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Fig. 1.—A. Typical response at Donnybrook to molybdenum application. No molybdenum has been applied to the plot on the left

MOLYBDENUM FOR SUBTERRANEAN CLOVER

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MOLYBDENUM is one of the elements required for the healthy growth of plants, but it is needed only in very small amounts. Even so it has been shown that some soils cannot meet the requirements of leguminous plants. In Western Australia, molybdenum deficiency of subterranean clover was reported at Donnybrook in 1947, and since then deficient soils have been found at Nannup, Bridgetown and Balingup.

Fortunately the symptoms of molybdenum deficiency are not difficult to recognise and the deficiency is readily overcome by the application of small quantities of molybdenum trioxide, the effect of which can last for a number of years.

Anderson first reported molybdenum deficiency of subterranean clover from South Australia in 1942. Since then Fricke (1944), Anderson (1948) and Newman (1955) have reported the occurrence of the deficiency over wide areas of Tasmania, New South Wales and Victoria respectively.

In Western Australia, Teakle (1945) investigated the effect of molybdenum application on clover growth at a number of sites. Since the original growth increases have been seen on the ironstone gravelly soils in South Australia, this work was carried out on similar soils. At only one site was there any indication of a growth increase.

Later Dunne (1949) reported a very marked increase in clover growth, following molybdenum application, at Donnybrook. It is an extension of this work which is reported here. The only other response to molybdenum application in this State was reported by Rossiter (1951) on clover growing on Muchea sand in a glasshouse.

SYMPTOMS OF MOLYBDENUM DEFICIENCY

Subterranean clover, in common with other legumes, has the ability to use atmospheric nitrogen for growth. This fixation of nitrogen is carried out, in the nodules on the clover roots, by bacteria which live symbiotically with the clover plant.

Although nodules are present on a molybdenum-deficient clover plant, the plant loses the ability to use atmospheric nitrogen. As a result it becomes nitrogen-deficient. The leaves of a molybdenum-deficient plant are uniformly pale green, or yellow, and there may be some reddening of the petioles and older leaves. Leaf size is greatly reduced and the leaves are thin and limp. Often there is plenty of clover in a molybdenum-deficient sward, but the spindly, yellow leaved plants cannot compete with the grasses which become completely dominant.

WHERE MOLYBDENUM DEFICIENCY HAS OCCURRED

Experiments have been conducted in a number of districts in the lower South-West. To date, growth increases have been obtained in the Donnybrook, Bridgetown, Balingup and Nannup districts. Symptoms of the deficiency have, however, been seen along the Darling Scarp as far north as Perth.

The results of some of the experiments conducted in these districts are given in Table I.

TABLE I.

Yield Data (cwt./acre).

Farmer.	District.	Treatment.	Dry Weight.	Clover Weight.
D. P. Reid	Bridgetown	Super only	23·9	10·1
		Super + Molybdenum	31·5	24·8
R. Smith	Bridgetown	Super only	28·1	7·5
		Super + Molybdenum	34·7	18·2
H. Dowrick....	Balingup	Super only	20·2	8·9
		Super + Molybdenum	31·5	21·8
D. Brockman	Nannup	Super only	19·5	....
		Super + Molybdenum	26·6	....

These data show the very substantial growth increases, particularly in clover growth, which have resulted from molybdenum application. The clover yield has been at least doubled in all cases.

THE SOILS WHICH ARE AFFECTED

The affected soils are the red-brown and brown sandy loams to clay loams, derived from granites, schists and gneisses, which occur in the Bridgetown, Nannup, Donnybrook and Balingup districts, and along the Darling Scarp. They contain unweathered quartz fragments and have a pH of between 5.5 and 6.0. There is no evidence that molybdenum deficiency of subterranean clover occurs on soils developed over dolerite, or on the ironstone gravelly soils associated with laterite.

In a past geological age the south-west corner of Western Australia was probably covered by a layer of laterite. The soils which are affected by molybdenum deficiency have developed only where this layer has been eroded away, exposing the underlying rocks to weathering. The resultant topography is that of a deeply dissected penoplain with characteristically steep slopes on which the molybdenum deficient soils occur.

The Muchea sand, on which the response to molybdenum application was reported by Rossiter, does not belong to this group of soils. It is a grey, infertile, slightly acid sand, usually several feet deep, with practically its entire plant nutrient reserves in the humus of the surface layer. This soil type is found on the coastal plain north and south of Perth. It is possible that other similar soils on the coastal plain will also respond to molybdenum application.

THE RATE OF MOLYBDENUM REQUIRED AND THE SOURCE OF MOLYBDENUM USED

In the early experiment at Donnybrook, the first growth increase was not seen until eighteen months after the first application of molybdenum. Although it now seems that this delay was caused by a slow build-up in the amount of clover in the pasture, there was the possibility that the molybdenum trioxide used was only slowly made available to the plants. So, when work

Fg. 2.—B. A response to molybdenum at Bridgetown in 1954. The untreated area on the right has dried off while the treated area (left) has survived the spring drought

was commenced to determine the amount of molybdenum required to cure the deficiency, a soluble source, crude sodium molybdate, was compared with the less soluble molybdenum trioxide. These sources were compared at equivalent molybdenum levels. Since there is about a third as much molybdenum in crude sodium molybdate, (20 per cent.), as in molybdenum trioxide, (60 per cent.), 3 and 6 oz. of crude sodium molybdate have an equivalent molybdenum content to 1 and 2 oz. of molybdenum trioxide.

The results of the experiment are given in Table II.

TABLE II.

Donnybrook (Mr. E. F. Draper's Property)
Yield Data (cwt./acre)

Treatments (rates/acre) Super 2 wt. plus	Dry Weight	Clover Weight
1. Nil	26.4	7.1
2. Molybdenum Trioxide 1 oz.	32.8	15.8
3. Molybdenum Trioxide 2 oz.	40.0	19.5
4. Crude Sodium Molybdate 3 oz.	31.8	14.7
5. Crude Sodium Molybdate 6 oz.	37.6	15.6
For Treatment Means P<.05	5.8	5.6
P<.01	8.1	7.9

Examination of these data shows that the molybdenum sources were equally effective in overcoming the deficiency. The data also show that the higher rate of molybdenum (either 2 oz. of molybdenum trioxide, or 6 oz. of sodium molybdate) gave greater yield than the lower rate, which in turn gave greater yield than the control.

It is therefore recommended that the heavy molybdenum rate—equivalent to 2 oz. per acre of molybdenum trioxide—be used to overcome molybdenum deficiency of subterranean clover. In practice molybdenum trioxide is used because it is cheaper per acre to apply than commercial crude sodium molybdate.

THE RESIDUAL VALUE OF MOLYBDENUM TOPDRESSINGS

No direct determinations of the residual value of molybdenum topdressings at the recommended rates have been made. Information from experimental work outside the state indicates that dressings last from eight to ten years. Observations made on the experiment commenced in 1947 showed that the molybdenum treated plots were still healthy six years later. Controlled experiments are now in progress to determine this residual effect, but as these were not commenced until 1954, it will be some years before results are available.

MOLYBDENUM AND ANIMAL HEALTH

If molybdenum is used in excess, the content in the pastures can build up to a level which can have a detrimental effect on animal health. With the rates of molybdenum application recommended above, this build-up does not occur, as the added molybdenum merely raises the molybdenum level in the plant to normal. However, one application is sufficient to overcome the deficiency and molybdenum topdressings should not be repeated annually. Only where there is evidence that the

effect of the initial application is wearing off should a molybdenum dressing be repeated.

VANADIUM AND MOLYBDENUM DEFICIENCY

Overseas workers have suggested that vanadium can take over the function of molybdenum in nitrogen fixation. Since a high level of vanadium in the herbage has no detrimental effect on animal health, it has been suggested that it may be used, instead of molybdenum, on molybdenum-deficient clover pastures. An experiment at Bridgetown has shown that vanadium has no effect on the growth of molybdenum-deficient clover pastures. The results of this experiment are shown in Table III.

TABLE III.

Yield Data (cwt./acre)

Treatment	Dry Weight	Clover Weight
Nil	23.8	16.4
Sodium Vanadate 1 lb./acre	23.2	16.4
Molybdenum trioxide 2oz./acre	34.7	30.2
Sodium Vanadate 1 lb./acre + Molybdenum trioxide 2 oz./acre	32.8	27.1
For Treatment Means P.05	5.0	5.4
P.01	9.8	7.6

These data show that, while there is a marked growth increase following molybdenum application, there is no difference between the vanadium treated plots and the untreated control.

SUMMARY

1. Molybdenum deficiency of subterranean clover occurs in the Bridgetown, Balingup, Donnybrook and Nannup districts.

2. The affected soils are the red-brown and brown soils of variable textures developed from gneisses, granites and schists which have been exposed as the older, more extensive, lateritic mantle has been eroded away.

3. There is no evidence of responses to molybdenum application on soils derived from dolerite or laterite.

4. An application of molybdenum trioxide of 2 oz. per acre completely overcomes molybdenum deficiency of subterranean clover.

5. Sodium Molybdate is an effective source of molybdenum, but is more expensive to apply per acre than molybdenum trioxide.

6. Molybdenum dressings appear to last from eight to ten years.

7. Molybdenum should be used carefully as it is possible for a build-up in the molybdenum content of the plant to occur and reach a level which is detrimental to animal health.

8. There is no evidence that molybdenum can be replaced by vanadium in fertilisers for molybdenum-deficient areas.

Fig. 3. — Subterranean clover showing molybdenum deficiency symptoms—the leaves are small and very pale green