IMPROVEMENT OF LOW ALTITUDE TUSSOCK COUNTRY IN CENTRAL OTAGO

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This paper describes the research work undertaken in the last two and a 'half years into the improvement of run country in Central Otago. The district covers 4,500 square miles of the Clutha and Taieri catchments stretching from the Lakes in the west and Miller's Flat and Middlemarch in the east. About two-thirds of the area lies above 1,500 ft and is the run or pastoral country.

It is only in the last 5 to 10 years, since the control of rabbits and development of aerial topdressing and oversowing, that farmers have been able to take advantage of research findings on run country improvcmcnt.

A typical run in the dry part of Central Otago stretches from the valley floors to the top of the mountain ranges. These properties can be divided into three main zones:—

I. The scabweed and depleted tussock grasslands where the soils are brown grey earths. This zone stretches from above the irrigation races to an altitude of 1,500 to 2,000 ft and is the winter country. On the flatter areas outstanding improvement can be brought about by the introduction of lucerne and lucerne-cocksfoot mixtures by the conventional method of dry land development (I) and on the more extensive scale by the direct surface introduction of lucerne and cocksfoot (2). On the steeper, broken, rocky hill country spectacular improvement can be brought about by fencing the areas and spelling the country during the flowering and seeding period from November to March.

2. The snowgrass associations and other vegetation types which have been induced from snowgrass associations where the soils are yellow brown earths. To use this high country for summer and autumn grazing the runholder is forced to burn the vegetation. Raeside (3) and others have emphasised the serious consequences that burning this country can have on soil and water conservation, and, as you are aware, there are a number of irrigation and hydro-electric schemes which are almost solely dependent on water from these snowgrass catchments.

Burning when carried out judiciously, however, and under the supervision of Catchment Boards or other authorities, is in many cases an essential managerial practice to protect the country against out-of-season fires in the summer or autumn which could do untold harm.

There is a large area of low altitude snow tussock country in the Roxburgh district. This country lies below 2,500 ft and is rolling to flat and dissected by steep gullies; hence the winter snow risk is considerable. It will be shown that this is capable of considerable improvement for spring, summer, and autumn production,

3. It is in the third zone-the belt of fescue tussock country lying between 1,500 and 3,000 ft, where the soils are yellow grey earths and the rainfall is 20 to 25 in.-that research work has pointed the way to greatly increasing production.

Ten years ago runholders had seemingly no alternative but to graze and consequently burn their snowgrass country if they were to remain on their properties, but today we can offer them the alternative of improving their fescue tussock lands and grazing their stock on them during the spring, summer, and autumn.

Valuable information has been obtained by Dr Mark over the last two years concerning the climate on some of the mountain ranges in Central Otago (4). This information is invaluable because it describes accurately the climatic conditions at each altitude and the way in which they affect improvement work. Mark has shown that on the eastern slopes of the Old Man Range precipitation increases from 5 to 20 in. with each thousand foot increase in elevation up to the zone of maximum snowfall and snowlie at 3,500 to 4,500 ft, where it shows a further substantial increase.

Under the higher rainfall of the Lakes district the steep lower slopes are covered in bracken fern, and if the runholder is to use the country he is forced to carry out regular burning. Some runholders, particularly Mr Murdoch Drake and Mr Jim Gillespie of Hunter Valley Station, Lake Hawea, have had outstanding results from burning this country late and then topdressing and oversowing with cocksfoot and clovers. The subsequent management, particularly with cattle, is very important. This improvement work points to the way in which thousands of acres can be developed, Above the bracken fern is the fescue tussock grassland and then the steep snowgrass. On some runs there are large areas of fescue tussock country at low altitudes which are readily improved.

To improve run country legumes must be established successfully. My predecessors working in Central Otago showed that certain species were suited to specific areas (5). Messrs Hercus

and Tothill (6) showed that where the rainfall is less than 20 in. lucerne was the most satisfactory legume and cocksfoot the most satisfactory grass. Where the rainfall is greater than 20 in. red and white clovers were most satisfactory and cocksfoot was again the best grass.

It had been found that before legumes could be introduced successfully plant nutrient requirements had to bc satisfied. In a pilot trail laid down by Mr Hercus in the Kawarau Gorge near Cromwell marked responses were obtained to gypsum. This led to the laying down of a number of trials during the springs of 1958 and 1959. The treatments in these trials are shown in Table 1.

TABLE I-SULPHUR AND PHOSPHATE TRIALS, 19.58 AND 1959

Treatments (lb per acre)

1. Nil	8. Double Super 150	
2. Sulphur 12½	9. Double Super 1.50	+ Sulphur 12½
3. Sulphur 25	10. Double Super 150	+ Sulphur 25
4. Sulphur 50	11. Double Super 150	+ Sulphur 50
5. Sulphur 100	12. Double Super 1.50	+ Sulphur 100
6. Sulphur 200	13. Double Super 150	+ Sulphur 200
7. Gypsum 150	14. Double Super 150	+ Gypsum 150

The sites for these trials were chosen carefully after consultation with Messrs McCraw and Leamy of the Soil Bureau, Alexandra. A number of trials were laid down, but owing to the very dry springs in 1958 and 1959 the clover failed to establish on a number of trials. However, four trials showed outstanding responses. The location, soil, vegetation, and response indicator plants for each of the four sites are shown in Table 2.

TABLE 2—SULPHUR TRIALS IN CENTRAL OTAGO

Location	Soil	Vegetation	Response Indicator
I. Moutere Station, Alexandra.	Pigburn : Brown Grey Earth.	Formerly depleted Fescue Tussock	Lucerne
2. Waitiri Station, Kawarau Gorge, Cromwell.	Arrow: Yellow Grey Earth.	Fescue Tussock Assn.	Clover
3. Glendhu Station, Wanaka.	Bourke: Yellow Brown Earth.	Fescue Tussock Assn.	Clover
4. Teviot District, Bridge Huts—Roxburgh.	Wehenga: Yellow Brown Earth.	Snow Tussock (*Danthonia rigida*) Assn.	Clover

These sites cover a very wide range of climate, vegetative, and soil conditions; in fact, there is an example of each of three major zonal soil groups of Taylor and Cox's New Zealand Genetic Soil Classification (7).

Each trial consists of two replicates and was laid down according to standard procedure. Responses were measured by using fertility index pointings (8). Pointings were made at each trial on a number of occasions throughout the growing season. The results of each pointing were subjected to statistical analysis using Duncan's Multiple Range Test, and parabola curves were plotted.

Moutere Station Trial (Table 2). The trial laid down on 30.12.58, is on a fan soil on the Moutere Terraces north of Alexandra. The annual rainfall is 16 to 18 in.

There has been no response to phosphate alone in this trial, but there has been a significant response to sulphur at 50 to 100 lb per acre. The visual pointings (and the dry matter production figures which are not shown) show that there are indications of a slight interaction between sulphur and phosphate (Table 3).

TABLE 3—SULPHUR TRIAL-MOUTERE STATION

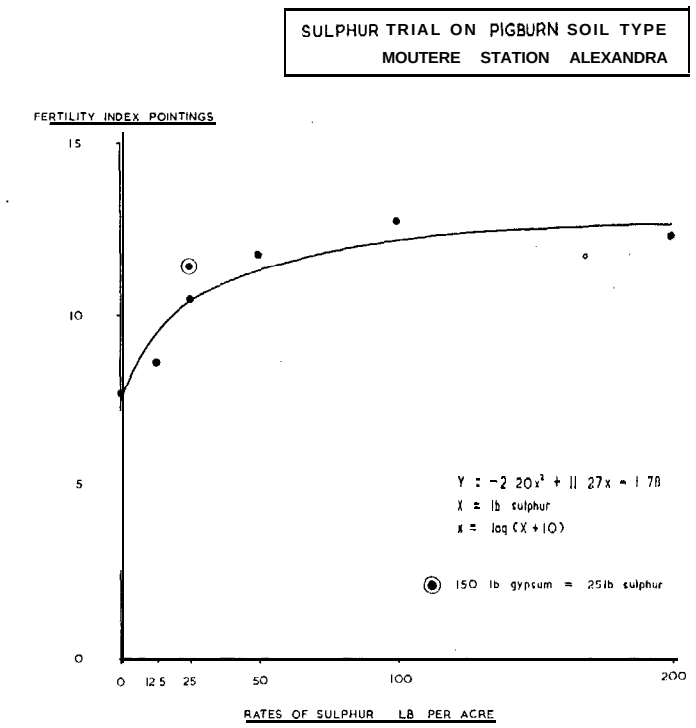
Average Fertility Index Pointings for the 1959–60 Season (Four Sets of Pointings)

	No Phosphate	Double Super 150 lb
Nil	7.8	7.6
Sulphur 12½ lb	8.2	9.0
Sulphur 25 lb	8.6	12.1
Sulphur SO lb	11.0	12.3
Sulphur 100 lb	14.5	10.8
Sulphur 200 lb	12.8	11.5
Gypsum 150 lb	11.6	11.1

Thus from the results it is probable that the same production can be obtained with 25 lb of sulphur with phosphate as with 50 to 100 lb of sulphur alone. The Field Experimental Section of the Department of Agriculture states, however, that calculations were made in this trial on the average of the pointings for phosphate and no phosphate. This is because this trial showed no response to phosphate and if separate curves were plotted they would be all but indistinguishable. A parabola curve was plotted (Fig. I). The equation of this curve is shown. The average Fertility Index

pointings for each rate of sulphur were calculated and plotted. There is good agreement between the mathematical curve and the actual average Fertility Index pointings.

Fig. I

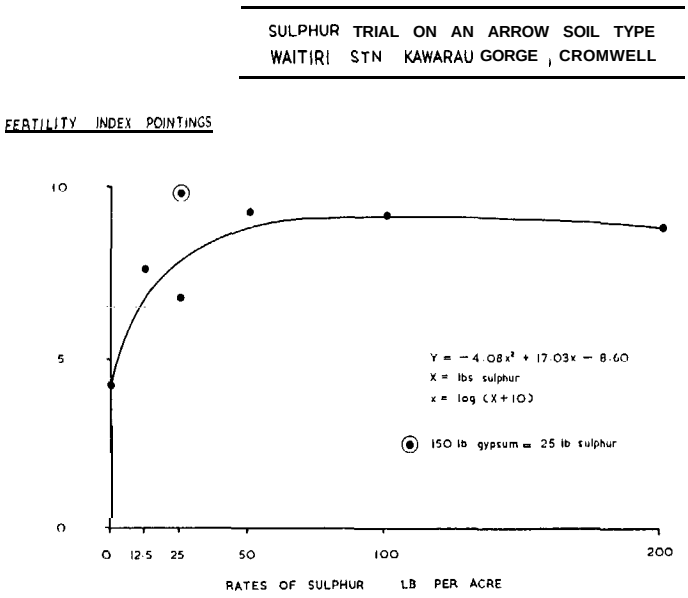


In this trial there were indications that gypsum alone may be superior to the equivalent amount of sulphur alone (25 lb per acre). Gypsum with phosphate is definitely not superior to the equivalent amount of sulphur with phosphate.

Waitiri Station Trial (Table 2). This trial was laid down on 8.10.58 on very steep hill country in the Kawarau Gorge near Cromwell at an altitude of 1,500 ft. The estimated annual rainfall is 20 to 25 in. There was no response to phosphate alone, but again there was a very significant response to sulphur and $12\frac{1}{2}$ to 50 lb per acre gives maximum production. There is no evidence of an interaction between sulphur and phosphate. For the same

reasons as in the Moutere trial calculations were done on the average of the pointings for phosphate and no phosphate. Again there has been good agreement between the mathematical curve and the actual Fertility Index pointings (Fig. 2).

Fig. 2

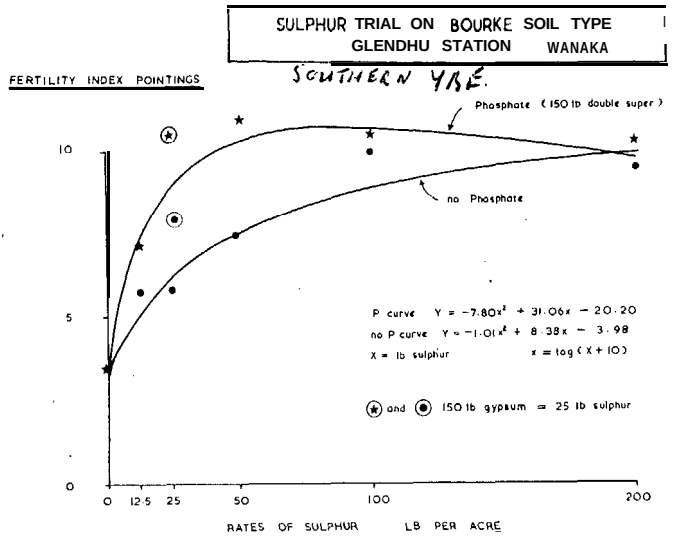


There are indications that gypsum alone may be superior to the equivalent amount of sulphur alone, but gypsum with phosphate is not superior to the equivalent amount of sulphur and phosphate.

Glendhu Station Trial (Table 2). This trial is on Bourke Soil which is weakly leached yellow brown earth on a fan. The trial, laid down on 29.9.58, is 1,800 ft above sea level and has an annual rainfall of 30 to 35 in. Again there has been no response to phosphate alone, but there has been a very significant response to elemental sulphur, and 50 to 100 lb of sulphur per acre is required for maximum production. The parabola curves have been plotted for the no phosphate treatments and the phosphate treatments (Fig. 3). The equations of these curves are shown on the graphs. The average Fertility Index pointings for the season are also plotted.

There has been excellent agreement between the mathematical

Fig. 3

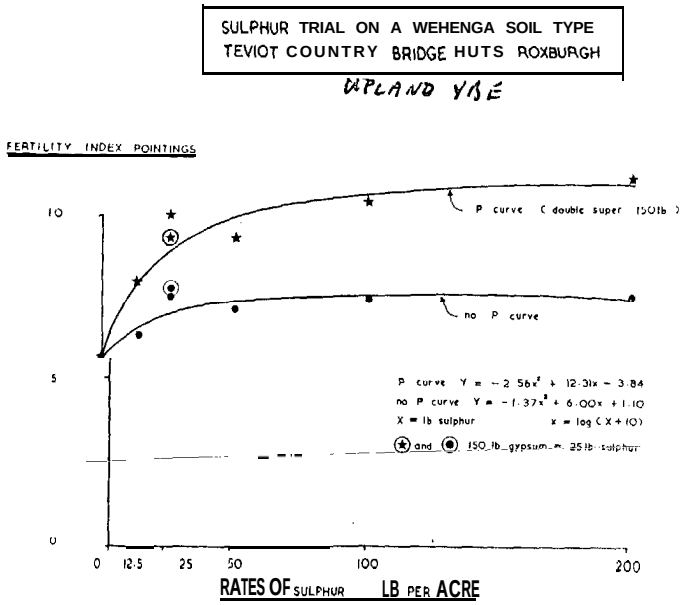


curves and the average Fertility Index pointings. There is a very marked interaction between sulphur and phosphate. The same production was obtained in the 1959-60 season with 25 to 50 lb of sulphur with phosphate as with 50 to 100 lb of sulphur alone. There were also indications that gypsum with phosphate may be superior to the equivalent amount of sulphur with phosphate.

Teviot Trial (Table 2). This trial was laid down on 11.8.59 at an altitude of 2,000 ft about 10 miles inland from Roxburgh on a very extensive plateau under snowgrass. The area was referred to in the introduction. I undertook research work to see if this country could be improved for summer production and the results have been outstanding. This trial received a basal dressing of 10 cwt of lime and 2½ oz of sodium molybdate. There was no response to phosphate alone and only a slight response to sulphur alone (not nearly as marked as in other trials). There was, however, a very marked interaction. Parabola curves were plotted (Fig. 4) and again good agreement was shown between the mathematical curve and the average Fertility Index pointings.

The graph shows that maximum production is obtained from 25 to 50 lb of sulphur with phosphate, but, unlike the Glendhu Trial, the production from sulphur alone at the higher rates, does not reach the production from sulphur at the lower rates in the presence of phosphate. This is a very real interaction, as in all

Fig. 4



pointings a number of rates of sulphur with phosphate were significantly superior to the equivalent rates of sulphur alone. Gypsum with or without phosphate is not superior to the equivalent amount of sulphur with and without phosphate.

Summary and Conclusions

The trials cover a wide range of virgin soils from brown grey earths to weakly weathered yellow brown earths. On no trial was there any response to phosphate. There was a response to sulphur on all sites. On the weakly weathered yellow brown earths there was a marked interaction between sulphur and phosphate. On the drier soils (Moutere and Waitiri sites) gypsum is possibly a superior form of sulphur to elemental sulphur in the first 12 to 18 months of the trials.

W. A. Lunn working in the Maniototo and Strath Taieri districts laid down a number of trials of the same design and his results have been very similar to mine,

Table 4 shows the soil analysis of each of the four trial sites.

TABLE 4-SOIL ANALYSIS OF TRIAL SITES

	Sampling	Depth	pH	Ca	K	P
Mouterc	(0″–5″)		6.3	6	14	18
Waitiri	(0″–3″)		6.1	7	12	13
Glendhu	(0″–3″)		5.4	3	8	2
Teviot	(0″–4″)		5.2	2	15	5

On the Moutcre and Waitiri trials where the interactions were nil or slight, phosphate figures (Truog test) are high.

On the Glendhu and Teviot sites the phosphate figures are low and yet there is no response to phosphate alone, but there is a very marked interaction between sulphur and phosphate.

The work of Wells and Saunders, using sweet vernal to assess the availability of phosphorus (9), also helps to explain the reason why the interactions are nil or slight on the weakly weathered soils (Moutere and Waitiri sites), for the amount of available phosphate is high. On the more strongly weathered soils in the same soil sequence (Glendhu and Teviot sites), where the interactions are marked, the amount of available phosphate is lower. These workers have also found that in the same weathering zone available phosphate is lower in the zonal soils than in the related azonal steepland soils. This explains why there was no evidence whatsoever of an interaction on the Waitiri site.

In the coming season it is planned to take herbage samples from these trials to determine the uptake of sulphur and phosphorus and thus try to explain the interactions. Trials were laid down this spring at Moutere,, Glendhu, and Teviot to determine the amounts of phosphate required to bring about the interactions. To complete the survey of the sulphur and phosphate requirements on the main hill and mountain soils in Central Otago, 10 new trials were laid down this spring. At Mouterc there is a detailed forms of sulphur trial. At Glendhu a detailed trial has been laid down to determine the maintenance requirements.

Practical Significance of Results

The responses to sulphur which have been obtained 'arc of great practical significance to the farming community. At Glendhu it was found that 50 lb of sulphur in the presence of phosphate was required to obtain maximum production. To apply this amount of sulphur the farmer would have to apply either,

I. 4 cwt of superphosphate per acre
2. 2.15 cwt of sulphuriscd supcrphosphate (240 lb of. sulphur per ton mix)
3. I .7 cwt of sulphurised superphosphate (400 lb of sulphur per ton mix)
4. 1 cwt of sulphuriscd superphosphate (800 lb of sulphur per ton mix).

We arc recommending the 400 lb mixture, as until we have this year's results we do not know how much phosphate is required to bring about the interactions. The farmer is saving a great deal of expense in three ways; cost of fertiliser, transport costs, and application costs.

The hill and high country farmers are making use of these research findings. According to the manager of Fertiliscrs South Island Ltd. the use of sulphurised superphosphate has more than doubled in Central Otago this year.

On some steepland soils where phosphate levels are high (for example, Waitiri site), it appears that no phosphate is required. Consequently bulking the sulphur with phosphate is a very expensive way of applying the sulphur. It may be cheaper to bulk the sulphur or gypsum with sand or some other inert material.

Effects of Sulphur on Soil Acidity

The principles of soil chemistry suggest that applications of sulphur could increase soil acidity. Hudson (10) states that on most soils elemental sulphur must increase the soil acidity and lower calcium levels. He states that a dressing of 30 lb of sulphur would necessitate the application of 120 lb of good quality limestone. If farmers have to apply lime at this rate I am extremely doubtful whether this improvement of tussock country would be economic. Table 5 shows the pH and calcium levels in the Moutcre trial after two years and the Teviot trial after one year. The sulphur must have been oxidised to obtain responses.

TABLE 5—EFFECT OF SULPHUR ON SOIL pH AND CALCIUM LEVELS

	Moutere		Teviot	
	pH	Ca	pH	Ca
Nil	6.3	5.5	5.5	3
Sulphur 12½ lb	6.3	6	5.4	3
Sulphur 25 lb	6.3	6	5.6	4
Sulphur 50 lb	6.3	6	5.5	3
Sulphur 100 lb	6.3	5.5	5.4	3
Sulphur 200 lb	6.1	6	5.4	3
Gypsum 150 lb	6.3	6	5.5	3
	Sampling Depth 0"-3"			

In neither of these trials has the application of sulphur at 200 lb per acre had any effect on the soil pH or calcium levels. Workers in other areas have found that very heavy dressings of sulphur are required to appreciably affect pH. McNeur (11) at Palmerston North had to apply 1,206 lb of sulphur per acre to lower the pH of a Manawatu silt loam from 5.8 to 5.0. He found that the artificially acidified soil was not comparable with naturally acidified soils until considerable leaching had taken place, as they contained a great deal of soluble calcium salts.

In Central Otago, even on acidic soils of an initial pH of 5.5, applications of 30 to 40 lb of elemental sulphur seem unlikely to have any effect on soil acidity.

Production Brought About by Oversowing and Topdressing Fescue Tussock Country

What increases in production can be brought about by oversowing and topdressing fescue tussock country? A trial was laid down at Mt. Benger on the Old Man Range above the Roxburgh Dam at an altitude of 2,000 ft by Hercus in 1955. This trial is on fescue tussock and the annual rainfall according to Mark (4) is 28 in. The soil analysis of the site is:—

pH, 5.6; Ca, 4; K, 11; P, 4

The treatments were:

1. Clover seed alone in September 1955.
2. Clover seed and 2 cwt of reverted superphosphate 1955.
3. Clover seed and 2 cwt of reverted superphosphate 1955 and 2 cwt of superphosphate, October 1958.

The treatments were replicated and each replicate was an acre strip down the mountain. A technique first had to bc found for measuring herbage production under these conditions. Hamblyn cages were used and it was found important not to clip the tussocks, as the microclimate was destroyed and production adversely affected. The production for part of the 1958–59 season and the 1959–60 season is shown in Table 6. These figures do not include the production from the tussocks.

TABLE 6-MT. BENGER PRODUCTION TRIAL

(Yields in Pounds of Dry Matter Per Acre)

	Cut 9/1/59	Cut 16/3/59	Total
19.58-59 Season (22/11/58–16/3/59)			
1. Clover alone	550	290	840 b A
2. Clover and 2cwt Reverted Super, 1955	910	610	1,520 b A
3. Clover and 2 cwt Reverted Super, 1955 and 2 cwt Super, 1958	2,210	1,020	3,230 a A
			C.V. 28.2%

	Cut 17/11/59	Cut 4/2/60	Cut 8/4/60	Total
1959–60 Season (24/9/59–8/4/60)				
1. Clover alone	450	570	90	1,110 c c
2. Clover and 2 cwt Reverted Super, 1955	660	920	160	1,740 b B
3. Clover and 2cwt Reverted Super, 19.55 and 2 cwt Super, 1958	1,530	2,670	260	4,460 a A
				CV . . 25% .

The production figures emphasise the important fact that it is quite useless to apply clover seed alone without satisfying the fertiliser requirements. In the 1959-60 season, 4 to 4½ years after

laying the trial down, the production from two dressings of superphosphate is 4,500 lb per acre, whereas the production from one dressing is 1,700 lb per acre and clover alone 1,100 lb. Thus by applying two dressings of superphosphate production can be increased 300 per cent. If all the herbage could be conserved, this improved pasture would support 2 to 23 ewes per acre. To maintain maximum production a dressing of superphosphate is required at least every third year.

The seasonal differences in production for the treatment where two dressings of superphosphate have been applied are shown in Table 7.

TABLE 7-MT. BENGER PRODUCTION TRIAL
SEASONAL DIFFERENCES IN PRODUCTION FOR TREATMENT 3 IN TABLE 6

	Production (lb D.M. per day)
1. November and December 1958	44
2. January, February, March 1959	16.6
Growth virtually ceased from mid March to end of September	
3. End September to mid November 1959	27.4
4. Mid November to beginning February 1960	33.8
5. Beginning February to beginning April 1960	4.5

The production is high in the spring and early summer but falls off markedly in the late summer and autumn when the summer drought sets in. These seasonal differences in production are important for farm management, as the availability of sulphur and nitrogen depends on sheep and cattle utilising the increased feed and excreting these elements in the dung and urine (12). Thus adequate fencing, enough stock to enable the areas to be managed correctly, and sufficient winter feed are essential.

There are indications that the production in this trial is equal to that of well irrigated trial areas in Central Otago during the spring and early summer (13), but is not nearly as good in the late summer and autumn. The great differences in cost in developing an acre of fescue tussock country and an acre of border dyked irrigated pasture should be borne in mind.

It is commonly observed that when tussock country is improved there is an initial dominance of clover. Table 8 is a comparison of herbage dissection results from Treatment 3 in the Mt. Benger trial, for cuts at the same time in successive years. The production for the two periods is approximately the same.

TABLE 8—MT. BENGER PRODUCTION TRIAL
HERBAGE DISSECTION RESULTS FOR TREATMENT 3

(Comparison between Results for Cuts on 9/1/59 and 4/2/60)	9/1/59		4/2/60	
Grasses and Dead Matter	23.5%	520 lb	36%	960 lb
Clovers	74.5%	1,650 lb	59.5%	1,590 lb
Other Species	2 %	40 lb	4.5%	120 lb
Total Production		2,210 lb		2,670 lb

In 1959 the production from the grasses (sweet vernal, Yorkshire fog, and browntop) was 520 lb per acre, but in 1960 the grasses produced 960 lb per acre. This increased production reflects the reaction of the grasses to the increased soil nitrogen levels. The tussocks also reacted markedly to the increases in soil nitrogen. The first essential then in tussock country improvement is to get vigorous clovers established.

This spring a new production trial was laid down on this site to compare the production from ordinary superphosphate and sulphurised superphosphate. On the Dunstan Range we have laid down trials every 500 ft from 2,000 ft to 5,000 ft to determine to what altitude it is economic to improve tussock country, what the fertiliser requirements are at different altitudes, and what species are suited to different altitudes. Trials are also being laid down to investigate the establishment of cocksfoot in tussock country which has been improved for a number of years.

Conclusion

If runholders of Central Otago put into practice some of the research findings which have been mentioned in this paper, some of the benefits that will be obtained are better soil and water conservation, increased wool weights, better lambing percentages, increased numbers of fat sheep, decreased death rates, increased sheep and cattle numbers, and pre-lamb shearing will be possible.

As soil scientists, soil conservators, and agriculturalists we recommend that the grazing pressure should be eased on higher snow-grass country where there is evidence of overgrazing. The spelling of depleted scabweed country to bring about natural regeneration is also recommended. Today we are able to show farmers that if they can improve the fescue tussock country on their properties, they can carry out these very desirable soil and water conservation practices and still carry the same numbers of stock.

I am convinced that with the continued control of the rabbit,

spelling of depleted country, over-sowing and topdressing with sulphurised superphosphate on the fescue tussock areas, and the introduction of lucerne and cocksfoot in drier areas, the pastoral lands of Central Otago will contribute a great deal to the economy of New Zealand.

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IMPROVEMENT OF LOW ALTITUDE TUSSOCK COUNTRY DISCUSSION

Q. What is the lime status of these soils?

A. The pH of the trial sites varies a great deal. On the most weathered and leached soil at the Teviot site the pH is 5.4 at O-4 in. The Tcviot trial was given a basal dressing of lime and molybdenum and there has been no response at all. The improvement of this tussock country would not be economic if lime had to be applied. due to the cost of application, I have evidence to show that sulphur at rates up to 200 lb per acre has no effect on soil pH—even on acidic soils.

Q. What about pelleted seed?

A. Mr Hercus and Mr Lunn laid down trials with lime pelleted seed and there was no response to lime pelleting.

Q. Was the lime pelleted seed inoculated on the outside, or the inside of the pellet'?

A. (Mr Hercus): Mostly on the outside, but both were tried. There was no difference.

Q. What is the role of cattle in tussock grassland improvement work?

A. Cattle are essential in any improvement programme because of the terrific seasonal fluctuations in production. An example of these differences in production is on the Mt. Benger trial. At Glendhu Station 1,700 acres have been oversown and topdressed: before the topdressing programme was commenced there were 50 head of cattle: today there arc nearly 400 head.

Q. To what extent are the farmers following up your work?

A. The response of the farming community is outstanding. For instance, sales of sulphurised superphosphate have doubled this last year, and all farmers are showing a great interest in the trial work. I have laid down over twenty fertiliser trials this last year, and have not had to arrange for the fencing of any of them-it has all been done by the farmers of their own accord,

Q. Have trees in this area any commercial value?

A. Economic forestry seems to be very limited in Central Otago.

Comment (Mr Sly): In Southland at higher altitudes trees were for protection only. Harvesting and maintenance would be very costly. There are continual risks with forestry from pests and fire in tussock grassland areas.