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closing date is complex since delaying closing will result in removal of the grass companion, but may lead to overgrazing and the removal of stolon and ultimately inflorescence buds. The balance between these factors will determine inflorescence production and influence other seed yield components. Results from this experiment suggest that small-leaf types may allow more flexibility with closing date and tolerate more severe grazing pressure than large-leaf types. This also suggests that while small-leaf types may be suitable for such a system, large-leaf types may be unsuitable since they require a lower grazing pressure to prevent overgrazing and early closing, which may not only restrict the grazing available but may also not control grass growth sufficiently. This experiment has not considered the effect of other factors such as the relative grass/clover content of the sward and how this could be achieved, perhaps by manipulating seed rates or the use of grass suppressants or the effect of grazing pressure. These factors and the unknown response of medium leaf types to this system require investigation.

Acknowledgments

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Response of permanent and reseeded grassland to fertilizer nitrogen. 1. Herbage production and herbage quality

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Abstract

The productivity of permanent swards of mixed species composition was compared with that of sown *Lolium perenne*, cv. Melle at five fertilizer-N rates (0, 150, 300, 450 and 900 kg N ha⁻¹) and with *L. perenne*/*Trifolium repens*, cv. Grasslands Huia at 0 kg N ha⁻¹. The investigation was conducted under two cutting frequencies at sixteen sites in England and Wales, representing a range of grassland environments.

Annual total herbage dry matter (DM) production from both permanent and reseeded swards increased with successive increments of fertilizer-N up to 450 kg N ha⁻¹. Herbage DM production from reseeded swards in the first year after sowing was significantly higher than from the permanent swards, at all fertilizer-N treatments. In subsequent years the production advantage of the *L. perenne* reseeded swards was maintained only at the higher N rates, though sown *L. perenne*/*T. repens* was the most productive sward type at 0 N. Average differences in modified acid-detergent fibre suggested small advantages in herbage quality to the reseeded swards.

It is concluded that, while reseeded swards are more productive in the year after sowing, many permanent swards are capable of high levels of production and that reseeding to a *L. perenne*

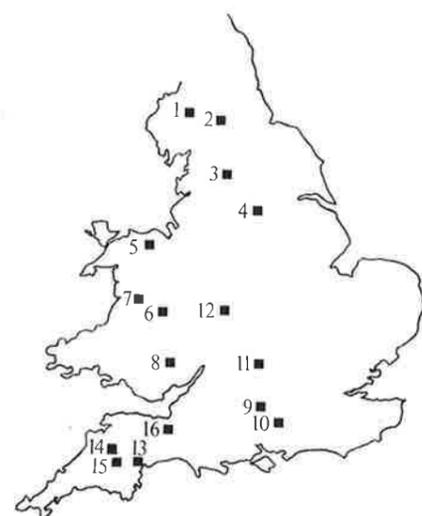
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sward cannot always be justified, particularly for grassland receiving low or moderate inputs of fertilizer-N.

Introduction

Permanent grassland occupies the majority of the 5 Mha of enclosed grassland in England and Wales. Over half is at least 20 years old. Swards are generally of mixed composition, in which perennial ryegrass (*Lolium perenne*) is often a relatively minor constituent. While the response of sown *L. perenne* to nitrogen (N) is generally well-understood, data on permanent swards, particularly in comparison with sown swards, are relatively sparse. Available comparisons usually relate to single sites, often in upland areas (e.g. Mudd and Meadowcroft, 1964; Davies and Munro, 1974) or to relatively low management input systems (Davies and Williams, 1948). In the seven trials reported by Davies and Williams (1948), comparing the productivity (under grazing) of permanent and sown swards under N inputs below 60 kg N ha⁻¹, output was generally higher from sown swards, though differences were small where the permanent swards contained over c. 20% of perennial ryegrass. In small-plot cutting trials the output of sown *L. perenne* has exceeded that of native *Festuca-Agrostis* and *Molinia caerulea* pasture (Davies and Munro, 1974) and that of an *Agrostis stolonifera* sward (Sheldrick *et al.*, 1986).

However, other trials have shown only small differences in production between permanent and reseeded swards, (e.g. Scott *et al.*, 1984). In Lancashire, the average DM production over 6 years from a permanent sward of mixed composition was only 70% that from a sown mixture at 0 N input (probably owing to the greater contribution of white clover in the sown



Site		Grid Reference
1.	Mungrisdale	NY393276
2.	Barnard Castle	NZ040192
3.	Winterburn	SD935575
4.	Cawthorne	SE302083
5.	St. Asaph	SJ082762
6.	Pant-y-Dwr	SN982742
7.	Ponterwyd	SN784826
8.	Tredeggar	SO125114
9.	Highclere	SU449598
10.	Selborne	SU766332
11.	Oxford	SP487127
12.	Great Alne	SP112607
13.	Exminster	SC946862
14.	North Wyke	SX648991
15.	Chagford	SX705839
16.	Bridgwater	ST293392

Figure 1. Location and National Grid Reference of trial sites.

sward), but similar to, or higher than, that of the sown sward over the 6 years on all treatments that received fertilizer-N (Mudd, 1971).

In Holland, Hoogerkamp (1971) found that under average conditions young grassland was less productive than old grassland with a good botanical composition, but the differences narrowed as more N was applied.

Several workers have conducted comparisons of sown *L. perenne* with sown indigenous pasture species (e.g. Haggard, 1976; Frame, 1983; Harkess and Frame, 1986) and shown that while *L. perenne* performs well at high levels of N, several of the species common in permanent swards can yield more under low or moderate rates of fertilizer input. Smith and Allcock

(1985) compared the output of *L. perenne*/*T. repens* with a sown complex mixture of these species plus several indigenous grasses. At 50 kg N ha⁻¹, herbage production harvested from *L. perenne*/*T. repens* exceeded that from the complex mixture, but at 300 kg N ha⁻¹, there was no production advantage to *L. perenne*/*T. repens*.

The wide range of sites in the grassland manuring (GM) trials (Jackson and Williams, 1979; Morrison *et al.*, 1980) provided information on the influence of climate and soil on the DM yield of sown *L. perenne*. However, these results may not be applicable to permanent swards; particularly those low in *L. perenne*.

In 1983 a small-plot cutting experiment was established at sixteen sites in England and Wales to compare the output of permanent swards with identically managed sown *L. perenne* under a range of N rates and two cutting frequencies. Results from the first phase of the experiment 1983–1986 are presented in this paper.

Methods

Sites were selected from the main grass-growing areas of England and Wales to represent a range of grassland environments and soil types under both high- and low-rainfall regimes. The distribution of sites is shown in Figure 1. Elevations ranged from 7 m above sea-level to over 400 m. Existing permanent swards were mainly over 20 years old. Swards were of mixed species composition with *L. perenne* contributing not more than 30%. Previous management had been relatively extensive, with inputs of N less than 200 kg N ha⁻¹. Most of the sites had received considerably less than this amount of N, and in some cases *L. perenne* was either absent or only a minor constituent of the sward.

Treatments began on the permanent swards in spring 1983. Reseeded swards were established during late summer of 1983, and an assessment was made of the resulting loss of production. The comparison of the herbage production from permanent and reseeded swards was made during 1984–1986. The trial was laid out on a randomized-block design with a split-block arrangement of permanent and reseeded treatments. There were three replicates of each treatment. Sward type was allocated at random within each of the three blocks at each site and

each main plot was then divided into subplots based on a range of fertilizer-N rates allocated randomly.

Treatments comprised five rates of fertilizer-N: 0, 150, 300, 450 and 900 kg N ha⁻¹ (denoted N₀, N₁₅₀ etc.), with cutting at intervals of 4 weeks at all the five N rates on all sites; plus either (1) an 8-week cutting interval for all N rates (at eight of the sixteen sites), or (2) an 8-week cutting interval for the N₃₀₀ rate only (at the other eight sites). In addition, a reseed of perennial ryegrass with white clover (*Trifolium repens*) was included at the N₀ level, again at the 4-week cutting interval (at all sites) and at the 8-weekly cutting (at eight of the sites).

Areas to be reseeded received 100 kg N ha⁻¹ in spring 1983 and a measured cut was taken at the same time as the first 8-weekly cut on the permanent treatments. Regrowth was treated with the herbicide glyphosate (Roundup, 48% e.c.; Monsanto) at 2 kg a.i. ha⁻¹. The sward was left for 14–21 d and then cultivated using a rotary cultivator followed by a roller and harrow, as required, to create a satisfactory seed bed. Fertilizers were worked into the seed bed at the following rates: 50 kg ha⁻¹ each of P₂O₅ and K₂O and 60 kg ha⁻¹ of N; the N omitted from the areas that were to be sown with a white clover mixture. Seed of *L. perenne* (cv. Melle) was drilled or broadcast at a rate of 25 kg ha⁻¹. The grass/white clover plots were sown with cv. Melle at 10 kg ha⁻¹ plus white clover cv. Grasslands Huia at 4 kg ha⁻¹. Sowings were established by mid-August. Immediately after crop emergence, plots were treated with the insecticide chlorpyrifos (Dursban 48% e.c.; Dow Chemical) at 1.5 kg a.i. ha⁻¹ as a spray and the molluscicide methiocarb (Draza granules, 4% a.i.; Bayer) at 0.7 kg a.i. ha⁻¹ using a hand-held shaker. Treatment to prevent damage by leatherjackets (larvae of *Tipula* spp.) was carried out using chlorpyrifos at 1.5 kg a.i. ha⁻¹ in early March on all treatments from 1984 onwards. Control of broad-leaved weed in the newly-established reseed was achieved by the application, at the grass-tillering stage, of a herbicide containing benazolin-salt with MCPA and 2, 4-DB (Legumex Extra, Schering Agriculture) at 0.7 kg a.i. ha⁻¹. No further applications of herbicide were made to the reseeded plots after the establishment phase and none was made to the permanent sward at any stage in the trial. Weed ingress and other

changes in species composition were monitored throughout the trial.

Fertilizer-N was supplied as commercial prilled ammonium nitrate in either six or three equal applications (4-week and 8-week cutting intervals respectively). First applications of N were made in late March (or as soon as possible thereafter, depending on soil conditions) and subsequent dressings applied after successive cuts. Adequate amounts of phosphate, potash and lime were supplied before and during the trial to avoid the risk of responses to N being limited by deficiencies of these elements. On the basis of soil tests carried out at the start of the experiment, soil pH values below 6.0 were corrected with the appropriate lime application, and P and K indices of less than 2 (MAFF, 1966) were raised by appropriate supplies of triple superphosphate and muriate of potash (MAFF, 1985). A further 150 kg P₂O₅ ha⁻¹ and 100 kg K₂O ha⁻¹ were applied in the spring of each subsequent year to all treatments. In addition, further K₂O was applied at the same time as the N, so that annual amounts of K₂O were 192 kg K₂O ha⁻¹ (at the N₀, N₁₅₀ and N₃₀₀ treatments) and 288 kg K₂O ha⁻¹ (N₄₅₀ and N₉₀₀ treatments). In spring 1985, soil analyses were carried out on each plot to confirm that the amounts of P₂O₅ and K₂O were sufficient to maintain soil P and K indices of 2. Soil pH determinations were also made at this time and applications of lime made where required.

The 4-week cutting interval plots were mown at least six times a year from early or mid-May and at least three cuts a year were taken from the 8-weekly treatments from early or mid-June. The 8-weekly cuts were simultaneous with cuts 2, 4 and 6 of the 4-weekly treatments. The date of first cut varied between sites, those in the south of England being about 2 weeks earlier than those in the north. Where herbage was available in late autumn, plots were trimmed in October or November, the herbage being recorded as a seventh (or fourth) cut. There was no further defoliation between this cut and cut 1 of the following year. Harvesting was carried out using either a hand-controlled autoscythe, with a fixed reciprocating cutter bar (Mayfield or Agria mower), or a Haldrup 1500 plot-harvester (Albertson's EFTF, Løgstør, Denmark). A cutting height of 5–7 cm was set for all cuts. A random subsample of herbage was collected and the whole swath was

Table 1. Herbage dry matter production ($t\ ha^{-1}$) from permanent pasture (PP) and perennial ryegrass reseeded swards (RS) under 4-weekly cutting. Average production from sixteen sites

	1984			1985			1986		
	1983 PP	PP	RS Significance level	PP	RS Significance level		PP	RS Significance level	
Fertilizer N ($kg\ ha^{-1}$ annually)									
0	4.21	3.73	5.37 ***	5.24	3.83 ***		4.09	4.13	NS
150	6.30	6.26	8.82 ***	8.10	7.45 **		6.88	6.51	NS
300	7.80	8.17	11.77 ***	9.93	10.28 NS		8.93	9.15	NS
450	8.97	9.64	13.25 ***	10.60	11.19 **		9.31	10.11	***
900	8.95	9.76	14.26 ***	10.23	11.22 ***		9.20	9.98	***
s.e.d. (means at same N rate)		0.320		0.206			0.206		
s.e.d. (means of same sward type at successive N rate)		0.231		0.210			0.188		
significance (N)		***		***†			***†		

†no significant difference between 450 and 900 $kg\ N\ ha^{-1}$ treatments (NS at $P < 0.05$).

immediately weighed together with the subsample. The dry matter (DM) content of the herbage was obtained by oven-drying the subsample at $100\ ^\circ C$ for approximately 12 h. The N content of the herbage at each cut was determined for all treatments to investigate N recovery, and the feeding value based on modified acid-detergent fibre (MADF) was also determined for the N_0 , N_{150} and N_{300} treatments (MAFF, 1986).

During the trial other records and assessments were made, including the analysis of minerals and trace elements in herbage, soil chemical and physical information and changes in botanical composition both by visual assessment and by hand sorting. Assessment of damage caused by pests and diseases was made during the trial, and on eight of the sites, additional experiments investigated the effect of agrochemical treatments on herbage production of permanent swards (Clements *et al.*, 1985).

Statistical analysis

Analysis of the treatment effects on harvested DM production followed a split-plot analysis of variance using GENSTAT (GENSTAT 5 Committee, 1987). Results were combined from sixteen sites to provide ninety-six main plots (or forty-eight main plots for 8-weekly cutting treatments). Tables of means are presented with

standard errors of differences of means (s.e.d.) calculated from the main plot residual mean squares (m.s.) on 47 d.f. (23 d.f. for the 8-weekly treatments at eight sites) and the subplots residual m.s. on 376 d.f. (230 d.f. for eight sites). Analysis of treatment effects on MADF followed a one-way analysis of variance (Ryan *et al.*, 1985) using weighted mean data from sixteen sites (or eight sites for 8-weekly cutting intervals) and the significance of the F-ratio was determined for 15 d.f. or 7 d.f. respectively.

Curve-fitting of the relationship between N and DM production was performed using the quadratic-on-quadratic model of the Maximum Likelihood Program (Ross, 1980). Values of Y_{10} (the DM production at which there is a response of $10\ kg\ DM\ (kg\ N)^{-1}$) and N_{10} (fertilizer N requirement for Y_{10}) were calculated for permanent and reseeded swards at each site using the same model.

Results

Herbage production and response to fertilizer-N: permanent and perennial ryegrass reseeded swards

Four-weekly cutting. Annual DM harvested, meaned for the sixteen sites in the trial, is summarized in Table 1 and response curves of mean DM over years in relation to N application for the two sward types are presented in

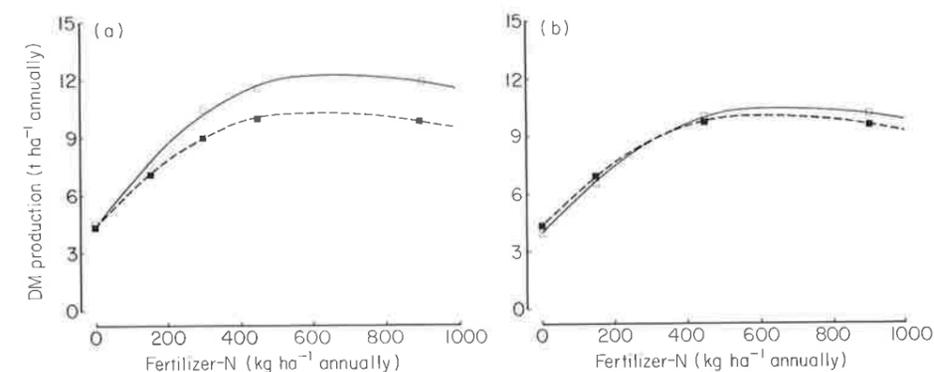


Figure 2. Fitted response curves showing dry matter production from permanent swards (—■—) and reseeded perennial ryegrass (---■---) in relation to fertilizer-N. Mean of sixteen sites under 4-weekly cutting (a) 3-year mean (1985-86) and (b) 4-year mean (1983-86) including the establishment-phase of the reseeded sward.

Figure 2. Herbage production from the reseeded sward in year 1 (based on herbage harvested before reseeding, and that from the reseeded sward in its establishment year) has been included in the 4-year total DM production in Figure 2. Loss of DM production during the reseeding phase was typically $3-5\ t\ DM\ ha^{-1}$.

Mean annual herbage DM harvested was significantly increased ($P < 0.001$) by applications of N up to N_{450} . Differences in production between the N_{450} and N_{900} treatments were not significant ($P < 0.05$) except in year 2, the first full harvest year of the reseeded swards, when an additional average DM of $1016\ kg$ was harvested ($P < 0.001$). However, the average herbage production harvested at N_{900} , compared with that at N_{450} , represented only $2.3\ kg\ DM$ for each kg of N. During year 4 the response on the permanent swards between the N_{300} and N_{450} treatments was low (average $2.54\ kg\ DM$ for each $kg\ N$) and only just reached significance at $P < 0.01$.

In the first full harvest year of the reseeded swards, significantly ($P < 0.001$) higher levels of DM production were harvested from the reseeded swards than from permanent swards at all levels of N. Additional DM production ranged from $1.63\ t\ ha^{-1}$ at the N_0 treatment to $4.50\ t\ ha^{-1}$ at N_{900} . Mean herbage DM responses for each $kg\ N$ applied were as follows: at N_{150} relative to N_0 , a response of $23.0\ kg\ DM$ on the reseeded swards and $16.9\ kg\ DM$ on the permanent swards; at N_{300} relative to N_{150} , a

response of $19.7\ kg\ DM$ on the reseeded swards and 12.7 on the permanent; and at N_{450} relative to N_{300} , responses of 9.9 on the reseeded swards and 9.8 on the permanent.

In years 3 and 4 the DM production advantage of the reseeded swards was not repeated except at the higher N treatments. In year 3 the herbage harvested from the permanent swards was significantly higher ($P < 0.01$) than that from the reseeded swards at the N_0 and N_{150} treatments, but at N_{450} and N_{900} that from the reseeded swards was significantly higher ($P < 0.01$), though by less than $1\ t$ of $DM\ ha^{-1}$. Higher levels of DM production were obtained from the reseeded swards in year 4 at the N_{450} and N_{900} treatments.

The mean response to N was consistently higher on the *L. perenne* reseeded than on the permanent swards in years 2 and 3 but in year 4 the pattern of response was similar for both sward types (Table 3). The response to the first two increments of N (N_{150} and N_{300}) was greater than at subsequent increments; mean response between N_{300} and N_{450} was only $6.2\ kg\ DM\ (kg\ N)^{-1}$ on the permanent swards and $7.4\ kg\ DM\ (kg\ N)^{-1}$ on the reseeded swards.

Average Y_{10} and N_{10} values for 1984-86, based on the quadratic-on-quadratic models (Ross, 1980) are given in Table 4. The 3-year mean Y_{10} for the permanent swards was 8.81 within a range of $5.58-11.31$ and the N_{10} also varied considerably (range 157-383). The 3-year mean Y_{10} for the reseed was 11.07

Table 2. Herbage dry matter production ($t\ ha^{-1}$) from permanent pasture (PP) and perennial ryegrass reseeded swards (RS) under 8-weekly cutting. Average production from eight sites (at five fertilizer-N rates) and from sixteen sites (N_{300} only)

	1983			1984			1985			1986		
	PP	PP	RS	Significance level	PP	RS	Significance level	PP	RS	Significance level		
Fertilizer N ($kg\ ha^{-1}$ annually)												
0	6.81	6.32	7.05	NS	8.85	5.72	***	7.28	6.56	*		
150	9.70	9.46	11.75	***	11.61	10.25	***	10.54	9.49	***		
300	11.17	11.88	14.86	***	13.05	12.21	*	12.20	11.16	**		
450	12.01	13.41	16.33	***	13.25	12.87	NS	12.94	12.29	*		
900	11.75	13.14	16.12	***	12.56	13.03	NS	11.89	12.14	NS		
300†	10.27	11.13	14.48	***	11.97	11.54	NS	11.72	10.85	NS		
s.e.d. (means at same N rate)	0.462				0.361			0.373				
s.e.d. (means of same sward type at successive N rate)	0.380				0.357			0.352				

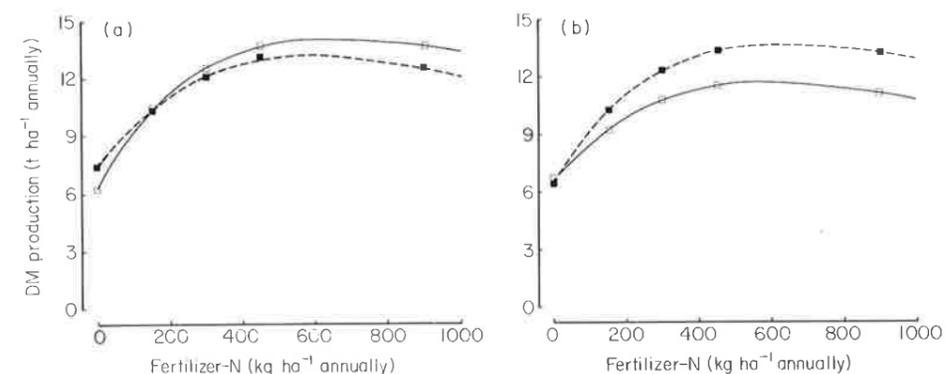
†Sixteen sites.

Table 3. Herbage dry matter response to fertilizer-N of permanent and reseeded swards at successive N rates relative to production without fertilizer-N

Range of fertilizer ($kg\ ha^{-1}$)	Herbage response, $kg\ DM\ (kg\ fertilizer-N)^{-1}$								
	Permanent sward					Perennial ryegrass reseed			
	1983 year 1	1984 year 2	1985 year 3	1986 year 4	mean	1984 year 2	1985 year 3	1986 year 4	mean
	4-week cutting intervals (mean of sixteen sites)								
0-150	14.0	16.8	19.0	18.7	17.1	23.1	24.0	15.8	21.0
0-300	12.0	14.8	15.6	16.1	14.6	21.5	21.4	16.7	19.9
0-450	10.6	13.3	11.8	11.6	11.8	17.6	16.3	13.3	15.7
0-900	5.3	6.7	5.5	5.7	5.8	10.0	8.2	6.5	8.2
	8-week cutting intervals (mean of eight sites)								
0-150	19.3	21.4	18.2	21.8	20.2	32.0	29.7	19.5	27.1
0-300	14.5	18.7	14.0	16.4	15.9	26.7	19.5	15.3	20.5
0-450	11.6	15.5	9.7	12.6	14.1	21.1	15.8	12.3	16.4
0-900	5.5	7.6	4.1	5.1	5.6	10.3	8.1	6.2	8.2

Table 4. Mean annual values of N_{10} , Y_{10} , N_{max} and Y_{max} for permanent and reseeded swards for 1984-86

		4-week cutting intervals†		8-week cutting intervals‡	
		Permanent	Perennial ryegrass	Permanent	Perennial ryegrass
N_{10} ($kg\ ha^{-1}$)	mean	281	363	285	313
	s.d.	64.3	90.4	34.9	71.6
Y_{10} ($t\ DM\ ha^{-1}$)	mean	8.81	11.07	12.25	12.88
	s.d.	1.41	3.10	1.65	2.08
N_{max} ($kg\ ha^{-1}$)	mean	637	669	566	640
	s.d.	108	73.9	56.2	83.8
Y_{max} ($t\ DM\ ha^{-1}$)	mean	10.31	12.33	13.54	14.17
	s.d.	1.39	3.36	1.52	1.88

†mean of 16 sites; ‡mean of 7 sites (values from one site out of range of the model); s.d. standard deviation of the mean (σ_{n-1}).**Figure 3.** Fitted response curves showing dry matter production from permanent swards (—■—) and reseeded perennial ryegrass (---■---) in relation to fertilizer-N. Mean of eight sites under 8-weekly cutting (a) 3-year mean (1983-86) and (b) 4-year mean (1983-86) including the establishment-phase of the reseeded sward.

(range 6.69-13.94) with N_{10} values ranging from 125 on the lowest-producing site to 480 on the highest. Mean N_{10} was $281\ kg\ ha^{-1}$ on the permanent swards compared with 363 on the reseeded swards.

Eight-weekly cutting. Annual DM production, meaned for the eight sites at which the full range of treatments was conducted, is summarized in Table 2. Fitted response curves for the two sward types are presented in Figure 3. The 1983-86 curve of the reseeded swards takes into account the loss of production during the reseeding phase.

Mean annual herbage DM harvested was significantly increased ($P < 0.001$) by applications of N, up to N_{450} , on both permanent and reseeded swards in year 2; differences between N_{450} and N_{900} were not significant at $P < 0.05$. In years 3 and 4 DM production from reseeded swards was significantly ($P < 0.001$) higher in response to N up to N_{300} . On the permanent swards response to N was lower, especially in year 3 ($P < 0.01$ between N_{150} and N_{300}) with a significantly ($P < 0.05$) decreased production between N_{450} and N_{900} in year 4.

In year 2, the first full harvest year of the reseed, significantly ($P < 0.001$) higher levels of DM production were obtained from the reseeded swards at all treatments except N_0 . At N_{300} , N_{450} and N_{900} the average DM production

advantage of the reseed was approximately $3\ t\ ha^{-1}$. At N_{300} the mean response for each $kg\ N$ applied was $26.7\ kg\ DM$ on the reseeded swards compared with $18.7\ kg\ DM$ on the permanent swards.

In years 3 and 4 the situation was reversed with higher DM production obtained from the permanent swards. These differences were most significant ($P < 0.001$) at the N_0 and N_{150} treatments of year 3 when $3.1\ t$ and $1.4\ t\ ha^{-1}$, respectively, of additional DM production was harvested from the permanent swards.

Herbage DM production harvested under 8-weekly cutting, compared with the same N rate under 4-weekly cutting, was 20-45% higher in the case of reseeded swards and 30-70% higher for permanent swards. For both sward types the effect on production of the longer interval between cuts was greatest on the lower N treatments.

Response to N under the 8-week cutting interval (Table 3) showed similar trends to that under 4-weekly cutting. In years 2 and 3 response to N was consistently higher on the reseeded swards than on the permanent swards, but by year 4 response was similar for both sward types. Response to N was higher under 8-weekly cutting than under 4-weekly cutting, though only at the lower N levels. Mean response at N_{450} compared with N_{300} was only $5.5\ kg\ DM\ (kg\ N)^{-1}$ for the permanent swards and $7.3\ kg\ DM$ for the reseeded swards. The

Table 5. Herbage dry matter production ($t\ ha^{-1}$) and proportion of clover in the dry matter from perennial ryegrass and perennial ryegrass/white clover reseeded swards

	4-week cutting intervals			8-week cutting intervals		
	1984	1985	1986	1984	1985	1986
DM yield:						
perennial ryegrass reseed†	5.37	3.83	4.13	7.05	5.72	6.56
perennial ryegrass/white clover	5.51	5.96	5.68	7.18	8.31	8.17
significance of difference	NS	***	**	NS	**	*
% white clover in perennial ryegrass/white clover reseed	8.9	31.4	28.4	7.6	30.7	28.4

†treatments receiving no fertilizer-N.

3-year mean Y_{10} values were higher under 8-weekly than under 4-weekly cutting and the average was similar for permanent and reseeded swards (12.3 and $12.9\ t\ ha^{-1}$ respectively). N_{10} values for the permanent swards were within a range of 244 – $326\ kg\ ha^{-1}$, and for the reseeded swards a range of 255 – $463\ kg\ ha^{-1}$ (Table 4). Mean N_{10} was $285\ kg\ ha^{-1}$ on the permanent swards compared with $313\ kg\ ha^{-1}$ on the reseeded swards.

Production from perennial ryegrass/white clover swards

Annual herbage DM production is summarized in Table 5. Production harvested under 8-weekly cutting was typically 35–40% higher than under 4-weekly cutting. In the first harvest year, average production from the *L. perenne*/*T. repens* swards was similar to that from the identically managed treatments sown to pure *L. perenne* (differences NS at $P < 0.05$). However, in the subsequent 2 years the DM production harvested from *L. perenne*/*T. repens* reseeded under 4-weekly cutting was, on average, 2.13 and $1.55\ t\ DM\ ha^{-1}$ higher (1985 and 1986 respectively) and under 8-weekly cutting 2.59 and $1.61\ t\ DM\ ha^{-1}$ higher than from the *L. perenne* without white clover.

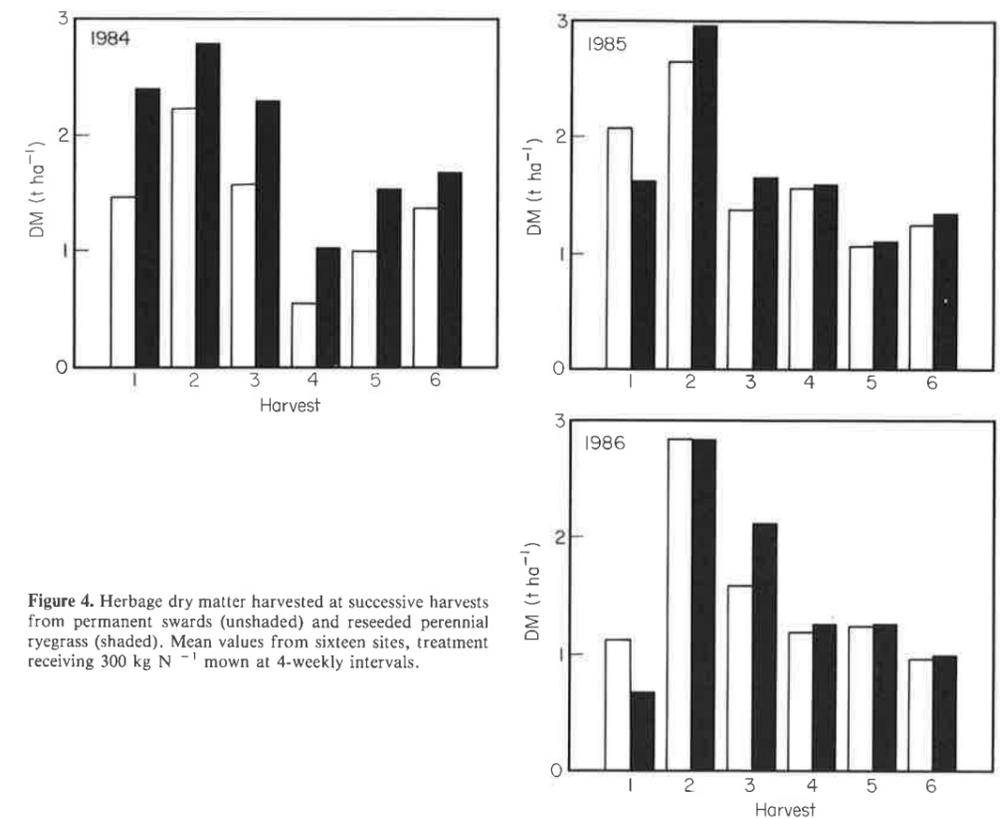
The average proportion of the herbage DM contributed by white clover, which was determined from hand separation of subsamples, is also summarized in Table 5. The poor performance of the *L. perenne*/*T. repens* reseed in the first harvest year (year 2 of the trial) was associated with a lower average white clover content than in subsequent years.

Variation in seasonal productivity

Variation in DM production harvested in successive years from permanent and *L. perenne* reseeded swards, meaned for the sixteen sites at the N_{300} 4-week cutting treatment, is summarized in Figure 4. The proportion of the annual DM production that was harvested at the first two cuts each year was about 40–45% of the total for both sward types in each year. The advantage of the reseed over the permanent sward was maintained at each cut throughout the first harvest year with this treatment (N_{300} , 4-weekly cutting). However, for this comparison with the N_0 treatment, the advantage of the reseed over the permanent sward was confined largely to the first two cuts of the first harvest year; production harvested at cuts 3–6 was similar for both sward types.

Variation in productivity between sites

Results summarized in Tables 1–4 and in Figures 2–4 are based on mean values for all sites in the trial. There was a wide variation in DM production between sites, reflecting the range of environments in which the trial was conducted. In year 1 the production harvested from the permanent swards at the N_{300} 4-weekly cutting treatment ranged from 4.85 to $11.42\ t\ DM\ ha^{-1}$. Production harvested from the N_0 treatment at the higher-yielding sites exceeded that from the N_{300} treatments at the lower-yielding sites. Although there were large differences between sites in terms of mean DM production, the patterns of response were generally similar. Reseeding resulted in a

**Figure 4.** Herbage dry matter harvested at successive harvests from permanent swards (unshaded) and reseeded perennial ryegrass (shaded). Mean values from sixteen sites, treatment receiving $300\ kg\ N\ ha^{-1}$ mown at 4-weekly intervals.**Table 6.** Annual DM yield ($t\ ha^{-1}$) in successive years of permanent (PP) and perennial ryegrass reseeded (RS) swards at sixteen sites for treatments at $300\ kg\ N\ ha^{-1}$ under 4-week and 8-week cutting intervals

Site	Elevation (m)	4-week cutting intervals								8-week cutting intervals							
		1983		1984		1985		1986		1983		1984		1985		1986	
		PP	RS	PP	RS	PP	RS	PP	RS	PP	RS	PP	RS	PP	RS		
1	305	6.84	9.08	11.88	9.81	9.85	7.87	7.71	10.60	13.30	17.16	12.87	12.42	11.19	11.11		
2	225	8.70	7.19	11.79	9.60	9.81	7.52	8.33	11.09	11.21	17.06	12.32	10.27	10.18	9.60		
3	200	8.38	8.69	13.41	11.33	11.98	9.22	8.99	9.97	12.95	17.57	13.02	12.68	11.27	10.54		
4	70	11.42	11.16	14.38	11.89	12.01	9.44	8.49	15.50	14.89	18.34	15.62	13.12	14.03	11.79		
5	245	7.68	8.40	11.33	9.51	10.02	8.47	8.78	10.91	12.22	12.38	13.38	12.24	11.91	10.87		
6	280	7.64	8.38	11.31	8.84	9.74	9.08	9.27	10.20	11.09	14.49	12.35	10.73	12.57	10.59		
7	310	6.82	6.84	8.55	9.22	10.20	7.62	8.95	9.97	10.22	12.71	9.33	9.78	10.05	9.21		
8	400	5.77	9.32	10.64	11.69	11.14	8.19	8.82	9.06	11.06	15.76	11.65	12.06	8.94	8.90		
9	150	6.79	7.82	11.94	11.04	12.82	8.66	9.15	6.80	9.17	11.02	10.93	12.06	9.75	10.31		
10	100	10.89	8.60	11.18	8.91	8.74	9.75	10.42	12.86	11.81	15.05	12.80	10.31	14.44	12.89		
11	60	9.15	9.17	15.15	15.18	14.28	12.04	10.97	12.14	10.37	16.21	15.04	14.63	14.03	11.90		
12	90	8.25	6.96	10.54	12.16	12.69	9.10	10.23	8.60	8.49	10.23	12.17	12.85	10.79	11.10		
13	15	4.85	5.77	10.27	4.21	4.59	10.18	9.37	7.81	9.04	12.83	6.27	6.79	13.00	11.96		
14	150	8.15	8.23	10.22	11.10	11.47	8.63	9.41	11.69	9.49	13.17	12.49	13.42	11.80	11.08		
15	290	5.61	7.30	9.54	6.58	6.07	8.31	8.80	6.63	11.92	10.81	10.54	9.53	11.24	10.74		
16	7	7.91	7.72	16.48	7.88	9.09	8.71	8.69	10.41	10.78	16.53	10.69	11.82	12.31	10.99		

†Location of sites shown in Figure 1.

Table 7. Modified acid-detergent fibre (MADF) as g kg DM⁻¹ and metabolizable energy (ME) as MJ kg DM⁻¹ of herbage from permanent and reseeded swards in relation to fertilizer-N level and cutting frequency

Year	Sward	Fertilizer-N (kg ha ⁻¹)											
		0		150		300		0		150		300	
		MADF	ME	MADF	ME	MADF	ME	MADF	ME	MADF	ME	MADF	ME
		4-week cutting intervals (sixteen sites)						8-week cutting intervals (eight sites)					
1983	Permanent	268	10.8	268	10.8	261	10.9	292	10.4	296	10.3	292	10.4
1984	Permanent	254	11.1	250	11.2	248	11.2	285	10.5	287	10.4	295	10.3
	Perennial ryegrass	242	11.3	237	11.4	238	11.4	268	10.8	269	10.8	274	10.7
	Ryegrass + white clover	245	11.2					271	10.8			275	10.7
	F value†/significance	8.71**		8.38**		4.52*		5.58*		7.86*		5.53*	6.40*
1985	Permanent	263	10.9	261	10.9	260	11.0	305	10.1	311	10.0	315	9.9
	Perennial ryegrass	250	11.2	249	11.2	250	11.2	275	10.7	281	10.6	287	10.4
	Ryegrass + white clover	248	11.2					278	10.6			284	10.5
	F value†/significance	6.87*		6.94*		5.36*		22.35***		21.89***		15.23**	23.19***
1986	Permanent	266	10.9	263	10.9	263	10.9	295	10.3	306	10.1	304	10.1
	Perennial ryegrass	259	11.0	254	11.1	251	11.1	279	10.6	274	10.7	281	10.6
	Ryegrass + white clover	254	11.1					279	10.6			280	10.6
	F value†/significance	1.99 ^{NS}		6.18*		8.29**		6.73*		16.90**		8.81*	5.53*

ME = 15.9 - 0.019 MADF (Ministry of Agriculture, Fisheries and Food, 1984); †F value: based on comparison of means of permanent and perennial ryegrass reseed at same treatment.

substantial increase in herbage production in the first harvest year at all sites. However, in subsequent years differences between permanent and reseeded swards were small; this was consistent across all sites (Table 6). In 1985 at the N₃₀₀ 4-week cutting treatment, mean DM production harvested from the permanent swards was 97% that of the reseeded swards, within a narrow range (86%–108%) between sites, and in 1986 it was again 97% that of the reseeded, within a range of 85% to 111%.

Herbage quality

For each site a weighted mean MADF value has been calculated on the dry matter of herbage harvested from the N₀, N₁₅₀ and N₃₀₀ treatments, taking into account the variation in DM yield and MADF at each successive harvest (Table 7). There were small advantages to the reseeded sward in terms of the calculated metabolizable energy (ME) content ($P < 0.05$). Under 4-weekly cutting the permanent sward contained about 10–12 g kg⁻¹ of additional MADF, equivalent to a reduction in the predicted ME value of the herbage of about 0.2 MJ kg⁻¹ DM. At the 8-week cutting interval, MADF was typically 30–40 g kg⁻¹ higher than at the corresponding 4-weekly treatment, for both permanent and reseeded swards, and

within the 8-weekly treatments the MADF content of the permanent sward was typically 15–30 g kg⁻¹ DM higher than for the reseeded swards, equivalent to a reduction in ME of 0.3–0.6 MJ kg⁻¹ DM

Botanical composition

At the start of the trial the permanent swards contained a mixture of sown and indigenous species; variation in botanical composition between sites reflected the range of environments and previous management. There were no sites that were dominated by one species. Lowland sites had more *L. perenne*, *Holcus lanatus*, *Poa* spp. and other grasses including *Alopecurus pratensis*, *Dactylis glomerata* and *Festuca pratensis*. On sites at higher elevations *Agrostis* spp., *Festuca rubra* and *Trifolium repens* were more frequent. On four sites, including two lowland sites, *L. perenne* was absent or was a very minor component, while on other sites it contributed some 10–30% of the initial sward. Changes in botanical composition occurred rapidly in response to the treatments imposed. An increase in *L. perenne*, associated mainly with a decrease in *Agrostis* spp., was recorded during the first and second years. Thereafter, *L. perenne* showed a small decline at all treatments.

Table 8. Annual total N (kg ha⁻¹) harvested from permanent pasture (PP) and perennial ryegrass reseeded swards (RS) under 4-weekly cutting. Average for sixteen sites

Fertilizer-N (kg ha ⁻¹ annually)	1984		F value †/ significance	1985		F value †/ significance	1986		F value †/ significance
	PP	RS		PP	RS		PP	RS	
0	101	117	0.66 ^{NS}	144	88	14.29***	111	116	0.08 ^{NS}
150	177	219	3.57 ^{NS}	231	178	6.29*	194	161	6.88*
300	258	332	11.92**	314	290	0.76 ^{NS}	283	263	2.54 ^{NS}
450	331	417	18.57***	361	357	0.02 ^{NS}	326	328	0.01 ^{NS}
900	375	522	36.70***	398	439	1.17 ^{NS}	358	381	1.93 ^{NS}

†F value: based on comparison of means of permanent and perennial ryegrass reseed at same treatment.

Recovery of N in herbage

The recovery of total N in herbage is summarized in Table 8. Total N harvested from the N₀ treatments varied widely between sites, variation being most marked in the first year of the reseeded when values ranged from less than 40 kg N ha⁻¹ on some upland sites to over 150 kg N ha⁻¹ on several of the more productive lowland sites. Total N in herbage from reseeded swards in their first year was higher than from the equivalent treatments of the permanent swards, and also higher than from the reseeded swards in subsequent years; these differences occurred across the range of N levels. In subsequent years the total N recovered in herbage was similar for permanent and reseeded swards receiving the same rate of N.

Discussion

The main objective of this trial was to compare the performance of permanent and reseeded swards under identical management in a range of grassland environments. The results confirm the advantage of reseeded *L. perenne* over the permanent swards at high levels of N (e.g. 450 kg N ha⁻¹) though at 0 and 150 kg N ha⁻¹ there was no advantage to the *L. perenne* reseed after its first year. Without fertilizer-N the highest-yielding sward type was the *L. perenne*/*T. repens* reseed.

This study has shown that many permanent swards, including some where *L. perenne* and *T. repens* are absent or are minor components, are capable of relatively high levels of production even with little or no N. On many commercial farms moderately high levels of output are achieved from old grassland, with little reliance on either white clover or N. Forbes *et al.* (1980)

in a study of productivity of a sample of 450 permanent grassland farms, reported that many farms using little or no N achieved a level of utilized output from grassland substantially higher than the average for farms in the sample.

An important feature of the present work is the relatively high level of production obtained from the reseeded swards in their first harvest year. This occurred at all sites and across the range of treatments. Similar findings were reported by Prins and Neeteson (1982). This increased production may be attributed, in part, to mineralization of soil N, reported to be greater in the first year after sowing than in subsequent years (Whitehead, 1970). For example, at the N₃₀₀, 4-weekly cutting treatment there was an average production advantage to the reseeded swards in the first harvest year of 3.6 t DM ha⁻¹, whereas in the following 2 years the advantage averaged less than 0.3 t DM ha⁻¹ year⁻¹. This was associated with a greater amount of N recovered in the herbage from the reseeded swards in year 1, compared with the situation in subsequent years when, at N₃₀₀ and below, more N was recovered in the herbage from the permanent swards (Table 9). Additional herbage harvested in the year after sowing was equivalent to that which might have been obtained by the application of 150–200 kg N ha⁻¹. This herbage production advantage was maintained at the N₄₅₀ and N₉₀₀ treatments: levels at which the N required for maximum or near-maximum production was already supplied. Maximum response to N on sown grassland occurs at 500–700 kg N ha⁻¹ (Morrison *et al.*, 1980) though Prins and Neeteson (1982) found that a sward in its first year continued to respond to at least 720 kg N ha⁻¹.

Sites for this trial were chosen to represent different initial sward types and contrasting soil and climatic conditions so that the responses to reseeding and potential of permanent swards could be evaluated across a range of grassland environments. There were large differences in herbage production between sites at each treatment, reflecting the range of environments, but the relative production of permanent and reseeded swards at each treatment showed remarkable similarity between sites. The results confirm that high levels of herbage production can be obtained from permanent swards of mixed species composition, even when the proportion of perennial ryegrass in the initial sward is low or even nil. At sites where *L. perenne* was present in the original sward, its proportion increased in response to fertilizer inputs, a finding noted in earlier experiments (Garstang, 1981).

The levels of herbage DM response to N in this trial were within the range of values reported elsewhere. Morrison *et al.* (1980) cite a mean response for sown *L. perenne* at N₃₀₀ (relative to N₀) of 23 kg DM (kg N)⁻¹ averaged over 4 years at twenty-one sites; this compares with mean responses of 20 kg DM (kg N)⁻¹ and 15 kg DM (kg N)⁻¹ for the equivalent treatment on reseeded and permanent swards, respectively, in the present trial. Response rates reported from other trials, expressed as kg DM (kg N)⁻¹ include: 22 for a permanent sward compared with 16 for a reseeded sward (Mudd, 1971); 13 for a predominantly *Agrostis stolonifera* sward compared with 17 for sown *L. perenne* (Sheldrick *et al.*, 1986), and 17 for both a permanent sward and a *L. perenne* reseed (Scott *et al.*, 1984).

In this trial the MADF content of the herbage from permanent swards was generally higher than that from sown perennial ryegrass. If MADF is assumed to be closely related to digestibility, the difference was typically equivalent to a reduction of one or two percentage points in DOMD, similar to that reported by Scott *et al.* (1984). Higher digestibilities for *L. perenne* than for secondary grass species have been reported elsewhere, though *H. lanatus* and *P. trivialis*, two common constituents of permanent swards, have been shown to have digestibilities little different from that of *L. perenne* (Haggard, 1976; Frame, 1983). However, it is important to recognize that

MADF may not accurately reflect differences in digestibility across species or varieties.

Until this study, there was relatively little information on the herbage production potential of permanent swards, particularly in comparison with newly-sown swards managed under the same conditions. However, it has been widely assumed that sown swards composed of species and varieties selected for a high potential production are inherently more productive than swards composed mainly or entirely of unsown species. A policy of ploughing and reseeding old pasture was widely adopted in the 1940s and was advocated for many years as a method for maintaining high productivity (Davies, 1960). This policy was not without foundation: before the 1970s fertilizer use on grassland in the United Kingdom, particularly N on older swards, was very low by current standards (Church and Lewis, 1977). Stocking rates were also often low. Surveys had shown a large area of permanent grassland to be in an agriculturally poor condition (Baker, 1960; Davies, 1960). Regular reseeding offered a means of quickly improving grassland productivity with a basis for the rotation of grass and arable crops.

This study has important implications in relation to reseeding policies and management of permanent swards. It demonstrates that, given adequate phosphorus and potassium and a satisfactory soil pH, high levels of production and response to N can be obtained from permanent swards. The presence of *L. perenne* or other sown species is not necessarily a requirement for this, although in situations reported elsewhere swards dominated by unproductive species have shown poor responses to N. While reseeding old grassland results in increased production from the new sward in its first harvest year, differences in productivity between permanent and sown swards are relatively small in subsequent years, particularly under low or moderate inputs of N. Reseeding of permanent swards may be justified when the existing sward is unproductive and unresponsive to management inputs, and if reseeding can be carried out at a relatively low cost with minimum loss of production during the establishment phase. The maximum benefit from reseeding is likely to be achieved under a high N regime (e.g. 450 kg N⁻¹). Reseeding can be used also to introduce white clover into a sward; however, changed management or the

oversowing of white clover into existing swards (Sheldrick *et al.*, 1987) are alternatives to full reseeding that might be considered if a switch to grass/clover swards is required.

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