manipulated at will. Colloidal clay presents itself as the tool for a complete control of cultures for vegetable growth in the study of the dietary importance of the chemical composition of such crops.

Literature Cited

1. Albrecht, W. A. Calcium and hydrogen-ion concentration in the growth and inoculation of soybeans. *Jour. Amer. Soc. Agron.* 10:793–806. 1932.
2. ———— Inoculation of legumes as related to soil acidity. *Jour. Amer. Soc. Agron.* 25:512–522. 1933.
3. ———— Physiology of root nodule bacteria in relation to fertility levels of the soil. *Proc. Soil Sci. Soc. Amer.* 2:315–327. 1937.
4. ————, Graham, E. R., and Ferguson, C. E. Plant growth and the breakdown of inorganic soil colloids. *Soil Sci.* 47: No. 6. 1939.
5. ———— and Jenny, H. Available soil calcium in relation to "damping off" of soybean seedlings.. *Bot. Gaz.* 92:263–278. 1931.
6. Jenny, H., and Overstreet, R. Cation exchange between plant roots and soil colloids. *Soil Sci.* 47:257–272. 1939.