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INGESTION OF SOIL BY SHEEP

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SUMMARY

Ingestion of soil has been established as the cause of excessive wear of incisor teeth of sheep. The quantities of soil involved can be substantial with greatest amounts taken in by the animal in the winter period when pasture growth is low and appetite high; it is at this period that the bulk of the wear for a year takes place. Provision of supplementary feed at this time can substantially reduce soil ingestion and hence wear.

Although stocking rates and management affect the quantities of soil ingested, soil type is of basic importance in this regard. Soils characterized by strong structure are associated with low levels of soil ingestion, while those with weak structures are associated with a high level of soil ingestion.

The effects of taking in large quantities of soil on aspects of animal health other than tooth wear, such as micro-element intake, and possible insecticide uptake, are briefly discussed.

INVESTIGATION of wear of sheep incisor teeth over the past three years has drawn attention to the substantial amounts of soil that can be ingested by grazing sheep. Initially these studies were directed at establishing the cause or causes of wear and the period of the year when wear is greatest and, although at this stage only a limited number of soils were involved, the importance of soil type on the quantity of soil ingested—and hence wear—was soon evident (Cutress and Healy, 1965; Healy and Ludwig, 1965; Ludwig *et al.* 1966).

Over the past year, measurement of soil ingestion by sheep has been extended to a number of soils important to the sheep industry, in each case intensively farmed units being chosen on each soil type. In all areas, sheep ingested some soil in the winter but the amounts of soil eaten and the period over which soil ingestion was appreciable were related to soil type.

That soils differ in their ability to supply nutrient elements to animals via the pasture they support is well recognized, and the inadequacy of certain New Zealand soils to supply micro-elements such as cobalt, copper and selenium is well known. However, the differences in soil ingestion by sheep on different soils are interesting in that they emphasize the importance of physical properties of soils, such as structure, as distinct from chemical properties, on aspects of animal health such as tooth wear, and perhaps others such as micro-element intake or insecticide uptake.

METHODS

Details of analysis of faeces, and methods of tooth measurement have been fully described (Healy and Ludwig, 1965; Ludwig *et al.*, 1966).

Soils were analysed for macro- and micro-elements to estimate possible amounts of elements absorbed by an animal from ingested soil, by leaching 10 g of air-dried soil with 200 ml of 0.1 N HCl, and determining the amounts of elements extracted by appropriate colorimetric, atomic absorption, and spectrographic techniques.

RESULTS AND DISCUSSION

Wear of Incisor Teeth

The seasonal pattern of soil intake, and the quantities of soil ingested, and their relation to soil type, can be seen from the data relating to excessive wear of incisal teeth.

In Fig. 1, differences in soil ingestion as indicated by soil content of faeces are shown for three Wairarapa

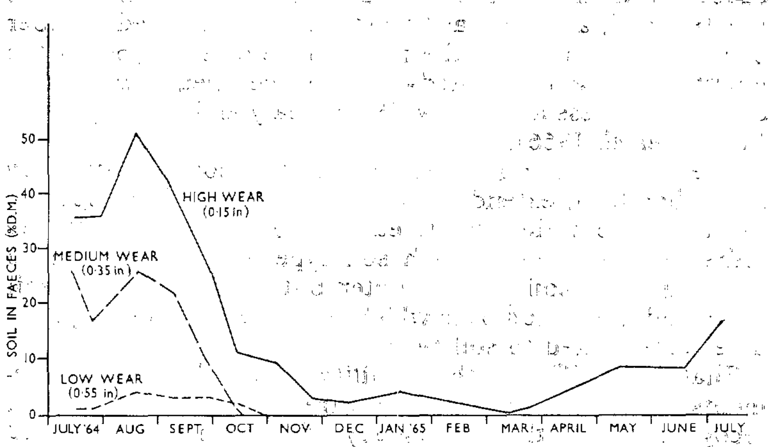

Fig. 1: Soil content of faeces from three farms on different soil types.

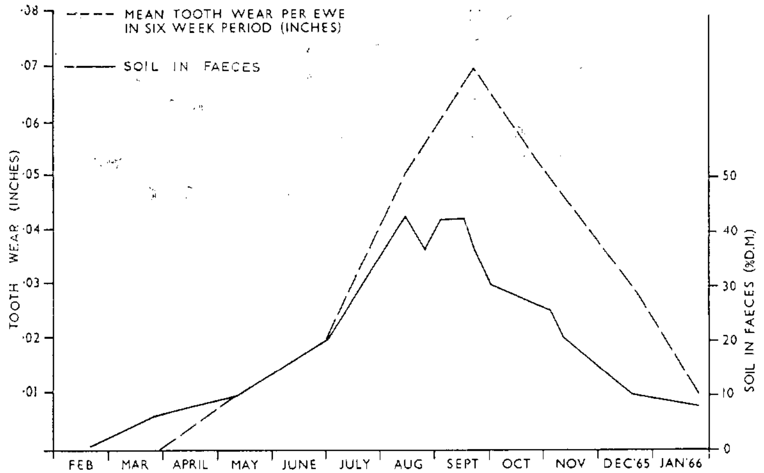

Fig. 2: Relationship between tooth wear and ingested soil at Te Awa.

farms where high, medium and low rates of wear occur. The period from about July to September is characterized by peak soil intakes, which correlate with the degree of wear indicated by mean incisal length for 5-year-old ewes.

The soil on the high wear farm (4 ewes/acre) is a wet yellow-grey earth (Wharekaka silt loam) with a weakly developed structure and compacted B horizon. Draining is impeded in winter and surface casting by earthworms is prominent. The medium wear farm (4 ewes/acre) is on a stony yellow-brown loam (Tauherenikau stony loam) with moderately-strongly developed structure and free draining. It is firmer, less prone to puddling, and with fewer earthworm casts. The low wear farm is at a much lower stocking rate (1 ewe/acre) and this is partly responsible for low soil intakes. It is, however, on a soil with well developed structure (Ruahine steepland soil) which, combined with an organic mat associated with unimproved grasses, and practically no surface casting, explains the negligible soil intake.

In Fig. 2 soil content of faeces from sheep (7 ewes/acre) on Paddock 5 at the Te Awa hill country research area (Grasslands Division, D.S.I.R.) shows a similar high peak in the July-September period. The soil in this area is a transitional yellow-grey earth (Raumai hill soil), with weakly developed structure, impeded drainage, and has abundant surface castings in winter. Included in this figure is the rate of incisal tooth wear and it can be seen to follow closely the pattern of soil ingestion.

That ingestion of soil on soil types associated with excessive rates of wear can be reduced by management is shown by the effects of supplementary feed in Fig. 3. It

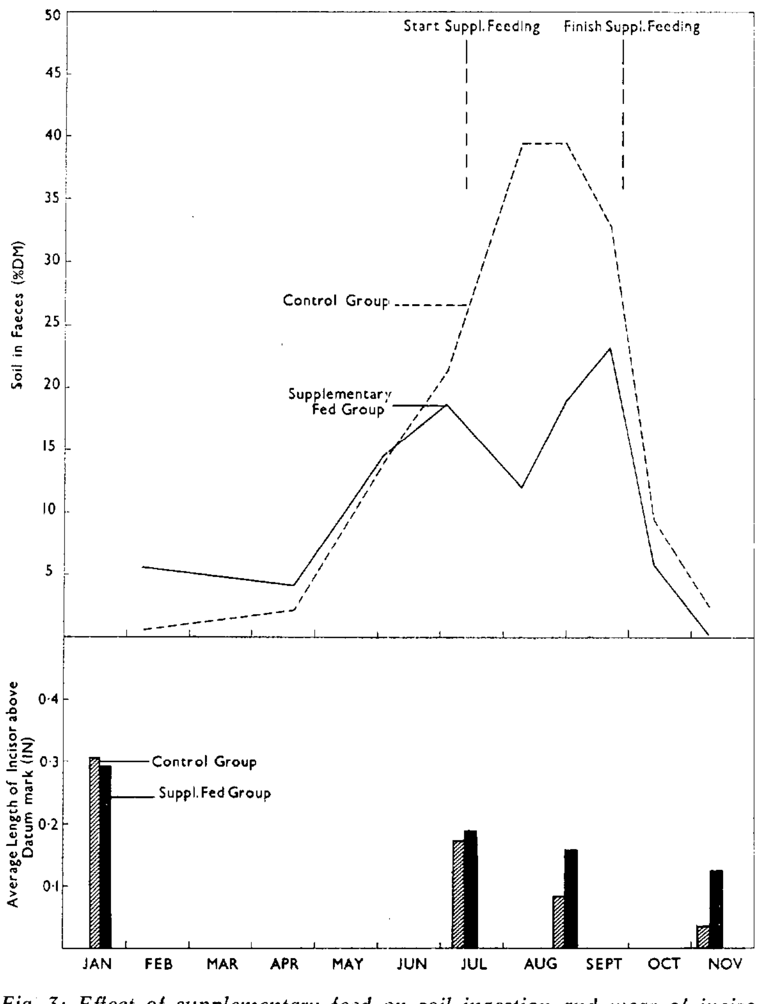

Fig. 3: Effect of supplementary feed on soil ingestion and wear of incisor teeth.

can be seen that, by supplying choumoellier in the July-September period on the high wear Wairarapa farm, peak levels of soil in faeces was reduced by half, and wear at this period reduced by two-thirds as compared with controls. Wear for the year was reduced by about half. A similar reduction was obtained at Te Awa using red clover hay.

THE EFFECT OF SOIL TYPE

Faeces samples were collected from intensively farmed units on a number of soils important in the sheep industry in both North and South Islands. The samples were taken monthly over 1966 and analysed for soil content. In Table 1 the peak soil levels in faeces samples are presented in relation to soil group and structure, since structural properties of topsoils influence puddling, drainage and earthworm casting. Projection of these data enables a broad prediction to be made as to whether soils will be characterized by high or low rates of soil ingestion and this can be seen in Table 2.

TABLE 1: PEAK SOIL CONTENT OF FAECES IN RELATION TO SOIL GROUP

Soil Group	Area	Structure	Peak Soil in Faeces % D.M.
Yellow-brown	N. Auckland	mod-strong	25
earth	Southland	mod-strong	30–35
Yellow-brown	Waikato	mod-strong	10–20
loam	Wairarapa	mod-strong	25
Yellow-grey	Wairarapa	weak	45
earth	Manawatu	weak	45
	Canterbury	weak	20–35
Podzol	N. Auckland	weak	40
Recent (from alluvium)	Manawatu	weak	65

TABLE 2: SOILS ASSOCIATED WITH LOW AND HIGH LEVELS OF SOIL INGESTION

Soils Associated with Low Soil Ingestion	Soils Associated with High Soil Ingestion
Yellow-brown loams	Yellow-grey earths
Yellow-brown earths	Recent soils from silty alluvium
Red and brown loams	Podzolized yellow-brown earths
Brown granular clays	Podzols

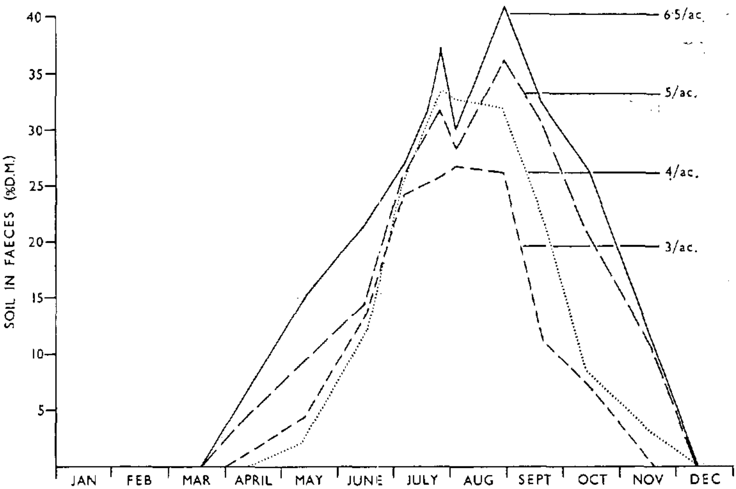

Fig. 4: Effect of stocking rate on soil content of faeces at Te Awa.

It should be emphasized that stocking rates and management affect amounts of soil ingested and are superimposed on the basic soil properties. The effect of supplementary feed has already been discussed, but the effects of stocking rates at Te Awa can be seen in Fig. 4. Not only do peak soil levels in faeces differ, but the duration over which soil ingestion is substantial varies. Since wear becomes appreciable when soil content of faeces rises above 20% of D.M., a comparison of ewes stocked 3/acre and 6.5/acre is made on this basis in Table 3.

Similar data on stocking rates and a comparison with mob stocked animals for samples collected in May and June 1966 from A. Campbell's plots at Ruakura is shown in Table 4. These results are interesting since they show

TABLE 3: DURATION OVER WHICH SOIL IN FAECES EXCEEDS A GIVEN VALUE FOR TWO STOCKING RATES

Stocking Rate (ewes/acre)	No. of Days when Soil Content of Faeces (% D.M.) is: 20–25	> 30
3	70	0
6.5	140	75

TABLE 4: SOIL CONTENT OF FAECES IN RELATION TO STOCKING RATES AND MANAGEMENT AT RUAKURA

Dry Ewes/ac.	Soil in Faeces % D.M. May	Soil in Faeces % D.M. June	Avail. D.M. lb/ac. June
21.5	18	41	200
17.9	22	48	240
16.1	23	44	220
14.3	0	13	610
12.5	2	14	400
10.7	0	3	1,000
3.6	0	4	4,000
15/28d.*	8	10	1,660–220
15/7d.*	4	37	440–310

*Ewes stocked 15/ac., rotated on 28-day or 7-day basis.

that, even on a yellow-brown loam soil which would be considered as being associated with low levels of soil ingestion, by raising the stocking rate sufficiently high, soil content of faeces can increase to a high level. The sharp break in soil ingestion for a comparatively small increase in stocking rate from 14.3 to 16.1 ewes/acre is striking and suggests a sudden deterioration in structure in the upper part of the profile.

Levels of available dry matter in June show an inverse relationship with soil in faeces and also show a sudden break at the same stocking rates. Ewes stocked 15/acre but rotated on a 28-day basis and a 7-day basis show the effect of rotating animals on to fresh feed—the available D.M. figures in this case give values at the beginning and end of grazing.

It is soils such as the yellow-brown loams which can stand up to high stocking rates that will be farmed to high levels, and it can be expected that under such conditions soil ingestion will be high. The effect of soil type will not have disappeared, but, instead of soil ingestions ranging from low to high under comparable stocking intensities, soil ingestion will become uniformly high and the effect of soil type will show in the stocking intensities.

The ingestion of soil in large amounts has other possible effects on animals besides wear of teeth.

MICRO-ELEMENT INTAKE

That grazing animals can ingest some soil when pastures become muddied has been recognized for many years. What perhaps is new is that the amount of soil eaten has now been measured. At peak periods in the winter, a ewe can ingest as much as 400 g (almost 1 lb) daily, so that annual intakes of soil of the order of 50 lb or more are possible, the bulk being ingested in the winter period.

TABLE 5: RANGE OF ELEMENTS EXTRACTED FROM SOIL

Element	(mg per 100 g soil)
Ca	150–500
Mg	10–40
P	5–120
Mn	1–60
Zn	1–5
Fe	3–35
Cu	0.2–1
Mo	0.001–0.1
Co	0.01–1
Ba	1–5
Sr	0.1–2.5
Cr	0.01–1
Ni	0.05–0.5

TABLE 6: POSSIBLE UPTAKE OF ELEMENTS BY SHEEP (MG/DAY) FROM INGESTED SOIL AND PASTURE DURING WINTER

Element	Soil*	Pasture†
Ca	1,500	3,500
Mg	125	1,500
P	350	2,500
Mn	175	50
Zn	15	20
Fe	100	125
Cu	3	4
Mo	0.5	0.5
Co	3.5	0.1
Ba	15	20
Sr	7.5	20
Cr	0.25	0.5
Ni	1.5	0.5
Se	0.05 (est.)	0.05

*300 g/day. †500 g D.M./day.

Assuming that some of the elements in soil can become available from digestive processes, it seems possible that ingested soil may be a substantial source of certain elements for an animal. In view of limited pasture availability at peak soil intake periods, it is possible that at this time animals absorb more of certain elements from soil consumed than from pasture consumed. Andrews *et al.* (1958), for example, consider increased liver cobalt at the end of winter to result from increased soil ingestion.

On the soils selected for the study of ingestion in relation to soil type, the opportunity was taken to make a crude estimate of the quantities of various elements that might be absorbed by the animal from ingested soil and to compare them with quantities absorbed from pasture. The word "crude" must be emphasized as the estimate is based on leaching of soil with 0.1 N HCl. This is a very simple system compared with the varied array of complexing compounds and hydrogen ion concentration present in the alimentary system. It is unlikely that any extraction system in the laboratory can hope to reproduce such conditions but the simple system used here forms some basis for comparison of soils and their contribution to element uptake.

In Table 5 the range of various elements extracted from the soils is given and it can be seen that amounts differ from about 5-fold to 50-fold.

In Table 6 a comparison is made between amounts of various elements that might be absorbed from ingested soil and from pasture. It has been assumed that 300 g of soil is ingested by the animal per day and the highest figures for soils given in Table 5 used to calculate the contribution from ingested soil. Also assumed is that 500 g of pasture D.M. of a given composition is taken in per day and that the elements present are completely taken up by the animal. On this basis, contributions of magnesium and phosphorus from soil are only a small part of that from pasture, but calcium approached 50%. The contribution of micro-elements from soil is, however, much more substantial and in most cases is comparable to pasture contribution, or in the cases of cobalt and manganese would appear to be substantially more. No measurement of selenium extracted was made but a total soil Se of 0.5 ppm is assumed and that approximately one-third of this might be absorbed by the animal.

In regard to ingested soil as a source of micro-elements, it is interesting to look at some of the early work on bush sickness. Rigg and Askew (1934) conducted experiments on bush-sick animals with drenches of soil, limonite, and iron ammonium citrate. Drenching with soil twice a week from October to April resulted in animals free of symptoms of bush sickness, which made continuous weight gains, and which were classed as fat sheep in the autumn. The interesting point is that less than 10 g of soil was given at each drench, making a weekly total of under 20 g. This emphasizes the ability of an animal to absorb cobalt, and presumably other elements, from comparatively small amounts of soil. With intakes of soil of the order of 300 g per day, the weekly total would be just over 2,000 g—*i.e.*, more than 100 times greater than the amount shown beneficial by Rigg and Askew.

In areas where mineral deficiencies in animals occur or are suspected, the picture is usually complicated by the varying incidence, with animals on one farm showing symptoms while those on an adjacent farm do not. Variation in amounts of soil ingested because of differences in stocking rate or management may be responsible for such variation.

As stocking rates rise to meet the demands for increased production, so will soil ingestion. Where stock numbers rise to the stage where supplementary feeding becomes increasingly important, soil intakes may fall sharply, especially if feeding-out techniques minimize access to soil. In some areas micro-element intake by the animal may fall sufficiently to affect nutrition, by such management changes. On the other hand, animal health may improve in other areas where soil ingestion is a source of elements harmful to animals.

INSECTICIDES

It is usually assumed that, after insecticide powder or prills have been washed off pasture, uptake by the grazing animal is negligible. The fact that insecticides can remain concentrated in the upper inch of soil and that sheep can ingest such soil suggested that winter could be a period of potential insecticide uptake. Harrison (1966) has investigated this possibility and does not consider soil ingestion as a serious source of DDT although it probably contributes to the low background level usually found; he does, however, consider that soil ingestion could be a factor in the intake of zero tolerance insecticides such as dieldrin and aldrin.

Animal Health

Apart from the element uptake already discussed, ingestion of soil in large quantities could affect animal health in other ways.

Intakes of soil of the order of up to 400 g/day—perhaps over 150 kg/yr—may have abrasive effects on the alimentary tract. Australian workers (Baker *et al.*, 1961) consider that particulate matter can affect the histology of the rumen walls and that the eroded appearance of certain rumen mucosal surfaces may be due in part to physical abrasion. Abrasion if it occurs could be harmful in its own right as an irritant but may also pave the way for infection.

As stocking rates rise, so does the possibility of stock diseases, and it is possible that ingested soil affects animal health in this way. Greater return of dung and urine associated with the increased soil uptake may increase the possibility of infection. Where infection increases, or there is a change in pattern with increased stock numbers, the possible influence of ingested soil should perhaps be considered.

* * *

The impact of soil on animals is usually recognized as a nutritional one via the composition of pasture. Under New Zealand conditions in winter when animal appetite is high and pasture growth low, ingestion of soil can be substantial, leading to an almost direct soil-animal effect which continues until the spring flush increases pasture availability, and a more normal soil-plant-animal relationship is once more established. Soil type plays an important role, together with management, during the winter period, in determining the amounts of soil ingested, and as such has a direct role in tooth wear and possibly other fields such as micro-element and insecticide uptake, and perhaps stock health.

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