PASTURE PRODUCTION ESTIMATES BY MEASURES OTHER THAN CUTTING

P. B. LYNCH, Senior Principal Scientific Officer, and N. S. MOUNTIER, Scientific Officer, Department of Agriculture, Wellington

We can distinguish two basic items about grassland that require measurement or assessment, namely (1) production and (2) botanical composition. Each has its own problems of evaluation. For the purposes of this paper we are concerned with production rather than with the species composition of pastures, although it may be difficult at times to consider one without the other. Production obviously depends to a considerable degree on the species present. Methods of assessing changes in production also assess the effect of changes in composition.

However, the work to be described rests on the basic assumption that we are primarily interested in the ***production*** of ***dry matter*** from swards kept in a relatively short, leafy condition. Such swards probably show least variation in respect of quality, as far as stock production is concerned, always assuming the presence of all essential nutrient elements and the absence of disease producing factors. We have argued that we want methods to assess and compare swards that -give results comparable to production measurements obtained by cutting.

It is, of course, true that no cutting method gives anything more than the production as measured by the particular technique employed (1, 2). However, if we are interested primarily in ***comparisons among treatments,*** as we are in experimental work generally, many difficulties of technique become less serious. The production measurements we have taken as a basis of comparison in this paper were secured using a motor mower and the technique "mowing only and returning clippings", as has been described by one of the authors.[1] It has been shown[2] that this method gives measures of treatment effects (as far as fertiliser responses are concerned) comparable with those from the "cage" method and from the "proportional return" method of Sears[3]. It is, therefore, a reasonable standard to employ.

Methods of Assessment Used

The methods of assessment that have been compared with production as measured by cutting fall into two main groups:

1. Observational methods.
2. Measurement methods.

1. Observational Methods

For some time we have been endeavouring to improve methods of observational assessment. Better observations will improve and expand the information secured from measurement trials. We have long recognised the necessity for observational trials on many classes of country and in circumstances where cutting trials are impracticable. There are many such circumstances, particularly in soil fertility investigations which are being conducted by the Department of Agriculture on the different pastures on hill and flat throughout New Zealand.

At the Grassland Conference of 1954[4] Miss Miller presented a paper on the accuracy of eye observations in pasture trials. She showed that observations by experienced observers were a sensitive tool and that there was reasonable consistency among observers scoring the same experiment.

Observational Scales Used

(a) **Direct Estimates of Production:** With training it has been found that reasonably accurate direct estimates of dry matter production are possible, or at least that it is possible to place a series of plots pretty well in the order in which they are producing. The usual estimate made is the "Production Index" (P.I.), which is the ***annual*** dry matter production of herbage in thousands of pounds (thus a P.I. of 5 = 5,000 lb of dry matter per acre per annum). The best procedure seems to be for the observer to have one or more mowing trials on which he assesses production so that he can check his assessment against the measured yields. It is then possible to assess P.I. on observational trials with some degree of confidence.

(b) **"Fertility Index":** For some years the Farm Advisory Division has been using a scale of "Fertility Index" (or F.I.) as a measure of pasture quality and production for use with advisory soil testing data. The scale has recently been applied to pasture experiments. There has been considerable success in standardising the F.I. scale among observers.

The F.I. scale ranges from 0 to 20 where 0 is an extremely poor, unthrifty pasture and 20 a vigorous, high-producing pasture of "cow to the acre" fertility. A guide to the use of the index is provided in a further classification known as "pasture class". This classifies pastures into nine groups according to the species present, and the limits of F.I. for each pasture class are specified as in Table 1. Thus class 1 covers swards where clovers such as suckling, striated, or clustered clover or Lotus *hispidus* predominate with poor quality grasses and the F.I. scale is limited to 1-6 for this class; whereas class 8 swards have white clover as the dominant clover species and species such as ryegrass, cocksfoot, and timothy as the main grasses.

TABLE *I-Fertility Index Scale (Abridged)*

Pasture Class	Main Clovers	Main Grasses	Fertility Index Range
0.	No perennial clover	Tussock, danthonia, browntop, annuals, etc.	0 - 2
1.	Suckling & annuals, etc	As above	1 - 6
2.	Subterranean	As above	2 - 8
3.	Subterranean	Ryegrass, dogstail, etc.	6 – 15
4.	*Lotus uliginosus*	Danthonia, browntop, etc.	3 - 6
5.	*Lotus uliginosus*	Ryegrass, dogstail, fog, etc.	5 - 15
6:	Red	Annuals, fog, etc.	5 - 10
		Ryegrass, etc.	6 - 20
7.	White	Tussock, danthonia, browntop, annuals, etc.	3 - 13
8.	White	Ryegrass, cocksfoot, etc.	6 20

(c) Response Pointing on Pasture Fertiliser Trials: In the past the Department of Agriculture usually scored fertiliser responses on trials by a 0 - 5 scale of *differences from control.* Thus a point of 1 is a "slight" difference, 2 a "fair". 3 a "good", 4 a "very good", and 5 an "excellent" response. There are several features of interest about this scale.

(a) **Responses** are observed. These may be shown in many things of which differences in pasture composition and production are probably the most important. Because of the rather indefinite nature of the term "response", training of observers and standardisation of their assessments have been essential features of the method. However, this scale is less amenable to rigorous standardisation than the F.I. scale described above. Despite its apparent vagueness of definition, many tests have shown that the "0 - 5 scale" is quite a sensitive and reliable scoring method in the hands of experienced observers.[4]

(b) In each replication the control plot is always given "0" regardless of its composition or productivity. With the P.I. and F.I. scales, however, the control plots are marked as one of the treatments. With the "0 - 5 scale" the control plot must be known (and this introduces the danger of bias).

The nature of the scale makes statistical analysis of the scores of doubtful validity. Not only is there a lack of linearity (that is, that a difference between 1 and 2 is not equal in any real sense to a difference between 4 and 5), but also there is the difficulty that a "slight" response on a poor sward is a very different thing from a "slight" response on a good sward. The scale is really only a simplified way of describing differences between plots. It is, therefore, difficult to assess the reliability of "0 - 5" response observations on any one trial by statistical procedures.

We can now consider the measurement methods used in this study.

2. Measurement Techniques (Other than Cutting)

Height of Pasture: This was assessed by a ruler at 10 points in each plot (of 25 ft x 5 ft). The sward height (to the nearest inch) in front of the ruler inserted vertically into the sward was an assessment of its mean height disregarding any occasional long leaves. It was thus: quite different from precise measurements of tiller or leaf lengths and was very much quicker.

Light Intensity at Ground Level: This was measured by a probe containing a photo electric cell connected to a conventional light meter. This probe received light in a narrow horizontal band from all directions about $\frac{3}{8}$ in. above ground level. The light meter reading was first taken just above the sward and adjusted to 100; the probe was then inserted vertically into the sward and the reading taken again. Ten places at random were taken in each plot at the same points as the height measurements (the height scale was, in fact, marked on the probe). The idea behind the light probe was that the light intensity at ground level should reflect the height and density of the sward. It should also measure the light intercepted by the sward and available for photosynthesis.

Appraisal of These Techniques

The most complete set of data was secured from a study which was conducted over a period of a year on two mowing trials at the Takapu Road Experimental Area near Wellington, Mowing trials were chosen so that we would have a satisfactory criterion to compare our methods against. It was realised that a mowing trial would generally be an easier trial to observe than an ordinary observational trial; that, in particular, the plots would tend to be more even.

Methods used for every cut were:

1. F.I. rating.
2. Height of sward.
3. Light intensity at $\frac{3}{8}$ in. above ground level; and methods used on some cuts only were:
4. Production Index (1,000 lb DM/acre/annum).
5. 0 – 5 pointing.

One of the trials compared rates of phosphate and had 40 plots divided into 5 blocks of 8 (there were only 7 distinct treatments at this stage of the trial and one treatment appeared twice in each block). The responses in this trial were substantial, with the best treatment yielding about double control. There were much finer differences between rates. The other trial was a lime, molybdenum trial with 48 plots divided into 4 blocks of 12. In this case 8 of the 12 treatments formed a 4 x 2 factorial, and although all 12 treatments were assessed in every case, it is convenient to compare results of methods on the factorial part only.

Just before each mowing the trials were pointed on the Fertility Index scale. It is therefore possible to compare these two methods of assessing the treatments. The same observer pointed the trials on each occasion.

Table 2 shows the dry matter production for a year for each trial and the mean F.I. value over that year. Each has been statistically analysed, and differences at the 5 per cent and 1 per cent significance levels on Duncan's test are indicated by the letters. (In this notation two treatments with a letter in common do not differ significantly; two treatments with no letter in common do differ significantly). The right hand columns of the table show proportional figures based on control as 100.

TABLE ***2-Comparison** of **Fertility Index** and **Production***

(a) ***Rates of Phosphate Trial*** (Summer to Spring 1958)

Treatment	D.M. lb/acre	Mean F.I. (1 observer)	Relatives D.M.	Relatives F.I.
1. Control	5,800 e C	7.2 e E	100	100
2 & 4. 1 cwt Double Super p.a.	8,800 c B	10.5 c c	152	146
3. 1 cwt D.S. every second year	6,720 d C	8.6 d D	116	119
5. 2 cwt D.S. p.a.	9,800 b A	11.8 b B	169	164
6. 6 cwt D.S. initially	10,330 ab A	12.7 a A	178	176
7. 2 cwt D.S. p.a. (Dalapon renovated)	10,100 ab A	12.7 a A	174	176
8. 3 cwt D.S. p.a.	10,740 a A	12.7 a A	185	176
Coefficient of Variation (C.V.) ..	7.2%	3.6%		

(b) ***Lime, Molybdenum Trial***

Treatment Means	D.M. lb/acre	Mean F.I. (1 observer)	Relatives D.M.	Relatives F.I.
No Lime	7,340 bB	10.1 b B	100	100
3 cwt Lime .	7,470 b B	10.7 b B	102	106
10 cwt Lime	8,560 a A	11.5 a A	117	114
20 cwt Lime	8,900 a A	12.1 a A	121	120
No Molybdenum	7,740 b A	10.3 b B	100	100
2½ oz Sodium Molybdate	8,390 a A	11.7 a A	108	114
C.V.	8.8%	7.0%		

Individual treatments show almost exact agreement in significant differences and closely similar relative yields. This is so whether the response is due to phosphate, lime, or molybdenum. The very few differences between the assessments indicate if anything a greater sensitivity in the F.I. observations.

The definition of Fertility Index shows no reason why a doubling of the F.I. mark should correspond to a doubling in yield, and yet in these trials this seems to happen over the part of the scale that is used; that is, the relative figures are similar for yield and F.I.

From its description the F.I. may be expected to remain fairly

TABLE 3-Comparison of Fertility Index and Production by Seasons (Relatives only)

(a) ***Rates* of *Phosphate Trial***

Treatments	Summer D.M.	Summer F.I.	Autumn D.M.	Autumn F.I.	Winter D.M.	Winter F.I.	Spring D.M.	Spring F.I.	Year D.M.	Year F.I.
1. Control	100	100	100	100	100	100	100	100	100	100
2 & 4. 1 cwt Double Super p.a.	161	138	122	151	166	143	151	150	152	146
3. 1 cwt D.S. every second year ..	123	116	98	124	115	117	116	121	116	119
5. 2 cwt D.S. p.a.	169	149	143	165	222	168	165	172	169	164
6. 6 cwt D.S. initially	172	162	150	176	241	185	180	183	178	176
7. 2 cwt D.S. p.a. (Dalapon renovated)	189	163	136	173	200	183	169	183	174	176
8. 3 cwt D.S. p.a.	188	161	158	178	220	175	184	186	185	176
Actual yield and F.I. of Treatment 1	2,110	7.6	920	7.4	590	6.0	2,180	7.2	5,800	7.2

(b) ***Lime, Molybdenum Trial***

Treatment Means	Summer D.M.	Summer F.I.	Autumn D.M.	Autumn F.I.	Winter D.M.	Winter F.I.	Spring D.M.	Spring F.I.	Year D.M.	Year F.I.
No Lime .... ----	100	100	100	100	100	100	100	100	100	100
3 cwt Lime	97	105	111	96	104	100	104	101	102	106
10 cwt Lime	115	119	128	113	117	115	114	114	117	114
20 cwt Lime	120	126	136	123	126	124	116	116	121	120
Actual yield and F.I. of no Lime	2,800	8.9	890	9.6	1,290	10.2	2,760	10.8	7,340	10.1
No Molybdenum	100	100	100	100	100	100	100	100	100	100
2½ oz Molybdenum ...	116	113	104	110	106	111	104	111	108	114

constant throughout the year and to fail to reflect seasonal response differences. This has been the case here, as Table 3 indicates. This has been restricted to relatives only for ease of presentation.

The F.I. scale in these trials is much less precisely correlated with dry matter production on a seasonal basis than is the case with the yearly figures. In the phosphate trial, for instance, yields of treatment 8 relative to control go down in autumn (158) and up in winter (220) after autumn topdressing, but the F.I. relatives remain constant for these two seasons, which is the sort of result one would hope for.

Comparison of Observers and of Scales

As mentioned earlier, previous work has been reported on observer consistency, and our results are in line with this. An attempt was made to see whether results were affected markedly by the particular observational scale used. In these trials there was very little difference between the **assessment** obtained from Fertility Index, Production Index, or 0 - 5 response scale. Table 4 shows a comparison.

TABLE *&-Comparison of Observers and Scales*

Rates of Phosphate Trial (December 1958 cut)

Treatment	F.T. Observer A	F.I. Observer B	P.I. Observer A	o - 5 Observer B
1	7.6 d C	7.6 d D	4.4 d C	0 c c
2 & 4 ----	10.5 c B	9.5 c c	5.5 c B	1.5 b B
3	8.4 d C	7.8 d D	4.5 d C	.5 c c
5	12.0 b A	10.2 c c	6.4 b A	1.8 b B
6	13.0 ab A	12.6 ab AB	7.1 ab A	2.8 a A
7	13.0 ab A	11.8 b B	6.7 ab A	2.6 a A
8	13.6 a A	13.4 a A	7.3 a A	3.2 a A
C.V.	8.9%	8.5%	8.8%	26.7%

(The figures in the preceding tables are based on the scores of observer A.)

It can be seen that the consistency both between observers and between scales is good. P.I. and F.I. given by observer A give identical significance letters. The discrepancies between the two observers using the F.I. scale are slight. Observer B showed a very similar picture using the 0.5 response pointing.

Height and Light Intensity

Table 5 shows the comparison of these with production in the two trials studied.

TABLE %-*Comparison of Height and Light at Ground with Production*
(a) ***Rates of Phosphate Trial*** (Summer to Spring 1958)

Treatment	D.M. lb/acre	Mean Height (in.)	Mean Light	Relatives D.M.	Relatives Height
1	5,800 e C	1.9 d C	11.8 c C	100	100
2 & 4	8,800 c B	2.9 c B	~8.3 a AB	152	1.53
3	6,720 d C	2.2 d C	10.1 b BC	116	116
5	9,800 b A	3.3 b A	7.9 a AB	169	174
6	10,330 ab A	3.8 a A	6.9 a A	178	200
7	10,100 ab A	3.7 ab A	8.5 ab AB	174	195
8	10,740 a A	3.8 a A	7.6 a A	185	200
C.V.	7.2%	9.2%	14.9%		

(b) ***Lime, Molybdenum Trial***

Treatment	D.M. lb/acre	Mean Height (in.)	Mean Light	Relatives D.M.	Relatives Height
No Lime	7,340 b B	2.8 c c	8.1 c A	100	100
3 cwt Lime	7,470 b B	2.9 c C	7.9 bc A	102	105
10 cwt Lime	8,560 a A	3.4 b B	6.9 ab A	117	121
20 cwt Lime	8,900 a A	3.8 a A	6.6 a A	121	137
No Mo	7,740 b A	3.1 b A	7.6 a A	100	100
Molybdenum	8,390 a A	3.4 a A	7.1 a A	108	110
C.V.	8.8%	9.8%	15.1%		

The correspondence between height and yield is good, both in significance and in relatives. The light readings show a similar trend, but correspond distinctly less satisfactorily. Treatment 2 occupies a different position according to light from that indicated by yield or height; treatment 5 is not distinguished from 6, 7, and 8 by light measurement, whereas both the yield and the height indicate it as different at the 5 per cent level of significance.

It is clear that in the trials the height measurements have been better indicators of yield than have light meter readings.

Conclusions

In the trials examined there is surprisingly good agreement between visual observations and mown yield and also between height measurements and mown yield. The light meter readings are much less promising in this respect.

Differences between different observational scales have been slight in this study. However, some scales 'are much more satisfactory than others from the theoretical point of view: the 0 - 5 is not satisfactory, the F.I. moderately satisfactory, and the P.I. quite satisfactory in this respect.

The measurement of height of sward seems well worth further investigation. It needs to be more precisely defined. Further work is proceeding to investigate whether the precision of methods under grazing conditions will be comparable with those reported here.

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DISCUSSION

Q. (C. E. Tversen): What are your estimated production figures for the pasture alongside Mr Black's woolshed?

A. Class 8, F.I. 15-16, P.I. 12-14.

Q. (P. D. Sears): How do you train observers and how do you compensate between green material and dry matter yield?

A. It is agreed that it is necessary to standardise observers, and much investigation into consistency has been done. A good correlation between observers exists. The observer needs a knowledge of yield from mowing trials to estimate Production Index (P.I.).

Comment (C. J. Hamblyn): There could be confusion between F.I. and P.I. judgments unless conditions for observation were suitable. There were occasions, such as in winter or drought, when judging could not be done.

A. It is useless attempting to make observations when conditions are not suitable.

Q. (Campbell): In comparing pastures, how useful is the comparison of heights in estimating production?

A. Though there hasn't been enough work, in most trials height measurement gave an estimate of production agreeing pretty well with the mower.

Q. (Dr L. Corkill): Have you tried to tie in height and density in estimating yield?

A. (N. S. Mountier): Light intensity at ground level is a measure of pasture density while light by itself shows some relationship with yield, height is more satisfactory, and the light measure adds little of value to the height measurement.

Q. (C. E. Iversen): How do you allow for differences between individual observers?

A. Differences do exist, but the splitting into pasture classes automatically limits variation. It is largely a matter of training.

Q. (C. E. Iversen): Why would you mark Mr Black's pasture as only P.I. 1 5? What type would you mark as P.I. 20?

A. It is not up to maximum standard., A P.I. 20 pasture would be dominantly grass under very high fertility conditions.

Comment (N. A. Cullen): Percentage of grass is the important factor and must be about 80 per cent for peak production.