The comparative yield method for estimating dry matter yield of pasture

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Summary—This paper describes a new method for estimating pasture yield in which the yields of random quadrats are rated with respect to a set of reference quadrats preselected in the field to provide a scale which is available for reference throughout the sampling. Three alternative calibration procedures are described based either on the dry matter yields of the reference quadrats or on the yields of quadrats rated and cut either during or at the end of sampling. The second and third procedures are shown to have advantages over the first.

When testing the method with four observers and two types of calibration scales, estimates of mean yield were generally within 4 per cent of the actual mean with a maximum difference of 8 per cent.

Methods are given for calculating the number of samples required to obtain minimum variance for the estimate of mean yield for a given cost in terms of time spent in the field.

The need for a method to estimate the amount of herbage in a pasture quickly and accurately is recognized by all workers. Measuring yield directly by cutting is costly and destructive, and while the individual sample is measured accurately, the limitation remains that each measurement represents only one sample from a highly variable population of yields within a pasture. The main problem lies in the variability of the population and not in the precision with which an individual sample is measured, and hence many samples estimated with an acceptable lower precision are better than a few samples measured precisely, provided there is no bias. Various techniques have been proposed to overcome this problem involving either estimation of yield or measurement of some attribute that can be related to yield.

This paper describes The Comparative Yield Method for estimating pasture yield in which the yields of random quadrats are rated with respect to a set of reference quadrats preselected to provide a scale which is available for reference throughout sampling. Sufficient quadrats are harvested to calibrate the scale, which permits use of the double sampling principle as proposed by Wilm, Costello and Klipple (1944). The method is similar to that of Morley, Bennett and Clark (1964), which has been investigated by Campbell and Arnold (1973), the essential difference being that instead of estimating the yield of a quadrat as a weight it is rated in relation to the reference quadrats. We believe that relative weight is easier to estimate than absolute weight, which will lead to greater precision. Our method is basically similar to that of Hutchinson, McLean and Hamilton (1972) except that it is applicable to any height of pasture whereas they state that it is difficult to use their method in pasture more than 20 cm in height. The method is non-destructive and permits large numbers of yield estimates to be made in one day by one observer, and is therefore especially valuable in large grazing experiments.

Methods

The first procedure is to select either five or nine reference quadrats, which constitute the yield scale against which the yields of sample quadrats are rated. To construct a five-point scale, two quadrats (standards 1 and 5) are placed on low and high yielding areas such that rarely will the dry matter yield of a sample quadrat lie outside this range. The observers

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then select a position for standard 3 estimated to have a dry matter yield half-way between those for 1 and 5. Then they select standards 2 and 4 which have yields half-way between those for 1 and 3, and 3 and 5 respectively. If a 9-point scale is required, further standards viz. 1.5, 2.5, 3.5 and 4.5, are found by the same procedure.

There are several points to note:

1. Each observer independently selects a position for the mid-point yield, standard 3 in the first place, and then final selection is made after consultation and, if necessary, after comparison of several subsequent choices.
2. To facilitate comparisons while selecting standards and during sampling, it is an advantage to have the standards located close to one-another and centrally situated, provided a suitable range of botanical composition is incorporated.
3. A quadrat frame should be left in position at each standard and a protection cage is needed in grazed paddocks.

After establishing the scale an initial training period is required in which all observers simultaneously rate a series of quadrats until an acceptable degree of uniformity is achieved; we aim to reach a point where our estimates do not differ by more than 0.25 of a scale unit. Frequent returns to the standards are necessary during this training period which usually takes about 30 minutes.

In subsequent sampling, quadrats are placed according to some appropriate sampling plan and in each case an observer gives a yield rating relative to the standards. We rate in quarters, e.g. 1.75, giving a 17-point scale but other methods could be used. During sampling it is wise to return to the standards from time to time to refresh the memory. The standards should also be re-examined after any break in sampling e.g. after lunch, and each morning where sampling extends over a number of days.

We have used three different procedures for calibrating the standard yield scale:

Type 1

After all plots have been rated, the reference quadrats are harvested and the regression equation of dry matter yield on scale rating is calculated. The yield estimate for any sample is then obtained by substituting the rating in this equation. We have found that the relation is usually linear. When using this calibration Type the observers should check each other's estimates periodically to maintain uniformity, and if there is disagreement all observers should go back to check against the standards.

Type 2

This calibration Type is designed to allow for the fact that an individual observer may have a consistent bias in his estimations; for example he may consistently over-estimate high yielding quadrats.

During the sampling each observer constructs a personal calibration scale by harvesting quadrats which he is confident he has rated correctly. An observer is not necessarily confident of his rating for every quadrat because 1. he is estimating to the nearer 0.25 of a scale unit. 2. the pasture may be very uneven in height, 3. there may be an unusual complex of species present in the quadrat, or 4. there may be variation in herbage density throughout the quadrat. There is no restriction on the number of quadrats harvested but their ratings should cover the range from low to high. Once the initial training period has been carried out there is now no need for observers to check each other's estimates because each will have his own calibration curve. However, individual checks against the standard quadrats would help to maintain precision and accuracy.

The quadrats in the initial reference scale need not be harvested and the estimated mean dry matter yield of a plot for an observer is obtained by substituting his ratings in the calibration equation obtained from the quadrats he has harvested.

Type 3

One practical disadvantage in using Type 2 is that an observer has to carry hand-shears, bags and labels, plus bags of cut samples, in addition to his quadrat and recording sheets. We have found that this becomes cumbersome and have therefore adopted the following modification. Special quadrats are cut after all estimations have been completed instead of during sampling. The observers each select a set of quadrats to cover the range from low to high, and these quadrats are then rated by all observers and harvested giving a calibration scale for each observer which is based on the same quadrats; observer scales may then be compared to detect differences between ratings for particular quadrats and for differences in bias; bias may arise either from a consistent difference from the calibration line throughout the range of

ratings or from a difference at one end of the scale associated with the opposite bias or with no bias at the other end. For this calibration Type we usually cut a total of 12 quadrats.

We have not conducted a formal test of Type 3 calibration because it is essentially a variant of Type 2 in that it attempts to record personal calibration lines for each observer. It should therefore give accuracy and precision similar to that for Type 2.

Testing the method

Tests have been made on a native pasture/*Stylosanthes humilis* mixture in which the dominant grass was *Heteropogon contortus* as described by Shaw and 't Mannetje (1970). Tests 1 and 2 were done in March 1972 and test 3 in March 1973, all three being in the same paddock. Square quadrats (0.25 m^2) were used and all herbage was harvested at ground level with hand shears and weighed after drying at 70°C for 17 hours. The tests examined construction of the scale, and compared calibration Types 1 and 2.

Constructing the scale

To construct a scale, observers must be able consistently to pick a quadrat whose dry matter yield is half-way between those of two other quadrats. For a scale to be linear the estimation must be unbiased. Test 1 and 2 were designed to test the ability and precision of three observers to estimate mid-point yields.

Test 1—Each observer independently made nine estimates of the mid-point between the yields of two reference quadrats having either 1. low and high, 2. low and medium or 3. medium and high yields of pasture. The nine quadrats of each observer and the two references were then harvested for each of the three categories.

A summary of the data and results for various tests is shown in table 1.

Skewness and kurtosis estimates test the normality of the distribution of estimates and they indicate that the estimates of observers A and B were generally symmetrically distributed about their respective mean estimates. Observer C's estimates showed irregular skewness but were leptokurtic, which means that besides having a smaller standard deviation his estimates clustered closer about their mean than would normally be expected.

There was a wide range in precision with observer B's pooled variance significantly greater ($P < 0.01$) than the pooled variance for A and C.

The predominantly positive biases of observer B show that he was inclined to over estimate the mid-yield.

TABLE 1

Summary of data and test for observer estimates of nine mid-yield values for each of the three categories shown (test 1).

Estimate	Category: Low-High Observer			Low-Medium Observer			Medium-High Observer		
	A	B	C	A	B	C	A	B	C
Lower yield (*kg ha*$^{-1}$)	—	400	—	—	440	—	—	4880	—
Higher yield (*kg ha*$^{-1}$)	—	10320	—	—	4720	—	—	8680	—
Mean yield (*kg ha*$^{-1}$)	5542	6009	5444	2560	2756	2360	6253	7578	6751
Bias (%)†	3.4	12.1*	1.6	− 0.8	6.8	−8.5	−7.8	11.8*	0.4
S.D. (*kg ha*$^{-1}$)	582	1066	619	713	681	191	735	1116	576
Skewness: *t*-test	−0.2	0.2	1.7	0.2	1.1	2.2*	−1.4	1.6	−2.1
Kurtosis: *t*-test	−0.9	1.6	1.1	−0.6	0.2	2.7**	0.7	0.1	2.5*

† Tests for bias were carried out on data transformed to square root scale to equalize the variances of observers.

*, ** Significant at $P < 0.05$, $P < 0.01$ respectively.

Test 2—One objection to the procedure in test 1 is that an observer's ability to estimate the mid-yields accurately might be confounded with his ability to learn from experience, because nine estimations were made for each set of references. Accordingly, in this test nine pairs of reference quadrats were randomly selected for each estimation, and the three observers each made single estimates of the mid-point.

The precision of observer B (S.D.= 689 kg ha^{-1}) again was poorer than that for A (572 kg ha^{-1}) and C (460 kg ha^{-1}). The mean value of the actual mid-yield was 3590 kg ha^{-1} and the biases for A and C were 2.1 and −6.1 per cent, and for B, 14.3 per cent ($P < 0.001$). The test was based on square root transformed data.

The results of this test confirmed the findings of test 1 that B was less precise than the other two observers and that he overestimated mid-yields. Observer C was the most precise but tended to underestimate mid-yields.

TABLE 2

Regression coefficients (b), *correlations* (r) *and residual standard deviations* (*S.D.*) *for the linear regression of dry weight of herbage* (*kg ha*$^{-1}$) *on rating for 17 type 1 calibration scales constructed on different occasions. The number of ratings* (n) *and the mean dry weight are also given.*

Occasion	*n*	Mean	*b*	*r*	S.D.
June 1969	5	2060	1036	0.98	362
Oct. 1969	5	2370	1096	1.00	134
Mar. 1970	5	5460	2512	0.99	811
June 1970	5	5760	2780	0.99	893
June 1971	5	6480	2981	0.99	666
Oct. 1971	5	6690	3224	0.99	421
Jan. 1972	5	3450	1388	0.99	475
Mar. 1972	5	6040	2304	0.99	429
Mar. 1972	5	5800	2531	1.00	357
Mar. 1972	9	5640	2603	0.99	435
June 1972	5	5040	2304	0.99	569
Oct. 1972	5	4090	1997	0.98	713
Mar. 1973	5	6870	2948	0.99	423
Mar. 1973	5	7820	3564	1.00	456
Mar. 1973	9	6630	2783	0.98	828
June 1973	5	6650	2998	0.99	395
Oct. 1973	5	7140	3536	1.00	472

Construction of scales—Positive bias of observers leads us to expect that, if they independently constructed calibration scales they would have difficulty constructing linear scales because the end points 1 and 5 are fixed without estimation.

In table 2 we present the mean yields, the regression and correlation coefficients and the residual standard deviations for calibration scales constructed by two or three observers on 17 occasions using the method described earlier. These occasions cover a wide range of average yields and different seasons of the year with contrasts between mid-summer, when all the pasture was green, and late winter when the pasture was predominantly dry material remaining from the previous season.

Table 2 shows that precise linear calibration lines were obtained which accounted for 95 per cent or more of the variance of yield between quadrats for all cases, and for 98 per cent or more for 12 cases. The residual standard deviation had a wide range but showed no association with regression coefficient.

We conclude from the evidence of these lines that by the method of independent action and joint consultation individual biases can be eliminated from the joint calibration line.

Application of the method

Test 3

This test was designed to test the accuracy of the method, to compare a 5-point with a 9-point calibration line, to compare four observers A, B, C and D, and to compare calibration Types 1 and 2. The three observers A, B and C were those used in the first tests whereas D had no previous field experience with the method.

Five quadrats for a calibration line were selected by the observers as described above and the required familiarization by observers was carried out. Forty quadrats were then placed in the pasture to cover a range of yields from least to greatest and with which was associated a range of botanical compositions. Each observer independently rated all quadrats and listed which quadrats they would like harvested for Type 2.

The 40 quadrats were left in position but the reference quadrats corresponding to ratings 2, 3 and 4 were harvested. Next day a 9-point calibration line was jointly constructed using the quadrats rated 1 and 5 the previous day as the extreme points.

After the familiarization period, all four observers independently rated the 40 quadrats with respect to the 9-point scale. Selections for Type 2 were not made. The reference and the sample quadrats were then harvested and dry weights obtained.

An analysis of variance on estimated dry weight of herbage showed that there were significant differences ($P < 0.001$) between observers and between scales with a significant ($P < 0.001$) interaction between these two factors. However the largest difference from the true mean was the 7.8 per cent obtained by observer A using the 5-point scale (see table 3).

A similar analysis was carried out on dry weight of herbage estimated by Type 2 and three observers had very satisfactory results (see table 3). The results for this calibration Type showed closer agreement among observers than did those for Type 1 and less bias, which is what it was designed to do.

The estimated dry matter, averaged over all observers, agreed very closely with the actual mean for all three methods (table 3). Such compensating estimates must be expected if a method is unbiased. Over half the individual observer estimates were within 3 per cent of the actual mean. Such results would be particularly satisfactory in large scale grazing trials where, in common with Campbell and Arnold (1973), we regard estimates within 10 per cent of the actual mean as acceptable. It is worth noting that observer D with no previous experience achieved accurate mean estimates.

TABLE 3

Mean values in kg ha^{-1} and biases for observer estimations using either a 5-point or a 9-point scale in calibration type 1 or using a 5-point scale with calibration type 2. The actual mean yield was 7510 kg ha^{-1} and the error standard deviation was 683 kg ha^{-1}.

Type 1 calibration	Observer A	B	C	D	Mean
5-point scale					
Mean	8093	7980	7243	7394	7678
Bias	7.8***	6.3***	−3.6*	−1.5	2.2
9-point scale					
Mean	7504	6972	7383	7597	7362
Bias	−0.2	−7.2***	−1.7	1.2	−2.0
Type 2 calibration 5-point scale					
Mean	7950	7415	7354	7352	7518
Bias	5.9**	−1.3	−2.1	−2.1	0.1

*, **, *** Significantly different from zero at $P < 0.05$, $P < 0.01$, $P < 0.001$, respectively.

To examine further the estimation by Types 1 and 2, the linear regressions of actual weight of herbage on estimated weight were calculated for each observer, Type and scale. If the estimation by an observer is unbiassed the slope of the regression line will be equal to 1.0, and the intercept on the y-axis will be zero. Because of the tendency for observers to overestimate the higher yields, the lines for Type 2 were expected to have slopes less than 1.0.

The statistics for these lines are not presented here, but the slopes were generally less than 1.0 with Type 2 slopes equal to or less than the corresponding slopes for the Type 1 lines, both scales. However, in only one case (A, Type 2) was the slope significantly less than 1.0 ($P < 0.01$).

The adjustment to the slopes of the lines made by observers using Type 2 indicate that these observers overestimated higher yielding quadrats. However, Type 2 allowed more accurate estimates to be made (table 3).

To compare observer predictions there is only one dependent variate, viz actual yield, and so we follow Williams (1959, p. 73) and compare the independent variables (observer estimates) for equal correlation with actual yield. This test showed that 1. observer C was outstandingly better ($P < 0.001$) than the others using the 5-point scale with Types 1 and 2, and 2. for Types 1 and 2 the correlations for the other observers were not different and 3. there were no differences between the observer correlations for the 9-point scale.

Although the experimental procedure was such that the calibration Types 1 and 2 could not be compared statistically, the greater accuracy achieved by Type 2 would make it (or Type 3) a preferable procedure.

Number of samples for minimum variance

If a straight line relation is appropriate for the regression of yield on rating, the mean yield for a plot, $\hat{\bar{y}}$, for n' ratings is read off at the mean of the ratings, $\bar{x}'$, i.e. from

$$\hat{\bar{y}} = y + b\,(x' - \bar{x}) \qquad \ldots (1)$$

Following Cochran (1963), the variance of $\hat{\bar{y}}$ for Type 1 calibration conditional on the x's chosen may be reduced to

$$\text{Var}(\hat{\bar{y}}) = \sigma^2_{y.x}\{1/n + (\sigma^2_x/n' + (A - \bar{X})^2)/B\} + \beta^2\sigma^2_x/n' \quad \ldots (2)$$

for an n-point scale and ignoring the finite sampling fraction. Here A is the mean of the x's ($\bar{x}$) and equals $(n + 1)/2$ for integer ratings; B is the corrected sum of squares for the n ratings and equals $n(n + 1)(n - 1)/12$; $\bar{X}$ is the mean of all possible ratings within a paddock; σ^2_x is the variance of the ratings and is estimated by s^2_x, the variance of the additional ratings; $\sigma^2_{y.x}$ is the variance of quadrat dry matter yields and is estimated by $s^2_{y.x}$, the residual mean square for the calibration line; β is the population regression coefficient and is estimated by b.

If we assume $(\sigma^2_x/n' + (A - \bar{X})^2)/B$ is small compared with $1/n$, (2) reduces to

$$\text{Var}(\hat{\bar{y}}) \simeq \sigma^2_{y.x}/n + \beta^2\sigma^2_x/n' \quad \ldots (3)$$

For Type 2 and 3 calibrations the A and B values are still non-random variables and it is reasonable to condition the variance upon these ratings. For a fixed n, the A and B values may not be very different from those for Type 1 calibration if a choice is made to cover the range of ratings.

Using $s^2_{x'} = 1.11$, which was obtained by pooling the variance for ratings over the paddocks of a large grazing trial, and taking a range of regression coefficients and residual mean squares (S.D.^{2}) from table 2 to estimate β and $\sigma^2_{y.x}$, respectively, we may calculate estimates of the variance of mean dry matter expected in similar situations with different values of n and n' by substituting in (3). These are presented in table 4.

Optimum allocation of n and n' is obtained by minimizing the variance given by (3) conditional on a total cost C given by the following function

$$C = C_0 + C'n' + C_in \quad \ldots (4)$$

where C_0 = overhead cost common to all types, arising from locating the initial scale and from training.

C' = cost of locating and rating a quadrat.

C_i = cost of locating and/or harvesting a quadrat which may depend on the calibration type ($i = 1, 2$ or 3).

Thus, the optimum $n(n_0)$ is approximately

$$n_0 \simeq (C - C_0)\sigma_{y.x}/(\beta\sigma_x\sqrt{C_iC' + C_i\sigma_{y.x}}) \quad \ldots (5)$$

The corresponding optimum value for $n'(n'_0)$ may be obtained by substituting n_0 in (4).

For optimum allocation, costs may be measured in equivalent units of time. In a large experiment, where 21 samples a hectare were being rated, the time taken to locate and rate a quadrat was approximately 38 seconds which gives C'. The time taken to establish and subsequently train to be familiar with the standards was 2 and 2.5 hours for a 5-point and a 9-point scale, respectively (C_0). Cutting time for a sample was 10 minutes giving C_1, and hence C_2 was estimated to be 10 min. 38 sec. C_3 was estimated to be 12 min. Using these estimates and a range of

TABLE 4

Optimum sample numbers, n_0 *and* n'_0, *in type 3 calibration for minimum expected standard error of the mean (S.E.; kg ha*$^{-1}$*) for a given cost (total time spent in the field in hours) and for selected values of the regression coefficient* (β) *for the calibration line and its residual standard deviation* ($\sigma_{y.x}$). *Expected S.E.'s are also given for a fixed* n *and the corresponding* n′ *calculated from the cost function.*

Cost	β	$\sigma_{y.x}$ 250			$\sigma_{y.x}$ 750			$\sigma_{y.x}$ 250			$\sigma_{y.x}$ 750
		n_0	n'_0	Expected S.E.	n_0	n'_0	Expected S.E.	n	n'	Expected S.E.	Expected S.E.
hours											
5	1500	6	168	159	10	93	288	5	189	160	355
	2750	4	207	237	8	134	366	5	189	239	396
7	1500	10	281	123	17	155	222	5	395	137	345
	2750	7	344	183	13	223	283	5	395	184	366
10	1500	16	449	97	27	247	176	5	679	127	341
	2750	11	551	145	21	356	224	5	679	158	353

values for β and $\sigma^2_{y.x}$, the optimum sample numbers n_0, n'_0 were calculated and are also presented in table 4. Comparisons between the expected standard errors for specific sets of conditions also indicate the decrease in the standard error that would be expected by increasing the sample number (n) for the calibration line.

Practical considerations in using the method

We have been using Type 1, 5-point scale, since 1969 and during this time practical difficulties have been met and resolved. We list below a number of these points as a guide to potential users of the method. Some of the points considered important and essential by Campbell and Arnold (1973) are in agreement with these.

In common with all estimation methods it is essential that the method be tested before use, particularly when pastures of different structure are being used.

There is little value in selecting standards 1 and 5 which are too extreme otherwise such ratings will be rarely met and the whole scale will not be used. Yields of occasional quadrats outside the range of the scale may be obtained by extrapolation.

To minimize bias from observers all observers should make similar numbers of independent estimates in each plot.

Where calibration Types 2 or 3 are being used it is still useful to cut the Type 1 standards. Observers' calibration lines can then be checked for bias by comparing the slope and intercept coefficients for the two lines. This would be particularly valuable if observers are not familiar with the method.

In retrospect, we feel that where the comparative yield method is being used for the first time observers should undertake a training program similar to the procedure in test 3. If biases are evident in any particular region of the calibration scale further training and checking in this region could be carried out as in test 2.

When sampling large trials it is tempting to use one calibration line for all plots in order to reduce the effort. This should be a safe procedure provided the botanical composition does not change markedly with treatment. However, if any plot is such that the ratings for the samples would lie predominantly at one end of the calibration scale, the factor $(A - \bar{X})^2$ in (2) will increase and so will the standard error of the mean. If this is unacceptable a separate calibration scale should be constructed for that plot and other plots of similar yield.

More than one calibration line may also be necessary where species with different growth habits are being compared; for example *Stylosanthes humilis*, which has narrow leaves and tends to grow among the grasses, and the broad-leaved trailing legume *Macroptilium atropurpureum* which forms a canopy over the grasses.

Where a single observer is constructing the Type 1 calibration scale, he should choose several quadrats which he estimates have yields half-way between those of the relevant standards. He would then re-assess his choice and, if necessary, repeat the procedure until he is satisfied with his final choice.

When estimating yield it should be remembered that a high proportion of the yield is in the lower layers of the pasture, and therefore height alone is not necessarily a good guide. It is essential to gauge the density of material in these lower layers and we find it helpful to handle the pasture to estimate this. Points to consider are the amount of plant material, the area of bare ground between plants, height, percentage of inert material and differences in moisture content of different species.

Photographs of the Type 1 standards could be carried and used as an aid in rating. If these proved to be helpful we would expect that there would be less possibility of bias and less time spent checking with the standards.

As a practical example, using this method combined with the dry-weight-rank method of 't Mannetje and Haydock (1963) we rate for yield and botanical composition approximately 2800 quadrats in a 130 ha experiment in 7 man-days.

Acknowledgments

We acknowledge with pleasure the technical help of Mr. T. W. Elich and Mr. G. A. Versace, C.S.I.R.O., Division of Tropical Agronomy, throughout the testing of the method. We are also indebted to Mr. R. L. Sandland and Mr. G. R. Dolby, C.S.I.R.O., Division of Mathematics and Statistics, for discussions on some of the statistical matters raised by the investigation, and to Dr. G. H. Brown, C.S.I.R.O., Division of Mathematics and Statistics, for the simplifications leading to equations (2) and (3).

REFERENCES

Campbell, N. A., and Arnold, G. W. (1973)—The visual assessment of pasture yield. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13**: 263.

Cochran, W. G. (1963)—"Sampling Techniques". Second edition. (John Wiley & Sons, Inc.: New York).

Hutchinson, K. J., McLean, R. W., and Hamilton, B. A. (1972)—The visual estimation of pasture availability using standard pasture cores. *Journal of the British Grassland Society* **27**: 29.

Mannetje, L't, and Haydock, K. P. (1963)—The dry-weight-rank method for the botanical analysis of pasture. *Journal of the British Grassland Society* **18**: 268.

Morley, F. H. W., Bennett, D., and Clark, K. W. (1964)—The estimation of pasture yield in large grazing experiments. C.S.I.R.O., Division of Plant Industry, *Field Station Record* **3** (2): 43.

Shaw, N. H., and Mannetje, L. 't, (1970)—Studies on a spear grass pasture in central coastal Queensland—the effect of fertilizer, stocking rate, and oversowing with *Stylosanthes humilis* on beef production and botanical composition. *Tropical Grasslands* **4**: 43.

Williams, E. J. (1959)—"Regression Analysis". (John Wiley & Sons, Inc: New York).

Wilm, H. G., Costello, D. F., and Klipple, G. E. (1944)—Estimating forage yield by the double-sampling method. *Journal of the American Society of Agronomy* **36**: 194.

Received for publication November 25, 1974