

TEA AND SOIL ACIDITY.

Water Culture Experiments, I.

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The nutrition of a plant is affected by many factors other than the presence of particular nutrients in the soil. These factors are so completely interdependent that it is unwise, when considering nutrition, to think of the soil as apart from the plant and climate. It has been recognised from classic times that different species of plants require different conditions for optimum growth, and that certain plants are indicative of conditions of the soil in which they grow. The suitability of a soil for a particular agricultural purpose may often be determined with greater accuracy from the presence of certain plants growing on it than from an elaborate chemical analysis. The presence of bracken in patana land is regarded in Ceylon as indicative that the soil is suitable for tea cultivation. Though such a criterion may be of great value to agriculturists when selecting areas for tea cultivation, a more detailed knowledge is required of the particular requirements of the tea bush if the soil fertility is to be maintained or increased.

It is well known that acids have an inhibiting effect on the growth of many bacteria and a favourable effect on the growth of fungi. There is also abundant evidence that acidity of the soil is closely connected with the distribution of wild plants. Some species grow by preference upon limestone and similar soils; others appear to avoid calcareous soils. It is not surprising, therefore, that cultivated plants also have particular requirements as regards soil acidity. Potatoes and oats thrive in acid soils, while other crop plants, *e.g.*, alfalfa, may die in an acid soil no matter how fertile.

The use of lime for the correction of soil acidity is amongst the oldest of agricultural operations. The correction or adjustment of soil acidity to an optimum value for a permanent crop, like tea, necessitates an exact knowledge of the plant's requirements in this particular. A general statement such as "Tea does not require lime" is insufficient, because, although tea may prefer an acid soil, it is possible that some soils may be improved by an application of lime, while others, being insufficiently acid, may be benefited by some treatment which will increase their acidity.

The characteristic sour taste—from which the term "acid" was originally derived—is dependent more upon the strength of the acid than upon its quantity. When considering soil acidity in relation to

plant growth, the *strength* of the acid in the soil solution, *i.e.* the hydrogen-ion concentration of the soil, is of greater importance than the *quantity* of acid as measured by titration. Two solutions of different acids may require equal quantities of alkali to neutralise them, but the one, *e.g.* Hydrochloric acid, of which a greater percentage is ionised and which, consequently, has a greater hydrogen-ion concentration, is more strongly acid than another, *e.g.* Formic acid, which is ionised to a much smaller extent.

It is unnecessary to consider here the different theories which have been put forward to account for the phenomenon termed soil acidity. Nor is it necessary to define more accurately what is meant by hydrogen-ion concentration or to explain the methods of its measurement. It will perhaps be sufficient for our present purpose if it is understood that hydrogen-ion concentrations are commonly expressed in terms of what is known as the pH scale.

The hydrogen-ion concentration of pure water has a value of 7 (approx.) in the pH scale and this value may be interpreted as neutrality. The lower the pH value the greater is the degree of acidity; the higher the value above 7 the greater is the alkalinity. It should also be noted that the scale is a logarithmic one and, as on a slide rule, begins at 1 not 0. A pH value of 2 represents a hydrogen-ion concentration 10 times greater than a pH value of 3 and 100 times greater than one of 4, and so on. A solution with a pH value of 5 is therefore 100 times more acid than another with a pH value of 7. Similarly water (pH=7) may be regarded as 10 times more acid than an alkaline solution with a pH value of 8.

In order to ascertain the effect of acidity (hydrogen-ion concentration) on the development of the tea plant, seedlings were grown in water culture solutions of various pH values. Before the actual experiment started, the seedlings were grown in a standard solution for six weeks. Each plant was provided with about 500 c.c. of solution, and light was excluded from the roots. The cotyledons (seed) were removed from the plants in order that any reserve food remaining in them would have no influence on the experiments. At the end of this preliminary period the plants were arranged in five pairs, and each pair was provided with water culture solution of a different pH value. A standard solution was used for all plants; sulphuric acid was used to increase the acidity, and sodium hydrate to render the solution alkaline. The pH values selected were 3.5, 4.5, 5.5, 6.5, and 7.5.

The plants were weighed at the beginning of the experiment and at intervals of three weeks, at which times the plants were provided with fresh solutions. After 9 weeks (Dec. 1st, 1926 to Feb. 2nd, 1927) the experiment was temporarily stopped and all plants were placed in tap water which had been filtered through a Berkfeld filter.

In Table A are given the initial and final weights of each pair of plants for this period. It will be noticed that the plants grown in the solution with a pH value of 3.5 showed the greatest increase in weight, viz., 2.52 gms. As the plants were not of equal size at the commencement, it is preferable to compare the increases on a percentage basis, calculated on their initial weights. These are given in the same table. The smallest increase was made by the plants grown in the solution at pH 5.5. Except for this result there is a direct correlation between growth (as shown by increase in weight) and the degree of acidity of the solution, the better growth occurring in the more acid solutions.

Table. A. First period (December 1st, 1926—February 2nd, 1927.)

Plants No.	pH Solution.	Initial Weight gms.	Final Weight gms.	Increase gms.	Increase per cent.
1	3.5	5.70	8.22	2.52	44.3
2	4.5	8.56	8.48	1.87	28.5
3	5.5	7.03	8.34	1.31	18.7
4	6.5	7.62	9.36	1.74	22.8
5	7.5	6.58	7.86	1.28	19.4

Table. B. Second period (March 3rd—March 30th, 1927.)

Plants No.	pH Solution.	Initial Weight gms.	Final Weight gms.	Increase gms.	Increase per cent.
1	6.5	8.78	10.12	1.34	15.3
2	7.5	9.32	10.50	1.18	12.7
3	5.5	8.96	9.40	0.44	4.9
4	3.5	10.29	12.81	2.52	24.4
5	4.5	8.31	11.10	2.79	25.1

After the plants had remained in filtered tap water for 4 weeks they were replaced in the culture solutions. This time, however, the plants which were previously in the solution at pH 3.5 were transferred to that at pH 6.5, and the plants from the pH 6.5 solutions were placed in that at pH 3.5. Similarly, the plants from the solutions at pH 4.5 and 7.5 were also exchanged, but those previously in the solution at pH 5.5 were replaced in the same solution. The seedlings were allowed to remain in these solutions for 12 weeks (March 3rd to May 30th, 1927) under similar conditions as before. The results obtained during the second period act as a check on those of the earlier period.

It will be seen from Table B, in which are given the initial and final weights of each pair of seedlings for this period, that the plants which previously made poor growth in solutions at pH 6.5 and 7.5 showed the largest increases in weight after they were transferred to more acid solutions. Similarly, the rate of growth of the plants which were, during the first period, in the acid solutions with pH values of 3.5 and 4.5 fell off after they were transferred to solutions with pH values of 6.5 and 7.5. These reversals can only be due to the change of acidity of the culture solutions, and they indicate clearly that tea seedlings require an acid medium for optimum growth.

The poor growth shown by the plants in the culture solution at pH 5.5 was unexpected. As these seedlings were maintained for the whole experiment in the same solution, except for the 4 week interval between the two periods, there must remain some doubt whether their weak growth was due solely to a detrimental effect resulting from an unsuitable degree of acidity. Tea grows well, as a rule, in soil with a pH value of about 5.5. This gives rise to the suspicion that some other factor had a detrimental effect on these plants. Consequently, it is advisable to leave them out of consideration, and to compare only the more acid solutions with those approximating neutrality.

Increase in weight was not correlated with the increase in number of leaves nor with elongation of the stem. Plants which made the largest increase in weight did not necessarily produce the greatest number of new leaves during the course of this experiment.

The experiment showed, however, that pH values of 6.5 and 7.5 tend to induce the production of smaller and yellower leaves, whereas the lower (more acid) values, 3.5 and 4.5, result in the development of normal green leaves. This fact may be illustrated by the following instances. One plant, grown first in the solution at pH 7.5 and later in that at pH 4.5 developed five new leaves. The first expanded while the plant was in the pH 7.5 solution and the second while in filtered tap water. These leaves were yellow and smaller than usual. The remaining three leaves were produced while the plant was in the solution at pH 4.5. These were normal in size and dark green in colour. Another plant, while in the solution at pH 6.5, produced three new leaves; these were sickly and successively smaller. Two fell off before the end of the experiment. After the plant was removed to the solution at pH 3.5 it expanded five more new leaves. These were successively larger and greener in colour.

The most marked effect of the differing degrees of acidity of the solutions was to be seen on the root growth. In solutions at pH 3.5 and 4.5, good root growth was made; numerous new rootlets were developed and these appeared white and healthy. In the less acid solutions no new roots were produced, and the existing rootlets turned brown. After the change over to more acid solutions, the plants with dead rootlets developed new ones which remained white and healthy. When transferred to solutions approximating neutrality the healthy young roots turned brown and flaccid after a short time.

These conditions are well shown in the accompanying photographs. Fig. 1 (Plate 1) is a photograph of the root system of a plant grown in the solution at pH 4.5. Note the young white roots amongst the dead ones. This plant had previously been grown in a solution at pH 7.5 when all the roots had turned brown and flaccid and resembled

those shown in Fig. 2. All the new root growth was made while in the acid solution at pH 4.5. Fig. 2 is of a plant first grown in a solution at pH 4.5 when it had a root system with white healthy roots similar to that shown in Fig. 1, but after transference to the solution at pH 7.5 all the roots turned brown and no new root-growth was made.

As the plants were grown for the purpose of these experiments in water culture solutions, *i.e.*, under unnatural conditions, no very great importance should be attached to any optimum pH value which might be calculated from these experiments. They demonstrate clearly, however, that the growth of tea seedlings can be controlled to a large extent by alterations in the hydrogen-ion concentration of the medium surrounding the roots, and that pathological symptoms, as shown by root-growth and the yellowing and dwarfing of leaves, can be induced with solutions approximating neutrality, and corrected when the acidity of the solution is increased.

Further details of these experiments will be communicated in a later article.
