SOILS AND MANURES.

SOIL ACIDITY AND THE USE OF LIME ON TEA SOILS.

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Lime is a necessary plant food, but practically all soils contain sufficient lime to supply the needs of plants for lime as food.

When lime is used in agriculture it is applied for the purpose of reducing the acidity* of over-acid soils. If it is applied in excess, the soil is then said to be alkaline. An alkaline soil will turn red litmus blue, while an acid soil will turn blue litmus red. If just sufficient lime is added to an acid soil so that it will not redden blue litmus, nor turn red litmus blue, but changes either to a purple colour, then it is said to be neutral.

Most farm crops do best on soils which are only slightly acid. When soil acidity is excessive the soil is said to be "sour," a condition readily recognised by practical farmers, for example on grazing land from the disappearance of clover and appearance of sorrel, and on arable land by the appearance of the disease known as "finger and toe" in turnips. In such cases the land may be made "sweet" again by liming. Even if an excess of lime is applied so that the soil becomes neutral or faintly alkaline, it is still better for most crops than an over-acid soil. In general therefore farms on acid soils are improved by liming, and the condition of soil acidity has been associated with the need of the soil for lime.

When it became known that lime favoured nitrification, that is, the formation of soluble plant food from crude insoluble organic matter, the general need for lime on all acid soils came to be considered an established fact.

The enormous majority of Indian tea soils are exceedingly low in lime, and when samples are submitted to British analysts this fact has always been (and still is) very strongly emphasised, and the use of lime has been advised. Mann, however, in spite of general home experience gives his opinion very definitely that tea soils in general do not need lime. In fact he expresses his conviction that: "The presence of more than a very small quantity of lime must always be regarded as evidence of unsuitability of the land (for tea)," and he also writes: "Small as the percentage (of lime) usually is in Assam soil, I think there is hardly any case where lime manuring is necessary because the soil is exhausted of this constituent. It

* The term acidity in reference to soil is used very loosely and is made to cover several phenomena such as the amount of lime that a soil can absorb and also the actual acidity in the soil or what might be called the intensity of the acidity in the soil. In this paper the reference is more particularly to the actual acidity of the soil rather than to its lime requirement.

may be applied . . . . . to improve the physical condition of the land, ... to eradicate blight, or it may even be put on to correct the acidity of soils, although acidity is unknown in India except in peat bheels. At this time methods of determination of the acidity of soils were not highly developed. We know, now, that tea soils with rare exceptions are acid, and many of the best relatively highly acid. Still, although Mann's facts with regard to the acidity of Assam soils were inaccurate, his advice (probably founded on observation in the field), was as usual very sound, and it is the object of this note to produce evidence in support of his opinion that tea soils in general do not need lime.

The evidence comes under two heads :—

Laboratory work.
Field Experiments.

The laboratory work includes a large number of determinations of acidity of soils from many districts.

The actual lime content of the soil appears to be of small importance. Soils of high lime content are found to do well under tea so long as they are sufficiently acid. Mann for example quotes a good soil from Jafflong containing 0·77 per cent. lime while many good tea soils in the Dooars approach 0·5 per cent. in total lime. These soils, however, contain sufficient acid clay to make the soil reaction definitely acid. The lime soluble in citric acid is a better indication of the actual basic lime present, and this figure for "available lime" rarely exceeds ·05 per cent. in a good tea soil even when the total lime is high. When, however, the total lime is much higher than about 0·3 per cent. the "available lime" is often in the neighbourhood of ·1 per cent., and in such cases the soil may be found to be not acid enough for vigorous tea, or may be even alkaline in which case it has always been found impossible to establish tea. Knowledge of the lime content of the soil is therefore only of value as an indication of the probable acidity of the soil, and hence we get more information from direct measurements of acidity than from measurements of lime content, though the latter are valuable as corroborative evidence. Many methods have been proposed for estimating the acidity of soils, and much time has been spent in trying various methods and modifying them if necessary to see which best serves our purpose, and in this direction much remains to be done.

These facts, however, are already clear, than in general :—

(1) The most acid soils grow the best crops of tea
(2) Soils of low acidity grow poorer tea
(3) On soils which are not acid but are neutral or alkaline the attempt to establish tea has always failed.

It will be understood of course that soil acidity is not by a long way the only factor determining the fertility of a soil for tea, so that a slightly acid soil may prove more fertile than a more highly acid soil which is not so good in other respects. Nor, probably, is it true that no tea soil requires lime.

Planters frequently connect soil acidity with water-logging but so far as our experience goes there is no connection between the two. A water-logged area is improved by drainage and not necessarily by liming.

FIELD TRIALS.

1. *Experiments with Heavy Dressings of Lime at Tocklai.*—For this experiment eight plots planted with three-year old tea, were treated respectively with crushed limestone at the rate of 50, 100, 150, 200, 300 and 400 maunds per acre of crushed lime stone and 100 and 200 maunds per acre of quicklime, while a ninth plot was left untreated. At the end of 1921 all the more heavily limed plots were giving greatly reduced crops compared to the crop from the unlimed plot. Even the most heavily limed plot, however, was growing tea which looked quite fair.

This tea was then uprooted and one-year old plants put in on the same plots without further treatment. Differences in growth very soon began to be apparent. Two years after planting the following remarks applied.

Plot 1.	No lime	... good tea
,, 2.	50 mds. lime	... good tea but poorer than 1
,, 3.	100 mds. lime	... poor tea, noticeably worse than 2
,, 4.	150 mds. lime	... distinctly poor tea
,, 5.	200 mds. lime	... still poorer
,, 6.	300 mds. lime	... very bad
,, 7.	400 mds. lime	... very bad indeed, very little growth since tea was planted

The plots receiving quicklime behaved similarly but were each a little better than the plot receiving the same quantity of lime as crushed limestone.

When young tea was planted on land limed five years previously, then the bad effect on tea of excessive lime in the soil becomes very noticeable ; whereas there had been no effect very striking to the eye, on the tea previously planted on these same plots.

From other trials it appears that this is not only because newly planted tea is more susceptible, but also that it takes some time for the effect of excessive lime in the soil to exert its maximum effect on tea.

2. *The Use of Sulphur on Soils of Insufficient Acidity.*—If soils of excessive lime content are bad simply because insufficiently acid, then it should be possible to improve them by using an acid substance to neutralise the alkaline lime. For this purpose there are not many substances which are cheap and convenient in application. Powdered sulphur appeared likely to answer the purpose best. Sulphur is known to be slowly oxidised in the soil to give sulphuric acid. An application of sulphur therefore slowly increases the acidity of an acid soil, or reduces the alkalinity of an alkaline soil.

In the Spring of 1924, each of the plots referred to in experiment (1) was therefore divided into two halves, and to one of the halves sufficient powdered sulphur was added to produce sulphuric acid enough to neutralize the lime originally added.

By the end of 1924, the improvement on the tea which had been thus sulphured was striking. Bushes which were already nearly dead, did not suddenly become first class tea ; but plants which had received only lime to slow down growth, had made improvement within a year after application of sulphur.

To one of the plots an extra quantity of sulphur was added by mistake so that instead of changing the soil from alkalinity to an acidity of about 450 (Hopkins method) which is the normal for a soil of the Tocklai type, an acidity of over 7,000 was obtained. This figure is about double that shown by the heaviest clays of North-East India, yet the bushes are improving.

Indeed it appears that the range of acidity which the tea bush will tolerate is fairly wide both when measured by the Hopkins method or when the actual acidity (hydrogen-ion concentration) is considered.

Good tea is found on soils with pH varying between about 4·5 and 6·0 yet at Rothamsted it has been shown that a variation of hydrogen-ion concentration from 4·4 to 4·8 is sufficient to distinguish between bad and good wheat.

3. Trials of smaller quantities of lime at Borbhetta.

A block of tea was selected which had been planted with 15 months plants in 1919, and had received no manurial treatment either before planting or during 1919, 1920 or 1921.

In 1921 the block was divided into 64 plots of about $\frac{1}{20}$ th acre each and five plots evenly distributed about the block were used for each treatment.

The treatment under trial is a rotation of manuring covering four years.—

First year	... ...	lime (1922).
Second year	... ...	phosphate and cowpeas (1923).
Third year	... ...	Complete artificial mixture (1924)
Fourth year	... ...	rahar (1925).

The treatment is the same for all plots during the second, third and fourth years; but the quantity of lime applied in the first year varies in each series. By "series" is meant a set of five plots receiving the same treatment.

The doses of lime applied in 1922 included—

Slaked lime.	*Crushed limestone.*
6¼ mds. per acre	7½ mds. per acre
12½ " " "	15 " " "
do " " "	do " " "
25 " " "	30 " " "
	80 " " "

The slaked lime applied was such that 6¼ maunds supplied the same quantity of basic lime as 7½ maunds crushed limestone. Twelve and a half maunds and 25 maunds slaked lime are similarly equivalent in acidity reducing power to 15 and 30 maunds crushed limestone respectively.

Taking the yield of the plots receiving no lime as 100, the following relative yields were obtained:—

	1921 before liming	1922 lime applied in March	1923 bone meal and cow-peas	1924 complete manure
No lime	100	100	100	100
6¼ mds. slaked lime	105	108	105	100
7½ mds. slaked lime	106	98	96	98
12½ mds. slaked lime	103	108	97	94
12½ mds. slaked lime	107	105	102	103
15 mds. crushed limestone	109	105	101	102
15 mds. crushed limestone	105	108	105	100
25 mds. slaked lime	110	114	101	100
30 mds. crushed limestone	113	108	93	93
80 mds. crushed limestone	103	115	104	97

The figures for 1921 were obtained from plucking records for two months only in a year when the young tea gave only 5½ maunds of tea per acre for the whole year. These figures are therefore not reliable. The 1922 figures were from pluckings from the whole season, and the tea in that year yielded .7 maunds per acre. It will be noticed that there is still a loss in yield in every case where lime was applied if the yield in 1924 be compared with that in 1922.

The losses however are in general small only, with regard to small dressings of lime, it may be said that they do little harm. This is quite clear since even the plots which received 80 maunds of crushed limestone per acre averaged 12½ maunds pucca tea per acre in 1924. The point is that these small dressings give no increase in crop, and the expenditure on liming shows no return.

Another experiment was tried using no other manures except lime with the following relative results:—Results are again averages from five plots for each treatment.

	1922	1923	1924
15 maunds crushed limestone per acre	100	94	93
No lime	100	100	100

Again there is a decrease from the use of lime.

Further experiments were tried using small annual dressings of lime, both alone and in conjunction with mineral manures.

The quantities used were approximately—

Crushed limestone	224	lb. per annum per acre.
Sulphate of potash	396	,, ,, ,, ,, ,,
Superphosphate	473	,, ,, ,, ,, ,,
Sulphate of lime	272	,, ,, ,, ,, ,,

The actual quantities were applied after analysis so that they were exactly chemically equivalent. The sulphate of lime is a neutral salt which supplies lime with only very slight change in the acidity of the soil.

Results are again averages from five plots receiving the same treatment

	1921 before manuring.	1922	1923	1924
No manure	100	100	100	100
Limestone only	113	112	112	104
Potash only	91	95	100	101
Potash and limestone	118	107	111	101
Super. only	113	111	113	99
Super and limestone	111	108	108	96
Super, and potash	95	96	108	95
Super., potash and limestone	104	101	105	95
Sulphate of lime	108	106	103	97

The differences are small, and irregular, but it is clear that in every case where limestone is used the crop is reduced. The use of the neutral sulphate of lime also reduces the crop.

The results from all these experiments are irregular, and not as concordant as could be desired. Variation due to differences in fertility of the different plots before treatment are not eliminated even by averaging from five plots for each treatment. Still in every case where lime is used the crop is definitely reduced and the number of cases where this occurs is too large to be put down to coincidence.

In our opinion it is already clear that the use of lime on Borbhetta and Tocklai soils gives no increase of crop, but a definite loss of crop, which is at present small.

This is the more remarkable since the soil is relatively highly acid, and liming would undoubtedly prove beneficial for most crops. On the very plots on which lime caused a depression of the tea crop, the cowpeas grown in 1923 showed a decided preference for the limed plots in that the more heavy the dose of lime the heavier was the crop of cowpeas grown. The cowpeas crop from the most heavily limed plots averaged just about double that from the unlimed plots. On adjoining land we had previously found that both guinea grass and maize were benefitted by lime, while jowar could not be made to grow at all without the use of lime (see Q. J. 1919). On the Government Experimental Farm just over our fence all crops tried including sugar, cowpeas, mustard and rahar benefit markedly from lime, while oats would not grow at all without it. It is clear then that different plants show different requirements for lime on the same soil, and that here is one case at any rate when tea requires no lime on a soil where most plants do require fair quantities of lime.

EXPERIMENTS ON GARDENS.

In addition to the experiments described there are about 60 other experiments on the use of lime on different tea estates mainly in the Dooars. These have been in progress for three years only, in which case initial differences in the fertility of the soil before it was under experiment make exact comparisons extremely difficult.

The results therefore are not yet worth quoting in full. Records however are being carefully kept and in no case has a limed plot shown an increase over an unlimed plot sufficiently great to be considered significant, while in the great majority of cases, the evidence pointing to a small depression in crop from the use of lime is fairly clear.

There is a certain amount of evidence that soil acidity may be associated with increased liability to attack by mosquito blight, and on two classes of soil the use of lime appears to give very slightly increased crop when mosquito blight is present. These are the heavy acid red clays of the Dooars Red Bank and the dark acid sands ("Mal sands") of the Western Dooars. On other soils this increase has not been observed, while it is still doubtful whether the apparent increase on these two classes of soil is really significant.

Other cases where lime appears at first to give increased crop are where lime is used in conjunction with either an organic manure (like oilcake or animal meal) or with sulphate of ammonia. In such cases the use of lime often gives a small increase in the year of application. The increases so obtained, however, are not equal to the increase

obtainable by the same expenditure on additional nitrogen. It appears probable that the increase obtained is due to the increased immediate availability of the nitrogenous manures, and is not due to the lowered acidity of the soil. These cases also will be watched and further investigated.

The chief exceptions to these observations come from gardens in the Doom Dooma district where carefully conducted experiments show that liming has an undoubtedly beneficial effect on certain soils. Here a dose of 80 maunds lime per acre generally depresses the crop or gives a small increase but smaller doses of 60, 40 or 20 maunds, give increases varying from 10 to 16 per cent. above the non-limed plots. An application of 10 maunds gives an increase of about 3 per cent.

CONCLUSIONS.

Our opinions, on the evidence available may be briefly expressed thus:

Tea only grows well in soils which are definitely acid, and a relatively high degree of acidity appears to favour rapid growth, a high degree of acidity appears to act as a stimulant to tea, but stimulants in excess may prove harmful and such an excess is reached when very heavy top-dressings of acid peat-bheel are applied to sandy soils very low in lime as are Surma Valley teelas. In such cases the first effect has always been an enormous increase in crop, which is followed in later years by serious deterioration of the tea due to attack by disease. In such cases lime has often proved useful; and although we have no definite experiments in support of the supposition, it is probable that lime would in some cases, prove useful on very acid peat-bheel soils which are suffering from diseases.

Certain root diseases also are encouraged by excessive soil acidity, and will not grow in alkaline soil; these diseases may be usefully treated with lime.

On excessively heavy soils an application of lime will render the soil more permeable to water and to plant roots: in such cases lime may often prove valuable if used in quantities which still leave the soil definitely acid.

With the exception of such cases, lime on tea soils in small quantities is likely to have generally no good effect, while in quantities large enough to reduce the soil acidity greatly, it will cause definite loss of crop.—Quarterly Journal of the Indian Tea Association, Part 1, 1925

THE CONTROL OF THE BIOLOGICAL FACTOR IN SOIL FERTILITY BY IRRIGATION.

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Recent advances in our knowledge of the science of soil biology have led to the general conclusion that the relationship between soil fertility and the bacterial action upon which this depends, is mainly determined by the water-supply in the soil. The aim, generally unconscious, of the cultivator in this respect is in most cases to secure nitrification of the organic nitrogenous matter either present in, or added to, the soil, and the measure of