SYMPOSIUM

SOIL, PLANT AND ANIMAL RELATIONSHIPS IN AGRICULTURAL PRODUCTION

SOILS AND ANIMAL PRODUCTION

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SUMMARY

The relationships between the nature of New Zealand soils and the occurrence and correction of factors limiting pasture and animal production are reviewed. Some problems of the future are considered.

THE NATURE of a soil plays a large part in determining its potential animal production since, together with climate, it determines the amount of fodder that can be grown, its seasonal distribution and its chemical composition. These are three fundamental factors influencing animal production and the manner in which they can be affected by the nature of soils will be discussed in this paper.

In the course of the development of pastoral farming in New Zealand from the grazing of native grass pastures at acre/sheep to present stocking rates of up to 10 and 12 ewe equivalents/acre, many soil weaknesses which have limited animal production have been revealed. After the successful use of soil survey methods in the delineation of the extent of the cobalt deficient "bush sick" soils of the North Island in the 1930s, there has been an increasing use of the soil type and of soil classification as a systematic basis for the study of the soil "weaknesses" which have limited pasture growth and affected animal health. Jackman *et al.* (1962) made an evaluation of the usefulness of the classification of New Zealand soils, and concluded that "the classification has been found capable of providing both appropriate and reasonably accurate predictions in dealing with a variety of practical problems, including those relating to the supply of both major and minor nutrients to plants; to animal and human health; to the siting of forest species and to soil conservation and to social planning."

OCCURRENCE OF SOIL WEAKNESSES

Jackman *et al.* (1962) noted that, of the essential plant nutrients affecting pasture growth, the occurrence of deficiencies of phosphorus, potassium and molybdenum were related to the nature of the soil. Boron deficiency, affecting mainly brassica root crops, can also be related to definite soil types, mainly those from volcanic ash showers (C. During, pers. comm.). The occurrence of severe and moderate deficiencies of cobalt, copper and possibly selenium also can be related to a soil pattern (Jackman *et al.*, 1962) but there are areas of marginal deficiencies which cannot be predicted on the basis of soil type (E. D. Andrews, pers. comm.).

Physical properties of soils also affect animal production. Some soils are more susceptible to erosion than others and have to be treated accordingly. Healy and Ludwig (1965) have some evidence that the nature of the soil influences the amount of soil ingested by sheep and the consequent wear of their teeth. Gibbs (1963) pointed out that the problem of puddling of soils is mainly limited to soils that have a clay content of more than 10% which consists predominantly of the crystalline clay minerals. Where the clay minerals are dominantly amorphous, allophane clays, puddling is not such a problem although the clay content may be as high as 30 to 40%—*e.g.*, the yellow-brown loams from volcanic ash. While these soils are not so susceptible to puddling, they have their biological problems as they are favoured by grass-grub, probably because of their open structure. The closely related yellow-brown pumice soils also harbour the grass-grub, and unfortunately these soils have some property, probably associated with the organic matter, which limits the effectiveness of DDT in the control of this pest.

Gibbs (1963) included many of these soil factors and also climate when he classified New Zealand soils according to the severity of limitations to pastoral production. His classification shows the close relationship that exists between soils and the occurrence of factors limiting pasture growth. His classification can also be used as an assessment of the relative potential animal production of New Zealand soils. The deficiencies of cobalt, copper and selenium which affect animal health directly would be classed as slight limitations according to Gibbs, use of the terms slight, moderate and severe limitations, and hence would not change the position of any soils in his classification.

Jackman *et al.* (1962) and Gibbs (1963) in their reviews have dealt mainly with the relationship between the occurrence of limiting factors and the soil pattern of New Zealand. They mention only briefly how the nature of soils affects the method by which any particular limitation is corrected.

NATURE OF SOILS AND THE CORRECTION OF SOIL WEAKNESSES

When some corrective measure is applied to a soil there is an interaction with the soil which may limit the treatment's effectiveness. The interaction may take the form of fixation by the soil in unavailable or ineffective forms (phosphate, molybdate and DDT), in slowly available forms (potassium), or it may take the form of weak retention in readily available forms which may lose their effectiveness by being lost by leaching through the soil profile (sulphate, potassium, magnesium, calcium). Water could be included in this latter class since water added in excess of the field capacity of the soil is lost as drainage or run-off.

The rate at which these two processes, fixation and leaching, reduce the effectiveness of the soil treatment is largely determined by the clay mineralogy of the soil. The clay mineralogy of New Zealand soils is closely related to their classification into the major soil groups, and is determined largely by the parent material and the degree of weathering of the soil minerals. (Fieldes and Swindale, 1954; Fieldes and Taylor, 1961). There are marked differences in clay mineralogy between the major soil groups, and these differences are reflected in the differing field behaviours of the soils to corrective treatments, particularly their interactions with fertilizers (Fieldes, 1958).

PHOSPHATE

On the basis of field trials and laboratory studies, the major soil groups of New Zealand can be put into four classes according to the rate and severity of phosphate fixation (Saunders, 1966; Karlovsky, 1966; Taraniv, unpubl.) which is apparently the main factor determining the effectiveness, or lack of effectiveness, of phosphate topdressing in New Zealand soils, and therefore the main factor determining the rate and cost of phosphate topdressing needed for any required level of available soil phosphate. For example (Jackman *et al.*, 1962), the establishment of high-producing pasture on a low phosphate fixing soil such as a yellow-grey earth requires 15 to 30 lb P/acre; 50 to 60 lb P/acre is required on a medium phosphate fixing soil, and 60 to 90 lb P on a high phosphate fixing soil such as the yellow-brown loams, the volcanic ash soils of Taranaki and Waikato. This represents a large difference in the cost to the farmer. The effectiveness of added molybdate is similarly affected by the nature of the soils and more information is required, for the different soil groups, of the number of years necessary between each topdressing so as to maintain an adequate level for plant growth and nitrogen fixation but to avoid excessive levels in the pasture which on some soils may affect stock health.

SULPHATE

Sulphate is only weakly retained on the soil colloids and, unlike phosphate and molybdate, it is apparently not fixed except possibly where organic matter is accumulated. Its effectiveness as a fertilizer is lost by its being leached through the soil profile beyond the reach of the pasture roots. It is readily displaced from the soil colloids by phosphate and other soil anions and appreciable losses of sulphate may occur in soils whose colloids have a low capacity to retain anions (organic soils from peat) or which have a low colloid content (coarse yellow-brown pumice soils and yellow-brown sands) (Hogg and Toxopeus, 1966), or in which the anion retention sites have been filled with phosphate following heavy phosphate topdressing (Saunders and Metson, unpubl.). Where appreciable sulphate is lost by leaching, the normal topdressing practices are being modified to minimize the losses, by altering the form of the fertilizer and the time of application (Toxopeus, 1965). On the other hand, in soils which have a high anion retention capacity, sulphate may accumulate with superphosphate topdressing building up a high level of available sulphate. On these soils a sulphur-free phosphate fertilizer could be used for a period.

POTASSIUM

Laboratory studies have shown that potassium may also be lost by leaching from some soils (Hogg and Cooper, 1964; Hogg, unpubl.) and D. E. Hogg has field trials in progress to determine whether leaching occurs under field conditions and whether a less mobile form of potassium, such as potassium metaphosphate, may be used with advantage over the usual potassium chloride. Potassium fixation by the clay mineral vermiculite could occur in many New Zealand soils but there has been little or no work to determine the extent of losses by this process. McNaught and Ludecke (1967) have reported on the effectiveness of magnesium fertilizers in raising the magnesium content of pasture species and the influence of soil on this objective.

Because soil fertility studies in this country, and the term soil fertility is used in its widest sense, are systematically based according to soil type, their results are readily applied by the farm adviser and the farmer. With knowledge of the soil type, the adviser or the farmer can know what nutrient deficiencies or other weaknesses exist in the soils of the farm and also know the most effective form of fertilizer or corrective treatment that can be used. However, soil type alone does not determine the rate of application of fertilizer or treatment to be used, and factors such as type of farm, stocking rate, nature and stage of development of pastures, and available finance are first considered. Then the relative rates of fixation or leaching on the soils of the district or farm can be used to adjust the estimated rates to allow for the loss of effectiveness of the treatment from these soil processes on the particular soils concerned.

A large proportion of work in the future must be toward increasing the effectiveness of fertilizer and other treatments with the object of lowering farm costs by better understanding the reactions that occur between soil treatments and the major soil groups.

MAN-INDUCED SOIL WEAKNESSES

Not only the financial cost of the soil treatment should be considered, but also the cost in terms of adverse effects on the soil. Man is now a very active soil-forming factor in New Zealand and, in general, he acts towards rejuvenating the soils by improving their fertility. However, this is not always true, and the soil scientist should be aware of how various soil treatments are changing different soils. On one soil adverse effects may be negligible, but on another they may be severe. For example, the soluble salt content of water used for irrigation is very critical and, while an appreciable concentration may be tolerated in water used on a soil which is leached thoroughly by the rainwater at some time of the year (*e.g.*, yellow-brown loams, Waikato), only a very low concentration can be tolerated in water used on a soil where natural rainfall only wets the profile but does not effectively leach it (*e.g.*, brown-grey earths, Central Otago).

Potassium deficiency in the yellow-brown loams from volcanic ash of Taranaki and Waikato is a good example of a deficiency induced by man. This was partly through the additions of calcium ions in superphosphate which displaced the potassium from the soil colloids (Dixon and Taylor, 1942; Elliott, 1962) but mainly because the dairy cow transferred the potassium away from the grazing areas in urine and milk (During and McNaught, 1961; Saunders and Metson, 1959).

The displacement of one ion from the colloids of the topsoil by another does not necessarily lead to a limitation of pasture growth, because the pasture roots may recover the displaced ion from the subsoil horizons. However, when the subsoil horizons are of a coarse texture and have a low colloid content, the displaced ion may be lost by leaching, or when the subsoil horizons present some physical barrier to root penetration (*e.g.*, hard pan) or chemical barrier (*e.g.*, high and toxic levels of exchangeable aluminium) again the displaced ion can be lost. The more the concern is with deficiencies of the more mobile ions in soils, such as sulphate, potassium and magnesium, the more the whole soil profile must be considered in nutrient studies and not just the customary top three inches where the immobile elements accumulate.

The continued use of superphosphate and potassium chloride displaces magnesium (Dixon and Taylor, 1942: Hogg, 1962) from the top inches of the soil, and, while there are only small areas of soils where plant growth is affected by magnesium deficiency, there is an increasing body of opinion which holds that animal health is affected by this decrease in soil magnesium levels, and grass staggers in cattle results. It is doubtful whether this is a simple magnesium deficiency. In the early spring, the magnesium levels of pasture are naturally at a minimum, and nitrogen and potassium at a maximum (McNaught, 1964; Metson and Saunders, unpubl.), possibly due to a physico-chemical interaction between monovalent and divalent ions at the soil colloid surface under the normally very moist soil conditions. This imbalance in the mineral composition is associated with the occurrence of grass staggers and it may occur to a greater extent on one soil than another. Soil Bureau workers (pers. comm.) consider that soils with allophane as the dominant clay mineral are more prone to the trouble but they suggest (Metson *et al.*, 1966) that the imbalance and the associated animal health problems are more associated with the soils of stock camps.

As grazing pressure increases with increasing stocking rates, the area of soil affected by stock will increase and the pasture thereon will become an increasing proportion of the animals' diet. There is a need to determine the properties of these "stock" soils, to examine their soil-pasture-animal relationships through all the seasons of the year, and to determine whether soil type can influence these relationships. There is a need to know the extent to which mineral imbalances in the pastures, which have been induced by fertilizer treatment or by "stock" treatment, may affect the nutritional value of pasture.

An outstanding feature of New Zealand agriculture in recent years has been the large increases in per acre production obtained by increasing rates of stocking. There are many people who believe that this relatively simple factor is the answer to increasing the national production. While the national average utilization of grown pasture is only about 30% (Brougham, 1966) there is a large margin of feed to cushion the effects of soil type on animal production, but as utilization is increased, the effects of the weaknesses of soils on pasture production are going to be felt much more violently by animal production, and farming according to soil types rather than according to district will become increasingly important. Conversely, the effects of animal and pasture management techniques on soils are going to occur much more rapidly and will not just slowly appear on occasional farms as at present, but probably will appear as epidemics. There is need for more soil work to evaluate the effects of more advanced production techniques—*e.g.*, high stocking rates—not on a single soil but on a range of representative soils. Soil-plant-animal studies must be given priority and the soil factors in new animal production techniques must be looked for and evaluated under contrasting soil conditions. This will, of course, mean a greater scientific input, but it could save the farmer from even greater expense if he had to adopt the new technique on a trial-and-error basis.

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