ESTABLISHMENT OF LUCERNE IN PUMICE SOILS

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In some areas of the droughty pumice soils of the central North Island considerable difficulties have been experienced in attempts to grow lucerne, especially in the Reporoa and Galatea districts and to a less extent at Taupo. The work described in this paper was carried out at Galatea on an area of low fertility with no history of topdressing.

Soil Type

Galatea sand is a light droughty soil derived from the Kaharoa ash and consists of a 4-6 in. layer of black friable sand overlying 20 in. of loose, fine pumice gravel. The blackness of the topsoil is caused by an increase in the organic matter and is a characteristic of a number of soils derived from volcanic ash. The Kaharoa ash overlies a brown pumice gravel, Taupo lapilli. A fuller description of this soil has recently been published in a Soil Bureau bulletin.

Climate

The district has a 50 in. rainfall, but this is not particularly well distributed and there is usually a drought of up to two months during summer from late December to February. On these free-draining soils, which dry quickly, lucerne is a staple crop, providing both feed during the dry summer and hay for the cold winter, which lasts from June to October and during which little pasture growth occurs.

Difficulties with lucerne on these soils are experienced in the establishment phase. Inoculated seed, sown in October or Novetnber in well prepared seedbeds adequately topdressed with phosphate, potash, and boron, will germinate and grow well for three weeks. After this plants become progressively more nitrogen deficient, levels falling below 2 per cent, and the majority die during the dry summer. The few survivors, with careful nursing for two or three years, produce reasonable plants, but these suffer considerably from weed competition.

Initial investigation showed that although extreme care was taken with inoculation and sowing, most plants did not nodulate, and the introduced *Rhizobium meliloti* disappeared rapidly from the soil. The only plants surviving the first season are those which

have nodulated, and even in these nodulation may be delayed for several weeks, causing a virtual cessation of growth and reducing plant vigour. Some small improvement in nodulation is achieved and more plants survive if an old lucerne stand is ploughed up and returned to lucerne. No other field legume is affected in this way in these soils; clovers, lotus, and lupins all nodulate well and little or no improvement has been obtained with inoculation.

Field Trials

To study the problem more closely a field trial was laid down in the spring of 1960. This trial was designed to study three aspects of the problem:

(1) To ascertain the role, if any, of soil fertility including the possible effects of the trace elements copper, molybdenum, boron, and cobalt.

(2) To attempt to increase the population of ***Rh.*** *meliloti* in the soil by growing lupins and clovers inoculated with this organism.

(3) To discover whether reducing soil surface temperatures by the use of lupins as a cover crop had any beneficial effect.

Each treatment was replicated three times and plots received a basal dressing of 6 cwt of superphosphate, 2 cwt of potassium chloride, and 10 cwt of lime. Seeds were lime pelleted and inoculated immediately before sowing.

Rhizobial counts were made on rhizosphere samples of both lucerne and lupins by a method with a sensitivity of 50 rhizobia/ gram of soil. Under normal conditions the rhizobial population would be expected to rise rapidly and after 10 days have reached about 1 million/gram from an initial inoculation of a few thousand/seed. In the above trial no rhizobia were recovered from any treatment ten days after the plants appeared. Plots which were topdressed with ammonium sulphate gave satisfactory luceme growth until the nitrogen supply was exhausted, after which the plants died.

A second field trial to examine the survival of different strains of ***Rh.*** *meliloti* was laid down in February 1961 after autumn rain. Eight strains of rhizobia isolated from nodules on plants surviving in old lucerne stands on the problem soils and four strains obtained from the U.S.A. and Australia were used. Seed was inoculated with approximately 2,000 rhizobia each from freshly grown cultures and sown immediately into small plots. Three replicates were set out in a random design for each bacterial strain. Counts were made at germination and then at weekly intervals for four months.

Although rhizobia were recovered initially from most plots, after two weeks they were found only rarely and no evidence of any population increase was obtained over the period.

A further trace-element trial was put down at this time, but this too was a failure and only very few plants survived.

Glasshouse Trials

A large sample collected from the O-3 in. layer of an infertile Galatea sand was used for pot trials at Rukuhia, and two experiments were carried out. The first was designed to examine whether nodulation would take place in the glasshouse with adequate nitrogen to stimulate root growth. In this experiment the problem soil was compared with Hamilton clay loam, in which nodulation occurs quite readily.

Similar treatments were applied to both soils as follows:

(1) Inoculation only.
(2) Inoculation plus 2 cwt of ammonium sulphate.
(3 j No inoculation.
(4) No inoculation plus 2 cwt of ammonium sulphate.

Ten pots each with four plants were used in each treatment. Plants were grown for four months and then examined for nodulation, and an attempt was made to recover rhizobia from the root zone of inoculated plants.

TABLE 1

	Treatment	Percentage Nodulation	
		Galatea sand	Hamilton clay loam
Control	Inoculated	30 (9.0)*	100 (62.5)
	Uninoculated	—	—
Nitrogen	Inoculated	18 (1.4)	100 (27.4)
	Uninoculated	—	—

* The figures in brackets are the average number of nodules per plant on the nodulated plants.

Approximately 10^8 rhizobiagram were found in the rhizosphere of plants from the Hamilton clay loam, but as in previous experiments with Galatea sand, a few thousand rhizobia were found only around those plants with nodules.

In the second experiment, soil was partially sterilised by heating to 80 degrees C for 45 minutes. The treatment had a profound

effect on the soil organic matter and a large quantity of mineral nitrogen was released; this delayed nodulation, but as the nitrogen disappeared nodules were produced on all plants.

About this time two further field observations were made. It was noted that in the Taupo district nodules were formed only on roots in contact with decomposing plant material. In the Galatea area, properly nodulated plants were found in a field of recently sown lucerne only where there was a large amount of decomposing organic matter on the site of an old silage stack.

These observations and the results obtained with partial sterilisation suggested that a change in the microbial population of problem soils had a beneficial effect on nodulation and that possibly some biologically produced "toxic factor" was present in the soil. Such a factor might well be destroyed by heat or by changing the microbial population.

Jackman (1960), working with Taupo ash soils, has shown that an increase in pH causes a marked increase in the rate of organic matter decomposition, and this was confirmed for Galatea sand by experiments at Rukuhia. This increase in the rate of decomposition is due to increased availability of the soil organic matter to attack by micro-organisms and could lead to a change in the composition of the soil flora. It seemed possible that such a change might produce effects similar to those which appeared to allow *Rh. meliloti* to survive in this soil. A pot trial, with five replicates, using lime at two and five tons per acre mixed through the soil, was set up. These treatments raised the pH from 5.6 to 6.5 and 7.4 respectively, and as with the partial sterilisation a considerable amount of mineral nitrogen was released. When plants were examined after two months nodules were found on all plants in both lime treatments and no nodules were formed on control plants in unlimed soil. A similar result was obtained in a glasshouse experiment when seed was planted in rows into which lime at 10 cwt and 5 cwt per acre or dolomite at 5 cwt and 2.5 cwt per acre had been drilled.

After these preliminary experiments three field trials were laid down in the spring of 1961. Lime broadcast at 1, 2, 3 and 4 tons per acre was compared with lime and seed drilled at 5 cwt and 10 cwt per acre, control plots received the normal application of 3 ton broadcast, each treatment being replicated three times. All plots had a basal dressing of 6 cwt of superphosphate and 2 cwt of potash.

Plots were examined regularly after the plants appeared and nodules were observed four weeks after sowing.

TABLE 2

Treatment	Percentage of Nodulated Plants
Control	0
Lime broadcast:	
1 ton	66
2 ton	70
3 ton	90
4 ton	50
Lime drilled:	
5 cwt	84
10 cwt	85

Examination of the nodule distribution on plants from these plots showed that nodules occurred only where roots were in contact with lime. One year after sowing nodulation is still restricted to this zone, but the plants are healthy and adequately supplied with nitrogen.

Trials have now been laid down in a number of areas where difficulty is experienced with lucerne establishment in an endeavour to confirm the above findings.

Further work is in progress on the survival of *Rh. meliloti* in these soils in an attempt to elucidate the nature of the toxic agent.

References

Jackman, R. H. (1960): "Organic Matter Stability and Nutrient Availability in Taupo Pumice", N.Z. J. Agric. Res., 3 6.

Vucetich, C. G. et al. (1960): "Soils, Forestry, and Agriculture of the Northern Part Kaingaroa State Forest and the Galatea Basin", D.S.I.R. Soil Bureau Bulletin 18.

DISCUSSION

Q. (O'Reiley): Similar problems with lucerne and subterranean clover have been encountered in Australia and we have had to use up to 2 tons of lime with lucerne. We have had results with massive doses of inoculum, and have also found that if the seed is inoculated and pelleted with certain materials nodulation has been produced effectively. If it is possible to give this protection it may prove successful in the pumice areas and also on the Wither Hills.

Comment (J. Parle): Yes, I am aware of some of the work in Australia. In the pumice area Mr Moody, Farm Advisory Officer, Rotorua, has put down a number of trials with massive doses of inoculum. At Rukuhia we put down a trial with 20 lb of inoculum to the acre. This worked, but we did not consider this amount economic. We found that 4 times the normal amount of inoculum had no effect at all and I think Mr Moody claims that plants were only slightly worse in the control. Pelleting with a large selection of materials has given no results in this particular case.

I am not quite sure why the rhizobia die. If one mixes rhizobia with this soil and there is no plant in the soil, the rhizobia survive, but as soon as a plant is put in the soil the rhizobia die. They die only in the rhizosphere of the plant which is where we want them any way.

Lime seemed to me to be the cheapest way of changing microbial flora in this soil. I am not at all sure whether this is a problem of micro-organism or whether it is a chemical problem associated with the high content of allophane and aluminium in these soils. I am working on this at the moment. I went to lime because with lime one can get an effect which appears to be the same as applying large amounts of organic matter, and high levels of organic matter appear to have some beneficial effect.

Q. (J. Beggs): Why did nodulation break off at the high rate of 4 tons of lime per acre.

A. I have no explanation for this. When lime is put on at these rates all sorts of things happen to the trace elements situation in these soils and this may have something to do with it.

Q. Have you tried mulch on anything of this type?

A. No. One of the local farmers who claims to get unfailing results with lucerne does this. On the area he intends to plant with lucerne he feeds out hay heavily all through the winter, and then ploughs it, and mulches it, and he never seems to have a failure.

Q. Did you drill the lime in contact with the seed? In the Wairoa district, lime in itself has not given results on a soil with a pH of 5.5 to 5.8, but lime plus sulphur has given results.

A. I would not care to comment on your problem unless I saw it. The problem varies in intensity all over the pumice country. It appears to be the most acute on the Kaharoa ash and less acute on the Taupo ash. As far as sulphur is concerned we have obtained nodulation in soils that have never had any topdressing. I just put on some lime and the plants grew and they nodulated without benefit of anything except lime. I don't know what the problem is in the Wairoa district.

Comment (Chairman): The use of lime on its own has been tried out for a long time without much success, and it is not until you get the lime in actual contact with the seed that it does its job.