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REVIEW OF FIELD RESEARCH SECTION FERTILIZER × STOCKING RATE GRAZING TRIALS IN NEW ZEALAND

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SUMMARY

Eight trials are reviewed where ewes and lambs, hoggets or dairy cows are being used for the estimation of responses from the application of fertilizers to pasture. Results are briefly summarized and it is concluded that all these types of trials are useful for the estimation of fertilizer response.

Ewe and hogget liveweights are particularly sensitive indices of short-term fertilizer response, with wool weights being a useful but generally less sensitive source of longer-term data. In the trials under review the relationship between pasture dry matter response and animal performance was generally satisfactory, confirming the usefulness of pasture dry matter measurements for the measurement of fertilizer effects.

It is suggested that these trials have considerable value as sites for the study of animal, pasture, soil and fertilizer relationships over a range of environments. Their use in the building and testing of models describing their relationships should be developed further.

THIS PAPER varies from most of those presented to this Society in that its objective is not so much the presentation of complete and detailed information on the trials under review, as to initiate a discussion on the concept of the trials and the techniques being employed. The data presented here are mainly illustrative of the type of results being achieved and the publication of detailed trial information remains the responsibility of the scientists in charge of individual trials.

The techniques employed in identifying the fertilizers required for the development of agricultural land were based initially on observational plots, followed by mowing trials of varying degrees of sophistication. However, these

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mowing trials have apparent weaknesses. Response is expressed in terms of pasture dry matter, which has, at present, no accepted market value. The assumption that increased pasture production will lead to increased animal production is reasonable in many farming situations, but not all. What is much more doubtful is the assumption that the magnitude of the increases in pasture and animal production will be the same.

EXPERIMENTAL AND RESULTS

Eight trials are currently in progress at the sites shown in Fig. 1. The layouts are summarized in Table 1 and the stocking rates used in Table 2. Management features of these trials and the main results being achieved are set out below.

(1) Te Kuiti—Ash

This is a hill country trial located on Mairoa ash. A mixed-age ewe flock is set stocked, apart from the mating

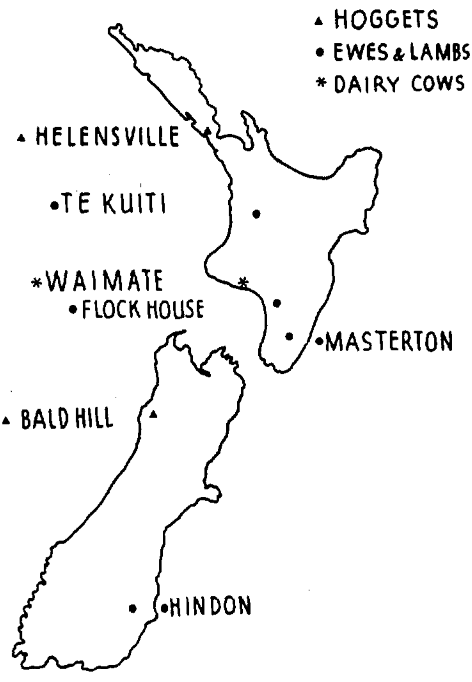

FIG. 1: *Location of trials.*

TABLE 1: TRIAL LAYOUTS

Location	Soil	Fertilizer	Treatment No. of Rates	Treatment Other	No. Replicates	No. Paddocks
Te Kuiti	Ash	Super.	3	—	3	18
Te Kuiti	Sandstone	Super.	3	—	3	18
Flock House	Pukepuke sand	Super.	2	—	3	24
		KCl	2			
Masterton	Kokatau silt	Super.	2	Clover types	4*	32
		Lime	2			
Hindon	Upland yellow brown earth	Super.	2	Earthworms	6*	24
Helensville	Red Hill sand	Super.	3	—	2	18
Bald Hill	Pakahi	30% K-Super.	2	—	3	12
Waimate West	Egmont loam	Super.	2	Rotation length	1	52

*"Other treatments" not yet effective and included in replicates.

TABLE 2: DETAILS OF STOCK USED IN TRIALS

Location	Class of Stock	Season	No. of Animals/ha* Low	Medium	High	% Increase Low to High†
Te Kuiti (ash)	Ewes and lambs	All year	14	—	18	28
Te Kuiti (sandstone)	Ewes and lambs	All year	10	—	14	33
Flock House	Ewes and lambs	All year	22	—	27	22
Masterton	Ewes and lambs	All year	15	—	22	50
Hindon	Ewes and lambs	All year	15		17	12
Helensville	Hoggets	Winter	25	30	35	40
		Summer	35	40	45	28
Bald Hill	Hoggets	Winter	10	—	15	50
		Summer	20		30	50
Waimate West	Dairy cows	All year	—	4.2	—	—

*To nearest whole number.
†Calculated from actual stocking rates.

period. Changes in pasture composition are assessed in this and all other trials by reading permanent line transects, and in this trial the pasture available in each paddock is assessed subjectively each week. Measurements of pasture production have been limited so far by the technique difficulties of accurately estimating pasture production on this class of land. On all sites apart from Te Kuiti pasture production is measured by the rate of growth technique (Lynch, 1966).

Fertilizer treatments have been 250, 500 and 1000 kg/ha of superphosphate applied annually in the autumn. Responses to increased fertilizer in ewe liveweights in the winter and early spring have been apparent in each of the two years that the trial has been operating.

Ewe fleece weights have shown the same trends with statistically significant increases being associated with the highest levels of fertilizer application. Subjective assessments of pasture availability have generally supported the animal data.

The responses in lamb liveweights and wool weights were less consistent although overall responses to increased levels of fertilizer were recorded. The lack of consistency with the other data appeared to be a consequence of between-treatment variations in the numbers of lambs born and reared.

(2) TE KUITI—SANDSTONE

The trial management is identical to the Te Kuiti ash trial, except that the stocking rates used are lower (Table 2).

The trial is located on a Mahoenui steepland soil. In this area these soils occur mainly on the steeper southerly faces of the hills.

No consistent fertilizer responses have been recorded during the first two years of this trial. In the high fertilizer, high stocking rate treatment, ewe and lamb liveweights and pasture availability ratings have been relatively depressed. It is suspected that this may be a trial malfunction due to the occurrence of atypical paddocks within this treatment.

(3) FLOCK HOUSE

This trial is located on flat sand country in the Manawatu, predominantly on Pukepuke sand.

Two levels of superphosphate (250 and 750 kg/ha) and two levels of muriate of potash (0 and 250 kg/ha) are being compared in a factorial design. Ewes and lambs are set stocked on the trial. Pregnancy toxaemia has been a recurrent problem on the high stocking rate treatments leading to relatively high levels of ewe replacements.

Lamb liveweights have responded significantly to potash. Ewe liveweights have shown small but significant responses to superphosphate in the early winter and highly significant responses to potash in the spring and summer. There has frequently been a highly significant positive interaction between these two fertilizers, showing that ewe liveweights were exhibiting their greatest improvement in the presence of both superphosphate and potash.

In the first year no significant responses in pasture dry matter yield were recorded, but in the second year there was a significant 18% increase in the spring yields of pasture topdressed with potash.

Ewe wool production did not give consistent results between years, being significantly depressed by potash in the first year ($P < 0.01$), but not in the second year.

(4) MASTERTON

This trial is located on a Kokatau silt loam on the Wairarapa Plains. The fertilizer treatments are 125 and 500 kg/ha of superphosphate in a factorial layout with lime at the rates of nil and 6,300 kg/ha. The lime was used to raise the soil pH from 5.4 to 6.5. The stocking rates were applied as sub-plots within this factorial design.

Romney two-tooth ewes were used to stock the trial which is now completing its fourth year.

Some transitory ewe liveweight responses to superphosphate were recorded, but the dominant response was to lime. A significant ewe liveweight increase occurred eight months after the first lime application (5,000 kg/ha) and was maintained at almost every weighing thereafter.

Responses in lamb liveweights to superphosphate or lime have been rare and no consistent pattern has emerged.

In the first two out of three years for which data are available ewe greasy wool weight was significantly increased in the high stocking rate ewes, by the application of lime. There was no evidence of a greasy wool weight response in 1970-1. However, measurements of tensile strength taken for the first time in this year showed a significant 12% increase ($P < 0.05$) in this characteristic in the ewes on the high superphosphate treatment, and a 26% increase in the ewes on the lime treated paddocks.

The application of lime increased pasture dry matter yields by between 10 and 19%, with the strongest responses occurring in the autumn and winter. The only significant phosphate response occurred in the first winter of the trial. The recorded stock responses appeared to be no more than reflections of increased availability of pasture dry matter.

The Ariki ryegrass content of the pastures on the limed paddocks was significantly increased and the rate of increase of browntop was reduced on both the lime and the high phosphate areas.

(5) HINDON

This trial is laid down on easy rolling hill country in Otago on a Wehenga soil. One hundred and twenty-five and 375 kg/ha of superphosphate are being compared in a factorial design with the presence and absence of earthworms. The earthworm treatments have not yet become effective.

The trial was set stocked with mixed-age Romney ewes in spring 1967, but complete and detailed statistical analyses of stock effects have yet to be carried out. The analyses that are available indicate that there has not been a consistent pattern of responses in stock production to the higher levels of fertilizer. Pasture growth rates, on the other hand, have consistently shown fertilizer responses varying between 4 and 22%. Management of this site is complicated at all times by the distance of the trial from resident research division staff and the severity and length of the winters. The trial site is very exposed to southerly winds and snow storms are a hazard.

An unusual feature has been the occurrence of significant increases in pasture growth at the higher stocking rate. This may have been associated with periods of poor summer utilization of pasture at the lower stocking rates and the occurrence of heavier porina (*Wiseana* spp.) damage in these more laxly grazed pastures.

(6) OTAKANINI

This trial, described by Cumberland *et al.* (1971) is situated on rolling country on a red hill sandy clay complex. Hoggets are used at three stocking rates to examine animal performance at the following rates of superphosphate—125 kg/ha every second year, 500 and 1000 kg/ha annually. Hoggets are added to the trial in proportion to the original stocking rates in spring, and again in summer, as pasture surpluses develop. Statistical analyses are restricted to the hoggets that remain on the trial throughout the year.

Three years' data have been analysed and each year has shown significant responses to higher levels of fertilizer in both hogget liveweight gain and wool growth. These increases approach linearity over the three fertilizer levels used. Wool weights have been a sensitive measure of fertilizer response in this trial, but not always as sensitive as liveweight.

Two paddocks on this trial appear to be giving atypical results, particularly in pasture measurements, and as they both occur on medium stocking rate treatments it is possible to analyse the data omitting this treatment. When the medium stocking rate was included the pasture measurements were relatively inefficient at detecting differences between medium and high fertilizer levels, but they were able to do this in two years out of three when the medium stocking rate was omitted.

(7) Bald Hill

The trial commenced on a flat "pakahi" soil in the spring of 1966. It was initially stocked with ewes and lambs, but the management difficulties encountered led to a switch to hoggets in March 1969. In the early years the class of animal used varied according to local availability and the time at which extra animals were added and removed was subject to these same restrictions. It was not until the 1970-1 season that these problems were finally resolved.

Five hundred and 1000 kg/ha of potassic reverted superphosphate are being compared using two stocking rates. In contrast to Otakanini, weight gains of both "full-time" and "part-time" sheep are being statistically analysed. Liveweight responses to fertilizer have been highly significant at the high stocking rate but have usually been absent at the low stocking rate. Liveweight gain has been a much more sensitive index of fertilizer response than wool weight.

Highly significant pasture growth rate responses to fertilizer have occurred at both stocking rates. The size of the fertilizer response has tended to increase over the four years for which data are available, reaching 36% in 1970-1.

(8) Waimate West Demonstration Farm

Dairy cows are used on this flat site on Egmont loam near Hawera, where three successive fertilizer trials have been carried out. The fertilizer treatments of the last two have remained constant. The first trial ran for four years and measured potash responses to 250 kg/ha of muriate of potash in the presence of 500 kg/ha of superphosphate. Significant potash responses in pasture growth rates were recorded, and these were reflected in generally higher milkfat production at the higher stocking rate of 3.7 cows/ha only.

After a uniformity period of one dairy season, a trial comparing 500 and 1000 kg/ha of superphosphate in the presence of 250 kg/ha of muriate of potash was commenced, using stocking rates of 3.2 and 4.9 cows/ha. The trial ran for four years, but the results were inconclusive. A 14% increase in milkfat production to the high rate of superphosphate occurred at the higher stocking rate in the first year, but this declined to 6% in the next two years and did not occur at all in the fourth year. No pasture growth rate responses to the high levels of superphosphate were found, and the first year's result led to considerable speculation that a specific pasture quality response was being observed (Smith, 1968). However, doubts were cast on this hypothesis through the difficulties being encountered at the time in the precise measurement of pasture growth.

The third trial was initiated to follow up the possibility of a phosphate response at this site. A common stocking rate (4.2 cows/ha) was used in a replicated design. The superphosphate topdressing regimes of the previous trial were maintained, but the level of muriate of potash was dropped to 125 kg/ha. A 13 versus 26 day rotation comparison was added as a factorial treatment. Responses to the extra superphosphate in milkfat (17%), cow liveweight (12%) and pasture production (9%) did occur in the first year of this trial. This response occurred at both slow and fast rotations, but these results have yet to be fully analysed. The 1971-2 results to the end of December suggest a much lower level of response in milkfat this season (5%), but this may be deceptive as last season the phosphate response appeared to be greatest in the summer and autumn.

DISCUSSION

Perhaps the most important point to come out of this review is that at the higher stocking rates, the relationships between measured pasture dry matter response and livestock performance were generally satisfactory. This supports the conclusion of Scott (1968) from a similar type of trial at the Invermay Agricultural Research Centre. Thus these trials increase the confidence with which data from mowing trials can be used to indicate probable levels of animal response.

However, it is important to remember that the mowing measurements in these trials have been made from continuously grazed paddocks. They do not necessarily follow the results of small-plot mowing trials where stock are excluded for variable and often lengthy periods and fertility can be transferred from plot to plot by the grazing animal. For example Cumberland (1969) concluded from small-plot mowing trials that pastures on Red Hill sand would not respond to more than 500 kg/ha of superphosphate, whereas he has recorded highly significant responses in pasture and animal production to 1000 kg/ha from his grazing trial.

In the trials grazed with sheep, liveweight gain is a sensitive index of fertilizer response. It is interesting to note how useful ewe liveweights have been in this respect and this adds appreciably to the data that can be drawn from a ewes and lambs grazing trial. Lamb liveweights have appeal as a practical measure of fertilizer response that is immediately translatable into cash returns. However, they suffer from the limitations of being unduly influenced by what can be random variation in treatment lamb numbers; of being dependent on good pasture control to give valid results, and of being a consequence of pasture production differences over a very limited period of the year.

Greasy wool weights can be classified as useful supporting data to those of liveweight change, although they will generally only show up long-term effects. They add to trial management complications in that sheep need to be shorn on entering and leaving a trial. Wool metrology measurements can add considerably to the value of a trial as the fertilizer-induced improvements in tensile strength at both stocking rates have shown at Masterton. This would not have been suspected from the other wool data available.

The relative merits of ewes and lambs, hoggets and dairy cows as animals for measuring fertilizer responses remain subject to conjecture. The evidence of this review would suggest that all three groups of animals can be used successfully for this purpose. Ewes and lambs give data in terms immediately applicable to farming systems, as do dairy cows. However, the most sensitive measure from a ewes and lambs trial appears to be ewe liveweights, which may well be the characteristic of least economic significance. Both ewes and lambs trials and dairy cow trials are dependent on continuous high levels of experimental management if they are to be fully effective. This usually means that they must be located close to a research centre. Hogget trials are most appropriate at the more remote sites, where a well-designed trial can operate efficiently with minimal supervision and without expensive facilities.

Hogget trials have the advantage of requiring fewer management decisions that might influence the results being achieved. In every trial it is essential, in our view, that the trial treatments be managed along similar well-defined lines, and that individual operator discretion should be reduced to a minimum.

This can be a difficult attitude to maintain against what can appear to be the dictates of common sense. The alternative is the production of data the relevance of which is limited to a particular trial manager, and differences between trial sites and between years within the one trial site, become almost impossible to interpret. The critics of the "artificial" management restrictions imposed in these trials can be partially answered by reference to the high output figures recorded. Nevertheless it is important to consider the relevance of the particular management systems adopted to the results achieved, and to give due weight to any treatment bias that may have been introduced. As techniques of rapidly and accurately assessing pasture dry matter available to stock improve it may be possible to run trials where "grazing pressure" rather than stocking rate, is maintained constant between treatments.

A technique question that merits discussion is the use of uniformity data gathered immediately before the commencement of the trial. The objective is to reduce extraneous variability through the formation of replicates on the basis of measured productivity. The concept of a uniformity period appeals to the biometrician as an opportunity to improve the precision of the trial, and to the trial operator as a "lead up" to the trial proper, during which he can build up information on stocking rates and management procedures.

Unfortunately these objectives tend to conflict, and the lack of experimental finesse during the uniformity period lowers the value of the data obtained, and the anticipated design improvements tend to be illusory. If uniformity data are going to be worth while they probably need to be collected intensively for at least a year, under conditions very close to those under which the trial is going to operate. If this cannot be done, the time invested in a uniformity period may be of doubtful value, and the trial might give a better research return through the application of the experimental treatments without a uniformity period.

Another trial technique that calls for comment is the use of "part-time" and "full-time" sheep in hogget trials. The assumption is generally made that "part-time" sheep are paralleling the "full-time" sheep in their growth responses. However, growth rates recorded from ewe and wether two-tooths grazing together at Bald Hill show that this is not necessarily so (Table 3). In this case the wethers

TABLE 3: LIVEWEIGHT GAIN (kg/animal) OF TWO-TOOTH SHEEP GRAZING TOGETHER FOR 70 DAYS AT BALD HILL

Factor		*Sheep Grazing for* *Whole Year (Ewes)*	*Part Year (Wethers)*
Response to	Low stocking	— 3.0**	+ 0.2
High fertilizer	High stocking	— 0.1	+ 1.8**
	Overall	— 1.5**	+ 1.0*
Response to high stocking		+ 3.4**	— 1.0*
Interaction (fertilizer × stocking)		$P < 0.01$	Not signif.

("part-time" sheep) behaved in a manner that would be expected in this trial, but the "full-time" ewe two-tooths gave very odd results. In their cases their weight gains seemed to be more strongly influenced by their liveweights at the beginning of this period than by treatment effects. This suggests that the weight gains of both "full-time" and "part-time" sheep should be analysed, whenever the latter have been on the trial long enough to give meaningful results.

Experience to date suggests that measuring fertilizer maintenance requirements should not be considered as an important justification for grazing trials of a simple factorial design. The narrow ranges of fertilizer and stocking rates that can be used mean that little more than rough observations on fertilizer maintenance requirements can be expected (*e.g.*, between 125 and 375 kg/ha of superphosphate). If a more precise estimate of fertilizer maintenance requirements is required consideration will need to be given to radical and as yet unproven experimental grazing trial designs such as "response surfaces". Initially these would need to be undertaken as technique studies on a major research station.

One of the greatest values of these trials is that they serve as sites where stock are managed under controlled defined conditions and the interactions of stock, pasture, fertilizer and soil can be studied in detail. Some examples of the type of information being obtained have been cited in the context of individual trials. Other examples include the effects of stocking rate on teeth wear and the incidence of goitre (at Masterton).

The stocking rate effect on wear in sheep's teeth has been spectacular, but the interesting observation is that the "gummy" high-stocking-rate ewes appear to be thriving under conditions where they compete for feed only with themselves and not with full mouthed ewes. In 1971 a severe outbreak of goitre occurred in the lambs from the low-stocked sheep on this trial. The studies of soil ingestion undertaken in co-operation with W. B. Healy on this and other sites have shown that high levels of soil intake occur in the high stocking rate treatments. Thus it would appear probable that soil intake was instrumental in avoiding the occurrence of goitre in the high-stocking-rate lambs.

A considerable body of information is being obtained from these trials on the responses of pasture components, including weed species, to variation in grazing pressure and fertilizer regime. No doubt more could be done in this and other respects. For example a detailed study of the treatment effects on soil characteristics has proved very rewarding at the Bald Hill site (O'Connor, 1971) and could well do so at others. Another possibility is the use of the scatter of sites available to examine the effects of environmental variation on the ultimate size of sheep from a common genetic source.

The trials also have merit as sources of data drawn from a range of environments for simulation studies of factors affecting stock production. More effort should be put into looking at the system as a whole. The computer should be used for this purpose and for testing the sensitivity of production to changes in the various parameters. In this way, the results of these trials could be extended to encompass a much wider range of farming situations.

One of the purposes of this paper is to make scientists aware of the existence of these experimental sites and to invite their co-operation in adding to both the quantity and the quality of the scientific data being obtained.

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