Netherlands Journal of Agricultural Science 45 (1997) 263-275

Effect of a spring application of nitrogen on the performance of perennial ryegrass-white clover swards at two sites in the Netherlands

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Received 12 August 1996; Accepted 12 January 1997

Abstract

In the Netherlands, the introduction of milk quota and concern about N losses has led to a lower N application on grassland. Moreover, the present government policy will lead to a further reduction of N application. These developments have renewed the interest in white clover. Two cutting trails were set up to (i) evaluate the potential performance of mixed swards in the Netherlands and (ii) to quantify the effect of spring N on mixed swards. In a five year trial on clay soil five rates of N application in spring (0, 25, 50, 75 and 100 kg ha^{-1} year^{-1}) were combined with two cutting frequencies (4–5 cuts year^{-1} and 6–7 cuts year^{-1}). In a three year trial on sandy soil only the effects of spring N application (0, 50, and 100 kg ha^{-1} year^{-1}) were studied. Average annual DM yields were 14.66 and 13.76 t ha^{-1} year^{-1} for the clay and sandy soil, respectively. Spring application of 100 kg ha^{-1} increased the yield in the first cut with 11.1 kg DM per kg applied N. White clover contents decreased with increasing N rate, reducing the DM yield in the remaining cuts on the fertilised treatments. Nevertheless, on an annual basis, 100 kg N ha^{-1} increased the yield with 7.4 kg per kg applied N. Annual N yields were not affected by spring N application. Compared to a cutting frequency of 4 to 5 cuts year^{-1} a frequency of 6 to 7 cuts year^{-1} increased the white clover content from 36 to 47% and the N yield from 458 to 524 kg ha^{-1}, but did not affect the DM yield. It was concluded that spring application of N can be a practical tool to secure herbage production in spring with only a short-lived negative effect on white clover content.

Keywords: Trifolium repens, nitrogen, cutting frequency

Introduction

At present white clover only plays a minor role in Dutch grasslands, mainly due to the large amounts of slurry and fertilizer nitrogen (N) used on these grasslands. However, since the introduction of milk quota in 1984, there has been a gradual reduction in stocking rates (Anon., 1996). With fewer cows per ha less fodder has to be produced and therefore less N is needed. Moreover, there is an increasing concern about N losses in dairy production systems (Aarts *et al.*, 1992) and future systems will have to comply with environmental targets (Peel & Lloveras, 1994). Dutch government policies for the near future aim at a gradual reduction of N surpluses (Anon., 1995). This development will lead to a further reduction in the use of fertilizer N on grassland so that on an increasing number of dairy farms the annual N application rate will be in the range of 200 to 250 kg ha^{-1}. This may increase the possibilities for white clover in Dutch grasslands.

There are only few data about the potential yields of perennial ryegrass – white clover swards in the Netherlands. Due to a growing interest in organic farming, field trials with mixed swards were carried out in the late eighties on organically managed swards (Baars & Van Dongen, 1993; Van Der Meer & Baan Hofman, 1989). Before that, the most recent report was from Kleter & Bakhuis (1972) on cutting trials performed between 1958 and 1965. So the first aim of the trials presented in this paper was to evaluate the potential performance, i.e. dry matter yield and N yield under a cutting management, of perennial ryegrass – white clover swards on a conventionally managed clay and sandy soil in the Netherlands.

On Dutch dairy farms, spring growth of grass is very important in order to secure a considerable proportion of the winter feed and to have grass available for early grazing. Acceptance and adoption by farmers of a system based on grass-clover swards will depend on its ability to produce enough spring herbage. Although there are prospects for breeding white clover varieties with improved spring growth (Rhodes, 1991), at present it seems sensible to enhance the spring growth of mixed swards with a strategic N application (e.g. Laidlaw, 1984; Frame, 1987; Frame & Boyd, 1987). Therefore the second aim of the trials was to quantify the effect of spring application of fertilizer N on the dry matter and N yield of perennial ryegrass – white clover swards in the Netherlands.

Materials and methods

Sites

One trial was sited at the experimental farm 'Waiboerhoeve' at Lelystad in Flevoland on well drained sedimentary calcareous light clay soil, reclaimed from the IJssel Lake in 1957 and under grass since 1971. A new sward was established in August 1988 using a seed mixture of 20 kg perennial ryegrass (*Lolium perenne* L., cvs. Profit and Magella) and 5 kg white clover (*Trifolium repens* L., cv. Retor) per ha. After establishment the sward was grazed with dairy cows in October so that the sward height was approximately 6 cm before the winter. At the start of the experiment in February 1989 the top soil (0–5 cm) had an organic matter content of 3.1% and a pH-KCl of 7.3. Available phosphate was low (16 mg P_2O_5 per 100 g dry soil) and potassium content was high (78 mg K_2O per 100 g dry soil) (Anon., 1989).

The other trial was located on sandy soil at the experimental farm 'Aver Heino' in Overijssel. The soil at the trial site has been classified as a mollic gleyey sand soil with a semi-permeable loam horizon at 70 to 80 cm. An existing grass sward, established in 1988 (cvs. Meltra, Citadel and Condesa), was sod-seeded with 5 kg white clover (cv. Retor) per ha in spring 1991. After establishment the sward was used in normal farm practice, which meant that it was alternatively grazed with dairy cows and cut for silage. At the start of the experiment in February 1992, the top soil (0–5 cm) had an organic matter content of 5.2% and a pH-KCl of 4.2. Available phosphate was high (89 mg P_2O_5 per 100 g dry soil) and potassium was low (14 mg K_2O per 100 g dry soil).

All six harvest years were warmer than average and, with the exception of 1993, also sunnier than average. At Lelystad, the accumulated precipitation surpluses (March – October) from 1989 to 1993 amounted to –105, +4, –83, +99 and +141 mm, respectively. Corresponding figures at Heino for 1992 to 1994 were +24, +239 and +191 mm, respectively (Anon., 1989–1994). Due to heavy rainfall the trial at Heino was partly flooded in September/October 1993.

Treatments

At Lelystad, the trial consisted of combinations of five rates of N application in spring (N_0, N_{25}, N_{50}, N_{75} and N_{100} i.e. 0, 25, 50, 75 and 100 kg ha^{-1} $year^{-1}$) and two cutting frequencies, a low frequency (LF) with 4 to 5 cuts $year^{-1}$ and a high frequency (HF) with 6 to 7 cuts $year^{-1}$. These cutting frequencies were included because they represent a range of 2 to 3.5 tonne DM ha^{-1} cut^{-1}, which is the common practice in the Netherlands. The experiment was a split plot with four replicates and N treatments randomised within cutting frequency treatments. The trial at Heino consisted of five replicates with three N application rates in spring (N_0, N_{50} and N_{100}; i.e. 0, 50 and 100 kg ha^{-1} $year^{-1}$). Fertilizer N was applied between the last week of February and the third week of March, depending on soil conditions. At Lelystad, the average date of the first harvest was the 20th April for HF treatments and the 3rd May for LF treatments. The following cuts were harvested with an average interval of 31 and 42 days for HF an LF, respectively. At Heino, the average date of the first harvest was the 9th May and the following cuts were harvested with an average interval of 33 days.

At both sites, the first cut received 125 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1} and the following cuts 50 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1} . Plots (4 m × 1.5 m) were harvested with a Haldrup plot harvester at a cutting height of 4 to 5 cm. Herbage was weighed and sampled for analysis of dry matter (DM) and total N concentration. To calculate the dry weight clover content another sample was taken which was separated into grass and clover fractions. The separated fractions were bulked per treatment and analysed for total N concentration. In 1989 (trial 1) the sampling procedure was different, in that N concentration was determined per treatment and white clover ground cover was assessed visually.

Results

Annual white clover content

At Lelystad, annual white clover contents ranged from 26 to 63% (Table 1). Each

Table 1. Annual white clover content in the DM and white clover yield for all combinations of N application rates and cutting frequencies at Lelystad.

Nitrogen (kg ha⁻¹ year⁻¹)	1989[1]		1990		1991		1992		1993	
	LF	HF	LF	HF	LF	HF	LF	HF	LF	HF
	White clover (%)									
0	57	63	44	62	41	48	44	46	42	53
25	57	59	45	54	39	43	40	42	36	51
50	52	54	43	59	33	45	36	45	35	46
75	48	48	41	55	31	39	39	37	37	42
100	46	51	37	50	26	33	31	37	29	45
mean	52	55	42	56	34	42	38	41	36	48
Significance[2]										
Nitrogen	***		**		***		***		***	
Cutting frequency	NS		*		**		NS		**	
Nitrogen × cutting frequency	NS		NS		NS		NS		**	
	White clover yield (t ha⁻¹ year⁻¹)									
0			6.05	8.51	5.59	6.39	6.05	6.40	5.25	7.16
25			6.17	7.63	5.40	5.63	5.65	5.65	4.68	6.88
50			6.15	8.48	4.79	6.31	5.09	6.75	4.53	6.24
75			5.85	7.98	4.45	5.33	5.65	5.39	4.87	5.81
100			5.29	7.24	3.73	4.46	4.63	5.66	3.81	6.64
mean			5.90	7.97	4.79	5.62	5.42	5.97	4.63	6.55
Significance[2]										
Nitrogen			NS		***		NS		**	
Cutting frequency			**		*		NS		*	
Nitrogen × cutting frequency			NS		NS		NS		*	

[1]: in 1989 figures represent ground cover
[2]: Significance: NS = Not Significant, *=P<0.05, **=P<0.01,***=P<0.001

year, fertilizer N application decreased white clover content significantly. Average (1990–1993) white clover contents were 48 and 36% on N_0 and N_{100} treatments, respectively. Averaged over all harvest years, white clover content was 47% on HF treatments and 37% on LF treatments. This beneficial effect of a higher cutting frequency on white clover content was significant in 3 out of the 5 years. In 1993, a higher N application rate on LF treatments resulted in a larger reduction in white clover content than on HF treatments. In the other years no interaction was observed between N rate and cutting frequency. White clover contents remained fairly constant throughout the experiment. In Heino, N application had a similar effect on white clover content as in Lelystad (Table 2). In the three consecutive years however, average white clover content decreased from 47 to 22%.

Table 2. Annual white clover content in the DM and white clover yield for all N application rates at Heino.

Nitrogen (kg ha^{-1} year^{-1})	White Clover (%)			White clover DM Yield (kg ha^{-1} year^{-1})		
	1992	1993	1994	1992	1993	1994
0	51	40	30	8.51	4.97	3.24
50	48	33	21	8.19	4.36	2.37
100	43	30	17	7.41	4.11	1.97
mean	47	34	22	8.04	4.48	2.53
Significance	**	**	***	*	**	***

Annual white clover production

The DM yields of white clover showed a consistent, but not always significant, reduction with increasing N rates (Tables 1 and 2). An N application of 100 kg ha^{-1} year^{-1} depressed white clover DM yield with 1 to 2 t ha^{-1} year^{-1} compared to no fertilizer N. A high cutting frequency (HF) had a beneficial effect on white clover yield. Between 1990 and 1993 the average annual white clover DM yield was 5.18 and 6.53 t ha^{-1} year^{-1} on LF and HF treatments, respectively. In 1993 there was a significant interaction between N application rate and cutting frequency. In that year the reduction in white clover yield with increasing N rate was larger on LF than on HF treatments.

Annual dry matter yield

At both sites annual DM production in the first harvest year was high with an overall mean of more than 17 t DM ha^{-1} year^{-1} (Tables 3 and 4). At Lelystad, DM yields in the following four years averaged around 14 t ha^{-1} year^{-1}. Mean DM yields at Heino dropped considerably over the years. The DM yields increased with increasing N rates on both sites. In 1992 and 1993 yields increased up to the highest N rate (N_{100}), while in the other years the DM yield only increased between N_0 and N_{50}. At Lelystad the mean apparent N efficiency (ANE) for fertilizer N was 11.3 kg DM per kg N between N_0 and N_{50}, whereas the ANE was only 3.5 kg DM per kg N between N_{50} and N_{100}. Corresponding figures for Heino were 9.5 kg DM per kg N for N_0-N_{50} and 5.3 kg DM per kg N for N_{50}-N_{100}. Cutting frequency had no consistent effect on annual herbage production. Only in 1991, the LF treatments had a significantly higher DM yield than the HF treatments. There was no significant interaction between N application rate and cutting frequency.

Annual nitrogen yield

Nitrogen yields ranged from 393 to 609 kg ha^{-1} year^{-1} at Lelystad (Table 3) and from 274 to 685 kg ha^{-1} year^{-1} at Heino (Table 4). Fertilizer N application had no effect on

Table 3. Annual DM and N yield for all combinations of N application rates and cutting frequencies at Lelystad.

Nitrogen ($kg\ ha^{-1}\ year^{-1}$)	1989[1]		1990		1991		1992		1993	
	LF	HF	LF	HF	LF	HF	LF	HF	LF	HF
	DM Yield ($t\ ha^{-1}\ year^{-1}$)									
0	17.51	16.91	13.68	13.77	13.75	13.23	13.72	13.89	12.61	13.40
25	17.60	16.57	13.68	14.16	13.97	13.24	14.08	13.61	12.84	13.54
50	18.00	17.31	14.49	14.48	14.36	13.68	14.01	15.03	12.95	13.79
75	18.05	17.29	14.38	14.47	14.49	13.75	14.56	14.96	13.46	13.69
100	18.25	17.10	14.10	14.57	14.35	13.37	14.85	15.39	13.17	14.67
mean	17.89	17.03	14.07	14.29	14.18	13.45	14.24	14.57	13.01	13.82
Significance										
Nitrogen	*		**		NS		**		**	
Cutting frequency	NS		NS		*		NS		NS	
Nitrogen × cutting frequency	NS		NS		NS		NS		NS	
	N Yield ($kg\ ha^{-1}\ year^{-1}$)									
0	543	584	467	553	393	457	467	514	408	500
25	482	537	461	549	406	453	465	485	415	496
50	552	559	493	579	400	465	452	558	407	506
75	552	609	491	567	419	464	470	518	444	490
100	538	559	460	574	393	450	467	548	415	534
mean	533	570	474	564	402	458	464	525	418	505
Significance										
Nitrogen			NS		NS		NS		NS	
Cutting frequency			**		**		NS		**	
Nitrogen × cutting frequency			NS		NS		NS		NS	

annual N yield. Cutting with a high frequency (HF) showed a consistent increase in N yield compared to a low cutting frequency (LF). The average N yield was 524 and 458 kg ha^{-1} $year^{-1}$ on HF and LF treatments, respectively. There was no interaction between N application rate and cutting frequency. The mean annual N yield at Lelystad showed no consistent trend over the years whereas at Heino a considerable decrease in N yield was observed from the first to the third harvest year.

Mean N concentrations over all harvest years for N rates N_0 and N_{100} were 34.3 and 33.0 g kg^{-1} DM at Lelystad and 33.4 and 32.6 g kg^{-1} DM at Heino. Cutting frequency had a large effect on N concentration. The mean N concentrations for LF and HF were 31.2 and 35.8 g kg^{-1} DM, respectively.

Seasonal white clover content

Figure 1 shows the seasonal variation in white clover content of the HF treatments at

Table 4. Annual DM and N yield for all N application rates at Heino.

Nitrogen ($kg\ ha^{-1}\ year^{-1}$)	DM Yield ($kg\ ha^{-1}\ year^{-1}$)			N yield ($kg\ ha^{-1}\ year^{-1}$)		
	1992	1993	1994	1992	1993	1994
0	16.67	12.56	10.78	667	392	278
50	17.12	13.04	11.32	680	397	274
100	17.35	13.61	11.31	685	416	276
mean	17.05	13.08	11.14	677	402	276
Significance	NS	**	NS	NS	NS	NS

Lelystad. For reasons of clarity only the results of N_0, N_{50} and N_{100} are shown. Each spring white clover content started of higher on the unfertilized plots. On the HF treatments mean white clover contents in the first cut (1990–1993) were 34, 24, 25, 21 and 19% for N_0, N_{25}, N_{50}, N_{75} and N_{100}, respectively. Mean clover contents in the first cut of the LF treatments (results not shown) were, in the same order of increasing N application 24, 18, 18, 15 and 13%, respectively. In most years, white clover content on the fertilized treatments had recovered by July or August.

At Heino (Figure 2) the average white clover content (1992–1994) in the first cut was 28, 19 and 14% for N_0, N_{50} and N_{100}, respectively. White clover contents were very high in the first year and at the start of the second year. As mentioned earlier, the trial site was flooded in September and October of 1993. At that time a dramatic reduction in white clover content occurred. In the third cut of the following year however, white clover content had recovered to average values.

Seasonal nitrogen and dry matter yield

The relationships between fertilizer N application rate, N yield and DM yield in the

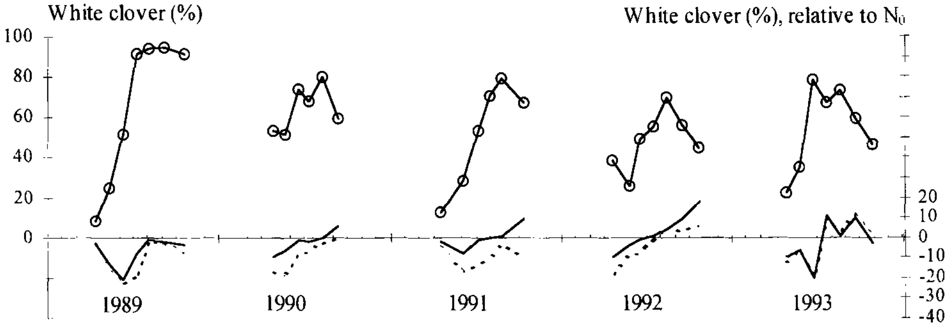

Figure 1. Seasonal white clover content of HF treatments at Lelystad; figures for N_0 (—O—) are plotted against left axis and figures for N_{50} (——) and N_{100} (------) are relative to N_0 and plotted against right axis. Figures for 1989 are ground cover.

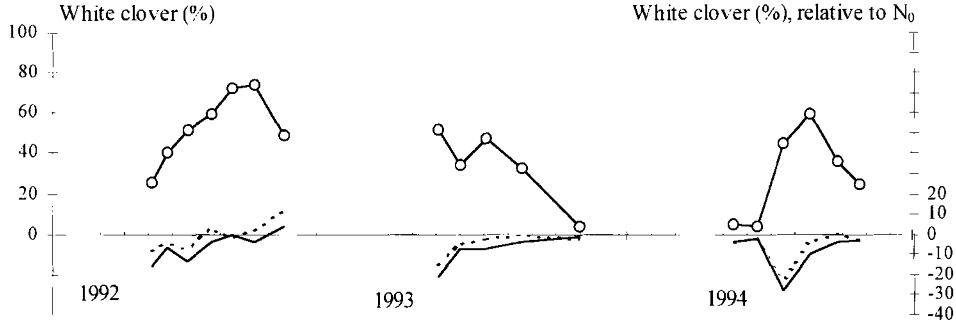

Figure 2. Seasonal white clover content at Heino; figures for N_0 (—O—) are plotted against left axis and figures for N_{50} (——) and N_{100} (------) are relative to N0 and plotted against right axis.

first cut are shown in Figures 3 and 4. For Lelystad, the data of 1989 are not included because the N yield of the components were not available. The relationship between DM yield and N rate is shown in quadrant II. In the first cut the DM yield of grass showed a positive response to N application, whereas the DM yield of white clover decreased with increasing N rate. At Lelystad the ANE of the mixture, measured between N_0 and N_{100}, was 12.6 and 9.3 kg DM kg^{-1} N for LF and HF treatments, respectively. The LF treatments were cut 13 days later than the HF treatments, but despite the longer growing period the absolute white clover DM yield was similar in both treatments. During this longer growing period only grass contributed to an increase in the yield of the mixture and consequently white clover content declined markedly. At Heino the mean ANE, between N_0 and N_{100}, was 11.2 kg DM kg^{-1} N. Quadrant I shows the DM yield as a function of N yield. At Lelystad, N rate had no effect on the N concentration of white clover, but N concentrations were always lower with a low cutting frequency than with a high cutting frequency. In the first cut the grass component showed a major increase in N concentration with increasing N application. This resulted in an increased N concentration of the mixture. At Heino, N concentration in white clover was reduced from 41.1 to 37.9 g kg^{-1} DM after an application of 100 kg N ha^{-1}. This was partly compensated for by an increased N concentration in grass after N application, but the N concentration in the mixture remained slightly higher without N application. The N yield as a function of N rate is shown in quadrant IV. In the first cut the N yield of grass showed a strong positive response to N application, whereas the N yield of white clover showed a slightly negative response to N application. Between N_0 and N_{100} the mean N yield of the mixture increased with 42 kg and 28 kg ha^{-1} at Lelystad and Heino, respectively. Comparable to the DM yield, only grass contributed to an increase in the N yield of the mixture during the longer growing period of the LF treatment.

In the following cuts at both sites (results not shown) the N yield of grass showed a small positive response to fertilizer N. However, the N yield of white clover was reduced and as clover had become a major component, application of 100 kg N ha^{-1} in spring reduced the N yield of the mixture with 41 and 11 kg ha^{-1} at Lelystad and Heino, respectively. DM yields of the mixture in the following cuts were hardly affected by fer-

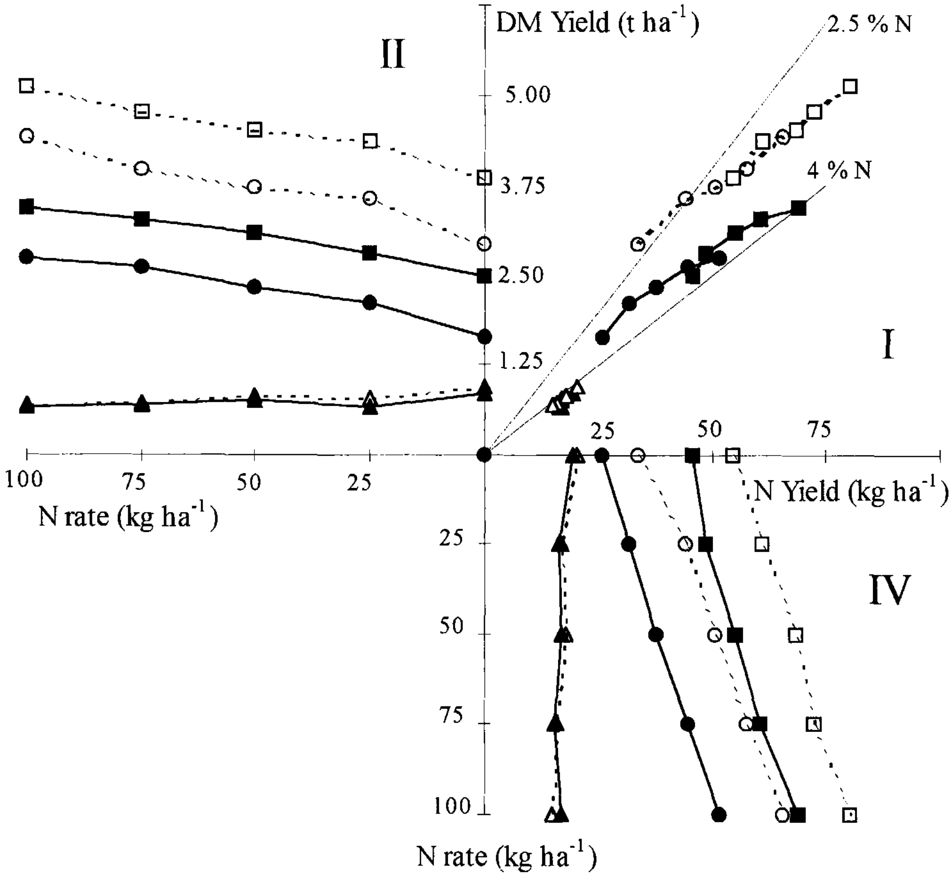

Figure 3. Relationships between N application rate, N yield and DM yield of the first cut at Lelystad (mean data over 1990–1993); grass-HF (—●—), clover-HF (—▲—), mixture-HF (—■—), grass-LF (—○—), clover-LF (----△----), mixture-LF (----□----).

tilizer N. Increased N rates led to slightly higher grass yields but this was almost completely offset by a lower clover yield. At both sites an application of 100 kg N ha^{-1} led to an average reduction in DM yield in the following cuts of 3.3 kg DM kg^{-1} N.

Discussion and conclusions

Annual dry matter yield and N yield

At both sites, DM yields in the first harvest year were high for Dutch standards (Sibma & Ennik, 1988). At Lelystad, annual DM yields in the next four harvest years remained at a satisfactory level of around 13.5 t ha^{-1} without any fertilizer N.

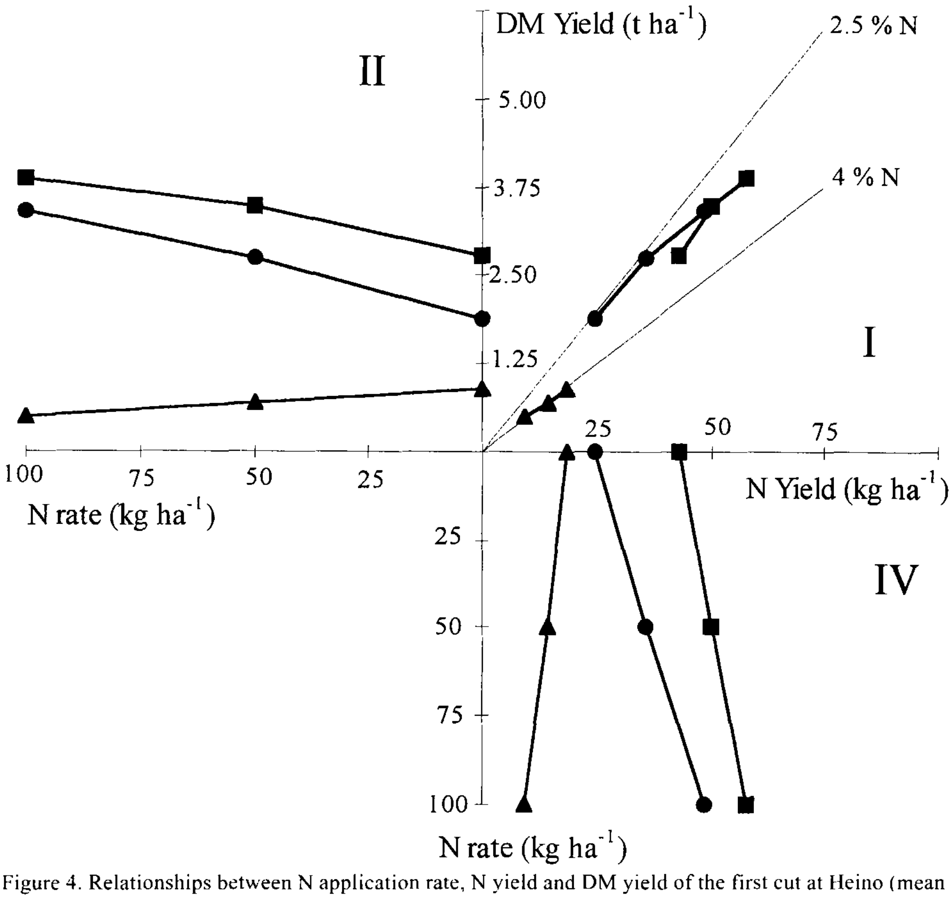

Figure 4. Relationships between N application rate, N yield and DM yield of the first cut at Heino (mean data over1992–1994).); grass (—●—), clover (—▲—), mixture (—■—).

Although white clover content and N yield were significantly higher with HF than with LF, no consistent differences in DM yield were found between the two cutting frequencies. At Heino, after the flooding in 1993, white clover was not persistent and annual DM yields dropped from 17 in the first to 11 t ha^{-1} in the third harvest year. There are limited data regarding DM yields of mixed swards in The Netherlands. In a five year cutting trial on a young sward with 36% white clover on humous sandy soil (Kleter & Bakhuis, 1972) average annual DM yields amounted to 9.0 t ha^{-1} year^{-1}. More recently on a river clay soil, Elgersma & Schlepers (1996) found average annual DM yields of 12.2, 10.5 and 8.7 t ha^{-1} in 1992, 1993 and 1994, respectively. The yield reduction in 1994 was attributed to heavy frost in February 1994. In an overview of a wide range of cutting trials, Frame & Newbould (1986) found that, without N, most DM production levels tend to be within a range of 6 to 10 t ha^{-1} year^{-1}. In National List trials in the United Kingdom average DM yields without fertilizer N were 8.3 t ha^{-1} and the lowest and highest recorded DM yield were 2.03 and 15.5 t ha^{-1}, respectively. The DM yields accomplished in the present trials are at the high end of this range.

Although high DM yields will possibly encourage the use of mixed swards, one has to be aware that there is also an increased risk of environmentally unacceptable N losses. At a similar level of N inputs the N losses of mixed swards have been found to be comparable with the N losses of fertilized grass swards (Jarvis, 1992; Hutchings & Kristensen, 1995). Although N fixation was not measured, the mean annual N yields of 491 kg ha^{-1} in Lelystad and 452 kg ha^{-1} in Heino indicate that white clover has fixed considerable amounts of N. In a literature review, Ennik (1982) concluded that, as an overall mean, each tonne of clover DM yield increases the N yield of a perennial ryegrass-white clover mixture by 55 kg N. Applied to our experiments, with mean annual clover yields of 5.9 t ha^{-1} in Lelystad and 5.02 t ha^{-1} in Heino, white clover would have contributed 325 and 276 kg N ha^{-1} $year^{-1}$ at Lelystad and Heino, respectively. It has to be considered however, that the clover contents and yields achieved in these cutting trials will not be obtained easily under practical farm conditions. On common dairy farms, swards will be cut and grazed alternatively. Grazing implies return of excreta and treading, leading to heterogeneous swards. Moreover, other factors like sub-optimal soil nutrient status, pests and diseases or mismanagement may disfavour herbage production. Experiences with mixed swards on commercial dairy farms in the Netherlands are rare. At present, swards with white clover are mainly used on organic farms. From 1983 to 1987, Van der Meer & Baan Hofman (1989) measured annual DM yields of 2.7 to 9.2 t ha^{-1} on grazed mixed swards on clay soil. Some of the low DM yields could be attributed to overgrazing, but the major part of the variation could not be explained. In a three year lasting experiment on clay soil, grass-clover paddocks fertilized with 15–25 ton farm yard manure ha^{-1} $year^{-1}$ and used for both grazing and cutting, achieved annual DM yields of 8.5 to 10.5 t ha^{-1} (Baars & Van Dongen, 1993).

Fertilizer N application

Averaged over both sites and all years, and with a N application of 100 kg $ha^{-1}year^{-1}$, the ANE in the first cut was 11 kg DM kg^{-1} N. This response falls in the range found in earlier studies in other countries. On 15 sites in the United Kingdom Morrison *et al.* (1983) found that on mixed swards the ANE ranged from 6 to 35 kg DM kg^{-1} N after a spring application of 67 kg N ha^{-1}. With an N application rate of 90 kg ha^{-1}, Laidlaw (1980) found an average ANE of 21 kg DM kg^{-1} N in year 1 to 3. Later Laidlaw (1984) measured an ANE of 28 kg DM kg^{-1} N in year 4 and 5 of the same trial. Trials in Scotland with a spring application of 75 or 80 kg N ha^{-1} and over a wide range of defoliation systems have shown mean ANE's of 16 (Frame, 1987), 18 (Frame & Paterson, 1987) and 12 (Frame & Boyd, 1987) kg DM kg^{-1} N, respectively. In Northern France, Laissus (1983) found a mean ANE of 11 kg DM kg^{-1} N after a spring application of 90 kg N ha^{-1}.

Growth of white clover was depressed by N application but recovered well enough to guarantee a satisfactory DM production in summer and autumn. Compared to no fertilizer N, an application of 100 kg N ha^{-1} reduced the mean DM production in the following cuts with 0.37 t ha^{-1}. So, on an annual basis, the mean ANE was reduced to 7 kg DM kg^{-1} N. Frame & Newbould (1986) noted annual DM responses from 3 to 30 kg DM kg^{-1} N, the highest responses obtained with N rates of 30 to 60 kg N ha^{-1}. This agrees with our results which show a mean ANE of 10 and 4 kg DM kg^{-1} N for the ranges $N_0 - N_{50}$ and $N_{50} - N_{100}$, respectively.

Nitrogen yield in the first cut increased after N application but this was compensated for in the remaining cuts so that annual N yield was unaffected by N application rate.

The results of this study indicate that a spring N application of 50 to 100 kg ha^{-1} can be a practical tool for farmers to secure the herbage production in spring, with only a short term negative effect on white clover content. Moreover the results at Lelystad show that, even after 5 years, repeated application of spring N had no detrimental effect on white clover. In a practical farming system the N does not necessarily has to be from artificial fertilizer but may just as well originate from slurry. For instance, shallow injection of 20 m^3 of cattle slurry ha^{-1}, which is approximately equivalent to 50 kg of effective N, is a common practice on most dairy farms. Preliminary results from research at the DLO Research Institute for Agrobiology and Soil Fertility (AB-DLO, Wageningen), suggest that white clover content responds in a similar way to N from shallowly injected slurry as to fertilizer N (T. Baan Hofman, Pers. Com.).

Conclusions

- Both the clay and sandy soils in the trials showed a good potential for perennial ryegrass-white clover swards with average annual DM yields of 14.66 and 13.76 t ha^{-1}, respectively. Cutting frequency had no consistent effect on annual DM yields.
- Mean annual N yields were, on sandy soil 452 kg ha^{-1}, and on clay soil 524 and 458 kg N ha^{-1} for a high and low cutting frequency, respectively.
- A spring N application of 100 kg ha^{-1}
  - increased the DM yield in the first cut and the annual DM yield with 11.1 and 7.4 kg per kg applied N, respectively,
  - reduced mean annual white clover content from 45 to 34%,
  - did not affect the annual N yield.

Acknowledgements

Thanks are given to J.L. Schepers, J. Van der Voort, H.T.M. Lugtenberg, F.J. Van der Kolk and other staff at the experimental stations 'Waiboerhoeve' and 'Aver Heino' for their contribution to the field work.

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