METHODS OF MEASURING GRASSLAND PRODUCTION

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I do not intend to review the techniques of grassland production measurement (1) (2), but to present the results to date from some measurement trials at the Rukuhia Soil Research Station, Hamilton, and the Marton Experimental Area. These trials can be considered under two headings: First, the comparison of different techniques of cutting, and, secondly the comparison of different methods of field experimentation as applied to grassland production records.

All workers in grassland research, in this country at least, appreciate the intimate relationship that exists between the pasture sward and the management of that sward. Sears (3) has demonstrated the profound effect of the grazing animal on the pasture with particular emphasis on the effect of dung and urine on sward production and composition.

The necessity of maintaining a "normal" sward under "normal" grazing management in pasture experimentation has led to the general acceptance of the "frame" or "enclosure" technique. In this method the experimental paddocks are large enough to permit "normal" stock grazing and pasture production records are obtained from the use of small movable cages or frames within each paddock.

However, the large area occupied by experiments under the "frame" technique, and the consequent difficulty of securing adequate replication of treatments, make it essential to look for suitable small-plot techniques.

COMPARISON OF DIFFERENT 'CUTTING TECHNIQUES'

A simple trial has been in progress at the Marton Experimental Area (4) since 1942, comparing three fields sown with the following seed mixtures per acre:

1. Perennial ryegrass 401b. + white clover 3lb.
2. Short rotation ryegrass 201b. + perennial ryegrass 201b. + white clover 3lb.

3. Short rotation ryegrass 40lb. + white clover 3lb.

Since early spring of 1950 herbage production has been measured in each of these three fields by the following tutting methods, all of which are based on the "frame" technique.

A. **"Standard" method of Extension Division**

A motor-mower is used, cutting to a standard height. The sward is allowed to recover above this height after grazing, then areas are trimmed for the placing of the frames in new positions. At the same time the areas protected by the frames are mown and weighed for herbage production. Note that a "trimming" cut always precedes a "mowing and weighing" cut, and growth is measured from the uniform height, left after trimming.

B. **"Difference" method of Extension Division**

"Trimming" and "mowing and weighing" cuts are made directly after grazing and the herbage removed by the "trimming" cut is weighed. The difference between the weight of grass removed from inside the frames (and protected from grazing) and that from equivalent areas outside the frames and subject to grazing measures herbage consumption, whereas the "mowing and weighing" cuts measure herbage production. If growth is grazed closer than mowing height under-estimates are made of both these factors. Close mowing and not-too-close grazing must therefore be adopted.

c. **"Difference" technique-Australian (5)**

The general technique is similar to that of the "difference" method above, but hand shears are, used to cut growth to ground level and frames are not placed on previously trimmed areas. After grazing the following cuts are made:—

1. Herbage inside frames protected from grazing.
2. "Open cuts" in the field subject to grazing.

The frames are then placed adjacent to these "open cuts".

Herbage Production. is measured by the weight of herbage inside the frames less that from the "open. cuts" made **when the frames were placed.** As the frames are placed on areas not previously trimmed, these open cuts estimate the amount of herbage on the frame areas at the start of the measurement period.

Herbage Consumption is the herbage in the frames protected from sheep (the amount that was available to them) minus that removed on the "open cuts" taken **on the same day** (that is the amount of herbage left after grazing).

D. **"Grazing Estimation" Method**

This has been discussed by Sears (1). The aim when cutting is to "copy the irregular defoliation pattern made by the grazing animals." This puts great reliance on the ability of the technicians doing the cutting. No "trimming" cut is required: the herbage within the frames is cut after a grazing to the level of grazing and the frames are then placed in new positions.

E. **"Rate of Growth" Technique**

Essentially this is the "standard" method except that **regular** intervals are maintained between cuttings. Pairs of frames are needed to operate the method independently of grazing. "Mowing and weighing" is always done after a "trimming" cut.

In the other methods cutting is made when the pasture is at a "normal" grazing height and the interval between cuts varies in consequence. In the "rate of growth" technique the interval is standardised-usually at 2 or 3 weeks-in an endeavour to follow more closely the changes in production over the year.

THE MEASUREMENT OF TOTAL HERBAGE PRODUCTION

Table I summarises the first year's results from the trial comparing these techniques as measures of herbage production.

TABLE; I

Herbage Dry Matter Yields in lb. per Acre
(Period 1.9.50 to 31.8.51)

		Yield	Differences from "A"
Technique	A (Standard)	11,380	—
„	B (Difference)	10,240	-1,140
„	C (Diffce.-Aust.)	12,590	1,210
„	D (Grazing Est.)	12,840	1,460
„	E (Rate of Growth)	9,110	-2,270 (Sig. 5%)
Significant Differences:	5 per cent. level	1,820	
	1 per cent. level	2,650	

The "difference" method of the Extension Division gives lower yields (but not significantly lower) than the "Standard" method. This effect is due to mowing immediately after grazing has finished and before all growth has recovered to mowing height. The Australian "difference" technique on the other hand, gives yields significantly higher than the New Zealand "difference" technique, but this method does not include a prior trimming cut and growth is cut by hand shears to ground level.

The "grazing estimation" method gives yields which are not far from being significantly greater than the "Standard" method. However, it would be interesting to see whether other technicians operating this method would have given a comparable result. Sears (1) states that this is "a good method so long as a very reliable team of workers is available, and also constant check is made within the field and with other measurements". However, because of the very real danger of personal bias operating if these checks are not adequately applied the method is not as foolproof as one; using a mower, which exerts no selection of the herbage it removes.

The "rate of growth" technique gives significantly lower yields than all methods except the "difference" method of the Extension Division. This is almost certainly an effect of the more frequent cutting with the "rate of growth" technique. A trial at the Marton Experimental Area with different frequencies of cutting illustrates this effect.

TABLE II

Effect of Frequency of Defoliation
(Period 28.9.49 to 59.51: 2 years)

	Dry Matter Yields (lb. per acre)	Yields relative to (1) = 100
1. Cutting at weekly intervals	6,330	100
2. „ „ 2-weekly „	8,530	135
3. „ „ 3-weekly „	9,930	157
4. „ „ 6-weekly „	13,390	212

In the "rate of growth" technique, cutting is made at two or three weekly intervals. Although it is clear that this method under-estimates total production it does give a reliable guide to **changes** in production throughout the year.

THE MEASUREMENT OF HERBAGE CONSUMPTION

The two "'difference" techniques "B" and "C" attempt to measure herbage consumption by the grazing animal. An examination- of the figures, however, suggests **100** per cent. utilisation of herbage by the animals. It is apparent that what is measured is really 'consumption plus wastage and as there is no obvious way of separating these two factors by -direct herbage measurement, it is not considered worth while to present the figures which have been obtained.

Linehan, Lowe, and Stewart (6) calculated grass consumption from a formula involving three factors, namely :

1. Quantity of grass nutrients present at beginning of grazing.

2. Quantity of grass nutrients in cages at the end. of grazing, and

3.. Quantity of grass nutrients left uneaten outfield at end of grazing.

Again this method cannot clearly separate consumption from wastage. I feel a much sounder approach is the "chemical marker methods" developed by the Ruakura workers (7), which measure consumption by estimation of the amounts and composition of faeces.

ERRORS OF ESTIMATION OF PRODUCTION

Sampling errors have been calculated for each of the cutting techniques and these are shown in the following table adjusted to give figures assuming equal areas cut by each method.

TABLE III

Sampling Errors Associated with Various Cutting Techniques

Sampling Errors	A. (Standard)	B. (Difference)	C. (Diffce. —Aust.)	D. (Grazing Est.)	E. (Rate of Growth)
Per cut as % mean yield	16.4	19.4	22.4	30.1	18.3
Per period mean as % mean yield	2.1	2.3	2.6	3.5	1.9

The outstanding feature is the relatively high error associated with the "grazing estimation" method. This probably arises from the element of personal

judgment of amount cut (which is associated with this method alone) being added to the normal random variation of sward production within the experimental fields.

COMPARISON OF TECHNIQUES, OF GRASSLAND PRODUCTION MEASUREMENT

The search for simple but reliable alternatives to the "frame" technique led to trials at the Rukuhia Soil Research Station where the following techniques have been compared for the past 3½ years.

1. Frame.
2. Hudson's "mowing and grazing" (8).
3. "Mowing only and clippings returned" (2) (No grazing).
4. "Mowing only" trial on pure white clover sward.

The same treatments were compared by each technique although, of necessity, there were only four replications in the "frame" technique, compared with eight in the two "mowing only" trials and eight in each of two sections in the "mowing and grazing" trial. The treatments were :—

1. Control.
2. Superphosphate 4cwt. per acre per annum:
3. Superphosphate 4cwt. per acre per annum plus lime 1 ton initially and 5cwt. per acre per annum in subsequent years.

The "frame" technique has already been described. The "mowing and grazing" technique uses small plots in common enclosures. Each trial is in two duplicate sections, one of which is mown for herbage production records while the other is grazed. After two mowings the areas are switched so that the grazed area is mown and the mown area is grazed. If "transference of fertility'? among treatments occurs at all, it occurs with the "mowmg and grazing" technique.

The "mowing only and clippings returned" technique is operated without stock grazing. Grass clippings are returned after weighing to the plots from which they were removed. The effect of rain and worm activity soon results in the incorporation of these clippings in the soil provided the growth is not too long and dense,- and provided the weather is not too dry. "Transference of fertility" through stock cannot operate.

The "white clover" technique is similar except that it operates on as pure a white-clover sward as can be obtained. It was hoped that white clover would prove a more sensitive indicator plant than a mixed sward association.

TOTAL HERBAGE PRODUCTION

Table IV gives the total yields of dry matter for the last 2½ years of the trial. Those for the initial year (1947-48) were erratic, probably as a result of "teething, troubles" often associated with a trial of this nature.

TABLE IV

Yields of Dry Matter in lb. per acre as measured by "Frame" Technique and Differences in Yields from that Technique as-measured by three other Techniques

Technique	Treatment 1 (Control)	2 (Super)	3 (Super + Lime)	Standard Error per plot as per cent. Mean Plot Yield
1. Frame	30,325	33,558	35,605	1.4
	Differences from "Frame" Technique			
2. Mowing and Grazing	-6,721	-8,015	-8,795	4.9
3. Mowing only	-8,299	-9,170	-9,995	3.7
4. White clover	-14,239	-16,359	-17,761	5.6

Table IV shows:—

1. That yields measured by the "white clover" technique are little more than one-half those of the "frame" technique (cut under the "Standard" Extension Division method).

2. That the "mowing only" and "mowing and grazing" techniques indicate yields about 25 per cent. less than the "frame" technique.

3. That the standard errors of all techniques do not differ greatly; all are satisfactory. The comparatively low errors associated with the "frame" technique are particularly pleasing.

Examination of the sward indicates that the lower productivity of swards under "mowing and grazing" and "mowing only" techniques is associated with increasing dominance of white clover-probably a result of the much greater frequency of mowing with these small-plot techniques. A dominantly white-clover sward is considerably less productive than a mixed pasture.

RESPONSES TO TREATMENTS

Table V, based on dry matter yields, shows the treatment responses measured by the different techniques.

TABLE V.

Dry Matter Yields relative to control = 100 and Significance of Treatment Differences

Technique	Year	Yields relative to Control = 100		Significance of Differences		
		Sup.	Sup. + Lime	Sup. — Control (a)	Sup. + Lime — Control (b)	Sup. + Lime -Sup. (c)
Frame	1948-49	109	116	1%	1%	1%
	1949-50	109	119	5%	1%	5%
	Winter and Spring 50	118	118	1%	1%	N.S.
	2½ years	111	117	1%	1%	1%
Mowing and Grazing	1948-49	108	116	1%	1%	1%
	1949-50	110	113	1%	1%	5%
	Winter and Spring 50	106	109	1%	1%	N.S.
	2½ years	108	114	1%	1%	1%
Mowing Only	1948-49	119	120		1%	1%
	1949-50	112	116	1%	1%	N.S.
	Winter and Spring 50	110	111	1%	1%	N.S.
	2½ years	111	116	1%	1%	5%
White Clover	1948-49	109	121	N.S.	1%	5%
	1949-50	106	107	N.S.	N.S.	N.S.
	Winter and Spring 50	105	104	N.S.	N.S.	N.S.
	2½ years	107	111	5%	1%	N.S.

N.S.: Yield difference not significant.
5% (1%): Yield difference significant at 5% (1%) level.
Column (a) gives response to superphosphate, (b) to superphosphate and lime' and (c) to lime.

The agreement among the techniques as measures of treatment responses is surprisingly good although there is some indication that the white clover sward method may be less sensitive than the others.

Table VI compares the sheep records with herbage weights under the "frame" technique. for the period 10/8/48 to 10/6/49.

TABLE VI

Yields, Weights and Grazing Days Relative to Control = 100

	Control	Super	Super + Lime
Gains in sheep weight	100	118	120
Grazing days (sheep) . .	100	100	112
Herbage production . .	100	109	117

Herbage weights give lower estimates of responses than sheep-weight gains over this period and grazing days lower than both these measures. Unfortunately, stock records for the whole trial period are not available.

GENERAL CONCLUSIONS

The techniques we have studied by no means exhaust the list. Sear's (1) "proportional return" technique. has now been incorporated into the Rukuhia trial and investigations are proceeding at Rukuhia with the "constant animal live-weight" (9) and various plot techniques. A pure grass sward adequately treated with nitrogen also has possibilities. At the present time, however, I consider the evidence justifies the following conclusions.

1. The "frame" technique; using for preference the "standard" method of the Extension Division (with prior trimming) is needed for:-

(a) Accurate measures of total herbage production.

(b) The comparison of pasture species and strains and seeds mixtures. (The constant use of the mower is too remote from "normal" grazing for small-plot trials to be successful with this class of work.)

(c) Those experiments where it is desired to correlate animal production records with pasture production records.

2. The, "mowing only and clippings returned" technique is most useful for trials comparing fertiliser responses and is simple enough to be used by field officers in co-operative experiments on farms.

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DISCUSSION

Mr Sears considered that the hand cutting with the "grazing estimation" method gave results more comparable with grazing than did the use of. the motor mower. The mower was difficult to use on small plots and on long grass. Hand cutting gave a much cleaner herbage sample for dissection or chemical analysis.

A. Agreed that hand cutting gave the cleanest sample but a satisfactory clean sample was secured with the mower provided a prior trimming cut had been obtained.

Q. What do you advise for techniques suitable for adoption by farmers or untrained workers.

A. The use of observational methods is desirable where possible. These fail under high fertility conditions when differences as great as 2.5 per cent. may be overlooked. In poor pasture, however, responses may be more obvious, especially if there was a change in botanical composition. If production records were required the frame technique could be used without interference with grazing management. Mowing strips in the paddock before grazing was a simple method.

Professor Hudson stressed the point that there is no universally satisfactory method and it was necessary to use the technique which best suited the problem studied.