
THE GROWTH OF CLOVERS AT DIFFERENT LEVELS OF SOIL ACIDITY

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The popular belief among many is that clovers will not grow in acid soils, and for this reason large quantities of lime are often used to make soil less acid in an attempt to increase clover growth. At the Grasslands Division of the Department of Scientific and Industrial, Research at Palmerston North there have been a number of experiments over the past few years which serve to raise doubts about the truth of some statements normally accepted as axiomatic as far as clover growth and soil acidity are concerned. Our experiments have been conducted in a number of ways, and some of these will be dealt with in detail.

First, for those not so familiar with technical terms, the following are the words normally used to express soil acidity. Such acidity is often referred to as "soil reaction" or "hydrogen-ion-concentration," and this is usually expressed in pH units. These pH numbers go from 1 to 14, a soil of pH 7.0 being neither acid or alkaline, while one of pH below 7.0 is acid and one above this is alkaline. On the acid side one must understand that the smaller the pH number the greater the acidity, so that a soil pH 5.5 is more acid than one of pH 6.5, and one of pH 5.0 is more acid still. The most acid mineral soils recorded in New Zealand have a pH of just over 4.0, while many peats are still more acid with a reaction as low as pH 3.0. However, the majority of the agricultural soils have a pH of between 5.5 and 6.5, so this will give a basis on which to make comparison with the acidity levels given in the trials to be detailed.

The first experiment was conducted in large pots using a fertile soil of pH 7.2. Some of this soil was brought to varying levels of acidity by saturating for 24 hours with sulphuric acid of different strengths followed by thorough leaching to remove all bases displaced by the acid. This treatment may sound very drastic and very artificial, but other workers have used it satisfactorily and agree that it produces an effect very similar to that obtained from a long term

of natural weathering. (Reid, 1932 ; Lundegarh; 1931.) The treatments used produced soils of the acidities listed below, and to show that the acidity was due to a reduction in bases and not just free acid from the treatments, figures for total bases after treatment are detailed also :—

TABLE I

Treatment letters	Acidity of soil after treatment in pH units	Total bases after treatment (m.g. equivs. per 100gms. soil)
A	7.2	17.32
B	6.7	14.93
C	5.9	12.41
D	4.5	6.96
E	3.6	2 . 8 3

After the treatments the soils were left standing for a few weeks, then placed in large pots and planted with clones of the following clovers:—Pedigree white clover (Type I), Type II white clover, Montgomery red clover and broad red clover or cowgrass. Five replications of each clover strain were used for each soil treatment, and plants were cut as required and dry weights recorded. The average clover yields for twelve months after planting are given in Table II.

The main points of interest in the results in Table II can be summarised as follows:-

1. White clover (pedigree) :-Definite superiority of yield at pH 5.9 and 4.7. All differences highly significant.

2. White clover (Type II) :-Significant yield increase only at the acid level of pH 4.7.

3. Red clover (cowgrass) :-All yields much, the same at pH 7.0 to 4.7.

4. Red clover (Montgomery) :-Yields at pH 6.7 and 5.9 definitely greater than at other pH levels.

5. Red clover (Montgomery) -root growth :-Weights of plant roots of this species. decrease sharply as acidity increases and show no co-oreation with herbage yields from the same plants.

In the second experiment a more acid soil was used and the trial carried out a plot scale. The trial area originally had a pH of about 5.0 and sulphur was mixed into the soil to a depth of 6 to 9 inches to bring two plots to different levels of increased

acidity, while on another plot slaked lime was added to decrease the acidity. On yet another gypsum was added to supply calcium equivalent to that in the lime without altering the acidity. At the end of six months, when the acidity levels were fairly stable, the following plots were available for planting:—

Plot	Treatment	Acidity Level
A	Gypsum ($6\frac{3}{4}$ tons per acre)	pH 5.0 \pm 0.2
B	Slaked lime (3 tons per acre)	pH 7.0 \pm 0.2
C	Sulphur ($\frac{1}{2}$ ton per acre)	pH 4.0 \pm 0.2
D	Sulphur ($2\frac{1}{4}$ tons per acre)	pH 3.0 \pm 0.2
E	Control-no treatment	pH 5.0 \pm 0.2

The majority of replications of these treatments were to be planted with white clover, but one set of plots was used to investigate the establishment of many pasture species at these acidity levels. For this study plots A, B, C, D, and E were crossed with treatments of superphosphate (3 cwt. per acre) and urea (3 cwt. per acre, to supply nitrogen) while the most acid plots C and D had strips limed to about pH 6.5.

The following diagram shows the layout of these plots at the time sowing took place:-

Lime	Control	Control	Lime	Control
+ - -	Three cwt.	Superphosphate	- - - -	- - +
+ - -	Untreated control		- - - -	- - +
+ - -	Three cwt. of urea to supply nitrogen		- - - -	- - +
Block C	Block A	Block E	Block D	Block B
pH 4.0	pH 5.0	pH 5.0	pH 3.0	pH 7.0

On each of the above plots all the main pasture species were sown, including the most important clover and *Lotus* species with which we will now deal.

In the first few weeks after sowing, it was very noticeable that in the extremely acid plot (D) there was absolutely no establishment of legumes except where the acidity had been reduced by liming, while on all the other plots germination and establishment were good. The plot C, at pH 4.0, was of particular interest because of the marked response by nearly all

T A B L E I I

AVERAGE PLANT YIELDS AT VARYING SOIL ACIDITIES

Yields are in grams of dry matter per plant. Relative figures are given in brackets (A = 100).

	Diff. for significance		A	B	C	D	E
	5%	1%	pH 7.0*	pH 6.7"	pH 5.9*	pH 4.7*	pH 3.7*
1. White clover, pedigree (Herbage)	10.0	13.9	43.8 (100)	65.1 (147)	87.5 (200)	89.2 (204)	24.8 (57)
2. White clover, Type II (Herbage)	13.0	18.0	26.5 (100)	31.8 (120)	31.4 (118)	48.6 (183)	21.1 (80)
3. Red clovergrass (Herbage)	18.4	25.1	44.5 (100)	42.4 (95)	50.5 (113)	44.5 (100)	23.5 (53)
4. Red clover, Montgomery (Herbage)	23.1	31.9	84.5 (100)	12.0 (144)	123.0 (146)	89.0 (105)	29.3 (35)
5. Red clover, Montgomery (Roots)			52.4 (100)	44.8 (85)	26.8 (51)	15.6 (30)	10.5 (20)

* As in the pH levels altered during the experiment, the figures-used are those taken midway in the experiment.

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the clovers to both the phosphate and the nitrogen added. The only clover that did not respond to these applications 'was red clover, which grew very poorly at that acidity. However, white clover (*Trifolium repens*), subterranean clover (*T. subterraneanum*), strawberry clover (*T. fragiferum*), *Lotus major*, *Lotus hispidus*, and *Lotus corniculatus* all grew fairly well except where no fertiliser was added, and it is of interest that where the phosphate was used nodulation occurred on all these species. Where lime had been applied to this acid plot the early growth was not as good as that where phosphate or nitrogen was used, but later most of the clovers on the limed strip did show a slight superiority over those on the rest of the plot.

The untreated plot, with pH about 5.0, along with the lime and the gypsum plots, also showed an initial benefit from the urea and phosphate, but on all these growth was fairly good even on the unfertilised strip. In fact after a month or so there was very little to choose between any of these plots, and certainly the one limed with an equivalent of about 4 tons of agricultural lime showed no superiority over the area at pH 5.0 where phosphate had been applied. Similarly no benefit was shown from using the gypsum instead of lime as a source of calcium.

A third trial of interest, where different results were obtained, was a pot trial using two different soils from the Rotorua area. (Actually these were obtained from the Atiamuri district.) These soils were placed in pots and treated with a wide range of fertilisers in an attempt to find their requirements for obtaining rapid pasture establishment. Both soils were naturally fairly acid, pH 5.0 approximately, and one showed a marked lime response when Virginian stock was used as an indicator plant. On both soils, clover establishment and growth were excellent when a complete fertiliser (N,P,K) was used along with 7 cwt. of lime (giving pH 5.5 approx.), but when the lime was increased to 28 cwt. the clover growth was very poor indeed. This amount of lime on these light soils had reduced the acidity to about pH 6.7 and this had evidently caused some essential nutrient to become deficient, thus limiting growth. As a check on this effect, pots had been treated with gypsum to provide an equivalent amount of calcium without reducing the acidity, and on these the clover growth was excellent. Further pots of these soils were also leached with sulphuric acid to increase the acidity to about pH 4.0,

and this treatment reduced the clover growth considerably even when the complete (N,P,K) fertiliser was used, although growth was normal where gypsum also was added to provide calcium. Thus on these soils growth was good at pH levels of from 4.0 to 5.5 when N,P,K, and Ca were applied, while the same fertilisers at pH 6.7 did not produce good growth. This again illustrates the ability of clovers to grow well under very acid conditions as long as nutrient requirements are met.

These various experiments help to illustrate the complex nature of soil acidity, and this is a point that must be stressed, for the actual acidity as measured by the pH value is not always a true indication of the usefulness of the soil as a growing medium. In this connection the following list (partly adapted from Hewitt, 1945) shows factors that may be concerned in the resultant plant growth:—

A. Direct acidity effects, i.e., excess of hydrogen ions.

B. Biological effects. Most micro-organisms and macro-organisms function best within fairly narrow pH ranges.

C. Nutrient availability. May be so available to be toxic, or may be too deficient for normal growth.

(1) On acid soils

a. Increased availability of manganese, iron, copper, or aluminium may cause toxicity.

b. Phosphate may be so fixed as to be deficient.

c. Low base status may result in complex magnesium, sodium, potassium, or calcium deficiencies, or in nutrient imbalance.

d. Direct calcium or molybdenum deficiencies.

e. Low nitrate production (indirect biological effect).

(2) On neutral or alkaline soils

a. Iron, copper, zinc, manganese, or boron may be deficient, causing chlorosis, stunted growth, or disease.

b. Bases may be so available as to make plant growth impossible.

To elaborate further, one can take the case of the element iron. If a soil is very acid; iron may be so available that it causes direct toxicity to the plants, or it may tie up the soil phosphate in an unavailable form, resulting in phosphate deficiency. If, however, the acidity is reduced and the pH raised even to just

over pH 6.0, the iron may become deficient and result in chlorosis of the plant.

Perhaps the complexity of soil acidity may be clarified if we compare it with the temperature of the human or animal body. We all know that an altered temperature 'is often a symptom of internal trouble; it is not the disease itself but is a result rather than the cause of illness. However, if the temperature change is very great, this abnormal temperature in itself can cause further illness or even death. So in soils an alteration in acidity is usually the result of changes in soil chemicals, but if the pH change becomes very great, this in itself may either inhibit plant growth or else cause further chemical changes which may have a similar effect.

The main use of the pH in the soil as a guide to *its* suitability for plant growth arises partly from the fact that pH is normally fairly well correlated with the base status of a soil and with the availability of certain nutrients, but there are many exceptions to this general rule and it must be fully realised that the soil pH on its own is not all that matters. Thus it is found, for instance, that when a soil contains amounts of active organic matter the pH can usually, be either very high or very low without producing much change in plant growth, whereas the same level of acidity in a soil low in humus might completely inhibit or at least very severely restrict plant growth.

In the foregoing sections we have generalised to a great degree as far as plant growth is concerned, for it is true that there are certain plants which definitely prefer soils of a very specific level of acidity, and which may cease to exist if the acidity is altered by even pH 1.0. However, as we have seen, most plants, including the clovers important in New Zealand agriculture, will grow well over a wide range of acidity, say from pH 4.5 to pH 7.5, as long as the nutrient status of the soil is adequate. This fact leads to the statement that the nutrient supply is of greater importance than the soil acidity as far as average plant growth is concerned. The nutrient level is normally maintained by the application of fertilisers, which are required first to build up the level of certain elements that may be limiting growth, and secondly to replace the amount removed every year by the animal body and by drainage. In this connection the use of lime, with, of course, other materials such as superphosphate and potash where necessary,

has, an undoubted place in agriculture, for even if no large amounts are required to raise the base content of the soil or to decrease the soil acidity, regular applications are required to replace the amounts lost every year and so to maintain the calcium status of the soil. The extent of the annual losses is largely dependent on such factors as rainfall, soil permeability, drainage, and the original level of lime in the soil, but for general purposes it appears that 2 or 3 cwt. of lime per acre/year will counteract losses on the average agricultural areas in this country. When liming is undertaken care must at all times be exercised not to overdo things, especially on areas where, for instance, boron or manganese is known to be at a rather low level, for these elements are certainly liable to become limiting deficiencies if the pH is raised much by over liming. This danger is especially real on light sandy or pumice soils, for the acidity in these cases is easily altered and a medium dressing of lime will often cause a considerable alteration in the level of acidity, while on a heavy clay soil the same rate of application may cause a minor pH change that is not likely to alter nutrient availability. Thus, as we have seen, in the trials mentioned earlier, less than $1\frac{1}{2}$ tons of agricultural lime caused a very marked depression of clover growth on the two Rotorua soils; whereas more than double this amount on the Palmerston North soil did not have any detrimental effect, even though the initial level of acidity was the same on both soils.

After a consideration of all these factors it is seen that most clover species can grow well over a wide range of soil acidity and that poor clover growth on the average soil in this country is not likely to be caused by soil acidity in itself, but is probably due to the low level of one or more essential nutrients in that soil.

REFERENCES

- Hewitt, E. J. (1945) The Resolution of the Factors in Soil Acidity. Ann. Report, Long Ashton Res. Station, P. 51.
- Lundegarth, H. (1931.) Environment and Plant Development. Arnold, London.,
- Reid, Mary E.. (1932) The Effects of Soil Reaction Upon the Growth of Several Types of Bent Grasses. The Bull. of the United States Golf Ass. Green's section., Vol. 12: 196.