WHITE CLOVER UTILISATION
ON DAIRY FARMS IN THE NETHERLANDS

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White clover utilisation on dairy farms in the Netherlands

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Abstract

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The present efforts to reduce the nitrogen (N) losses on dairy farms have reduced the use of fertiliser N and consequently renewed interest in white clover (*Trifolium repens* L.).

The general objective of this thesis was to provide a scientifically sound basis for the use of white clover on dairy farms in the Netherlands. The research consisted of a system comparison between a traditional grass/fertiliser-N system and a new grass/clover system. The aim was to design and demonstrate an agronomically, environmentally and economically sound white clover-based dairy system, and to identify potential problems with the utilisation of white clover in dairying. Simultaneously, specific research questions on processes within the new grass/clover system were addressed in separate field experiments with detailed measurements. The field experiments aimed to quantify the potential herbage yield and herbage quality of mixed swards, under a range of management practices, such as N and phosphorus (P) application, and cutting and grazing management.

Both the clay and sandy soils in the experiments showed a good potential for perennial ryegrass/white clover swards with average annual dry matter (DM) yields of 13.3 t ha^{-1}, respectively. The yields were among the highest recorded for unfertilised mixed swards in the Netherlands.

The year-round application of N is not considered to be economic, but N can be used effectively on grass/clover swards if its use is restricted to spring application. This so-called 'strategic' application of N increases the DM yield in the first cut, only temporarily reducing white clover content in the sward. Phosphorus application did not increase clover yield. The results suggested a negative effect of P application on clover proportions in mixed swards.

The results of the system experiment demonstrated the potential of mixed swards of perennial ryegrass and white clover in a rotational grazing and cutting system. In a field experiment, the average annual DM yields were 13.4 t ha^{-1} with rotational grazing and cutting, compared to 12.8 t ha^{-1} with cutting only.

The herd of the white clover based system produced 85% of the milk yield per ha of the grass/fertiliser-N based system. The N utilisation at farm level was nearly 25% in both systems, and there was no difference in the average nitrate concentrations in drain water. The total energy use of the clover based system was 15% lower than that of the fertiliser-N based system.

The agronomic and environmental performance show that white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t milk ha^{-1} year^{-1} or less. However, within the MINAS system more intensive farms can benefit from a partial conversion to grass/clover. The prospects for white clover will certainly be affected by the developments in the nutrient policy.

Keywords

botanical composition, carbon, cutting frequency, dairy system, energy, N fixation, gross margin, herbage quality, milk production, MINAS, nitrate leaching, nitrogen, nutrient balance, nutrient efficiency, perennial ryegrass, phosphorus, rotational grazing, soil, strategic nitrogen application, sward utilisation, white clover.

Woord vooraf

Ik zie Hein Korevaar nog zo mijn kamer binnen lopen, destijds in 1987. Zeg René, zou je het leuk vinden om "iets" met klaver te gaan doen? Niemand die toen kon voorspellen dat die vraag ooit nog uit zou monden in dit proefschrift. Het onderwerp sprak me wel aan. Het was nieuw, er was voldoende ruimte voor een eigen inbreng, en ook heel aantrekkelijk: we konden eerst op studiereis naar Engeland. Samen met Theun Vellinga en Gertjan Noij bezochten we verschillende instituten en leerden zo in korte tijd al heel veel over de ins en outs van witte klaver. Terug in Nederland werden de plannen voor "afdeling 2" van de Waiboerhoeve al snel werkelijkheid. Hier en daar moest nog wel een hobbeltje genomen worden, maar allengs raakten de meesten er wel van overtuigd dat witte klaver meer was dan een "ballonnetje water op een stengel". Geleidelijk aan maakte terughoudendheid plaats voor enthousiasme.

Als onderzoeker heb je het eigenlijk maar gemakkelijk. Aan het eind van de dag laat je de klaver voor wat het is en ga je naar huis. Voor Frans Meijer gold dat niet. Als bedrijfsboer was je dag in dag uit bezig met je bedrijf. Alles zag je als eerste, de leuke dingen, maar ook de vervelende dingen. Vrolijk stond je ’s ochtends in de melkput als de koeien weer melk "zeikten", nadat ze in een mooie klaverwei hadden gegraasd. Maar helaas zag je ook als eerste dat de koeien opgelopen waren. De angst dat het volgende ochtend weer zou gebeuren heeft je heel wat slapeloze nachten opgeleverd. Frans, bedankt voor alle energie die je in het bedrijf gestopt hebt. Daarin ben je natuurlijk bijgestaan door je collega's, Roelof Stapel, Jan Meijering en Martin de Bree. Naast de gewone bedrijfsexploitatie is er veel, zéér veel gemeten op het land, in de sloot, in de mest, het voer en de stal. Jan Lucas Schepers, in een kale polder in februari, in de koude snijdende oostenwind stond je drainmonsters te nemen. Er zijn leukere dingen. Jan Lucas, bedankt voor je nimmer aflatende inzet. Op de proefvelden is heel wat gras en klaver gemaaid gewogen en bemonsterd. Ook dank aan al die anderen die op de proefvelden hebben meegeholpen en die gras en klaver monsters uitgezocht hebben, Jan Zuidhof, Jan van der Voort, Wolter Prinsen, Lia de Jong-Smit, Jan Storteboom. Een speciale dank, of beter misschien, een speciale verontschuldiging, is hier op zijn plaats voor Martine Arkema. Ik weet het nu Martine, vrouwen zijn ook goede Haldrup-chauffeurs. Ook vanuit het kantoor op de Waiboerhoeve heb ik de nodige ondersteuning gekregen. Daarvoor dank aan Jan Visch, Herman ten Hove, Alfons Beldman, Harry Schippers en Piet Verschure. Alhoewel het leeuwendeel van het onderzoek op de Waiboerhoeve heeft plaatsgevonden, mag toch ook Aver Heino niet onvermeld blijven. Ik maak mezelf in ieder geval wijs dat die eerste klaverproef de kiem is geweest van het huidige nieuwe biologische proefbedrijf. De uitvoering van die proef lag in de goede

handen van Herman van Schooten, Willem Muller, Ferry van der Kolk en Harry Lugtenberg.

Hein Korevaar, Rinus Verboon, Paul Snijders en Theun Vellinga waren de inspirators van het eerste uur. Zonder hen was het onderzoek waarschijnlijk nooit van de grond gekomen. In de loop van de tijd hebben ook anderen, allen met hun speciale expertises, bijgedragen aan het succes van de diverse klaverprojecten. Hiervoor gaat mijn dank uit aan Tjerk Boxem, Pim Bruins, Gerrit Remmelink, Teun Kraak, Klaas Sikkema, Harm Everts, Cees Jagtenberg en Sicco Anthuma. Geert André wil ik graag bedanken voor zijn statistische ondersteuning en adviezen. Tevens dank ik Hetty Wolbers, Oane de Hoop, Leo Pelser en Herman Snoek voor de veelvuldige hulp bij het fotograferen, het ontwerpen van posters en het schrijven van teksten. Mijn afdelingshoofd Willem Luten, en later Frits Mandersloot, dank ik voor hun onvoorwaardelijke steun bij het volbrengen van dit a-typische product van praktijkonderzoek.

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Contents

CHAPTER 1

General introduction

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General introduction

Nitrogen and white clover in dairy production systems in the Netherlands

Trends in nitrogen use

From the 1950s onwards, dairy production systems in the Netherlands have become increasingly dependent on external inputs of fertilisers and concentrates (e.g. Aarts *et al.*, 1992; Van Der Meer, 1994; Oenema & Roest, 1998). In the early 1950s, fertiliser N was applied at a rate of approximately 50 kg ha^{-1} $year^{-1}$ (Figure 1). By 1970, fertiliser N application had reached a level of 200 kg ha^{-1} $year^{-1}$, and in the 1980s fertiliser N use peaked at around 300 kg ha^{-1} $year^{-1}$. Since the middle of the 1980s, developments such as the introduction of milk quota, a growing interest in organic farming and concern about N losses have caused a gradual decrease in the use of fertiliser N. The most recent data (1999) show that fertiliser N application levels are currently about 220 kg ha^{-1} $year^{-1}$.

In addition to fertiliser, cattle slurry is commonly used as well, which is not taken into account in these figures. Due to variability in amounts of slurry, N concentration in slurry, application time and application methods, there are no reliable data on N applied with slurry, and especially not on its fertilising value. Aarts *et al.* (1992) estimated a slurry N application of 120 kg ha^{-1} $year^{-1}$ for dairy farms on sandy soil in the 1980s. The introduction of new slurry application methods at the end of the 1980s (Van Der Meer *et al.*, 1987; Wouters, 1995), the ban of winter application of slurry and a gradual shift from day-and-night grazing systems to day-only grazing systems has improved the N use efficiency of slurry considerably. Therefore, it remains unclear to what extent the total level of N application, i.e. N from fertiliser plus effective N from slurry, has decreased since the 1980s.

Dutch Nitrogen policies

To reduce the N losses, Dutch government policies aim to reduce the annual N surpluses of dairy farms, using the instrument of the Mineral Accounting System (MINAS). It is a "farm-gate" balance, taking into account the N inputs such as fertilisers, feeds and animals and the N outputs through milk and animals. Nitrogen input through biological fixation and deposition does not have to be accounted for. By the year 2003 the allowed, levy-free, MINAS N surpluses are 140 kg ha^{-1} $year^{-1}$ for grassland on dry sandy soils and 180 kg ha^{-1} $year^{-1}$ for grassland on the other soil types (Henkens & Van Keulen, 2001). To achieve the MINAS targets, the application of fertiliser N will have to be reduced even further. At this moment, the farms leading in nutrient management, are already very close to the MINAS targets for 2003 (Oenema *et al.*, 2001). In 1999, the average annual fertiliser N application on these farms was 119 kg ha^{-1}, with a range from nil fertiliser use, on an organic farm, to 252 kg ha^{-1}.

Trends in white clover use

Along with the increased use of fertiliser nitrogen, the use of white clover (*Trifolium repens* L.) decreased during the last decades (Figure 1). Until the middle of the 1960s, approximately 80% of the certified seed mixtures contained white clover. Although the nitrogen use had already increased significantly between 1950 and 1965, the white clover use remained relatively constant until 1965. But from then on, in a time-span of 15 years, the proportion of seed mixtures with white clover rapidly declined to a level of 3 to 4%.

The data on seed mixtures only relate to certified seed mixtures with a standard prescribed composition, indicating the proportion of species and types. During the last 25 years, there has been a trend from uniform mixture compositions to a more diversified composition. Between 1985 and 1995, the proportion of certified non-standard seed mixtures was around 10 to 25%, but in the last years it has risen to 57% (Bonthuis & Donner, 2001). Additionally, there is an increasing sale of separately packed white clover seeds.

Until now, the change in the trend of fertiliser use has not led to an increased use of white clover. Despite the lower fertiliser N application, the current N level is still too

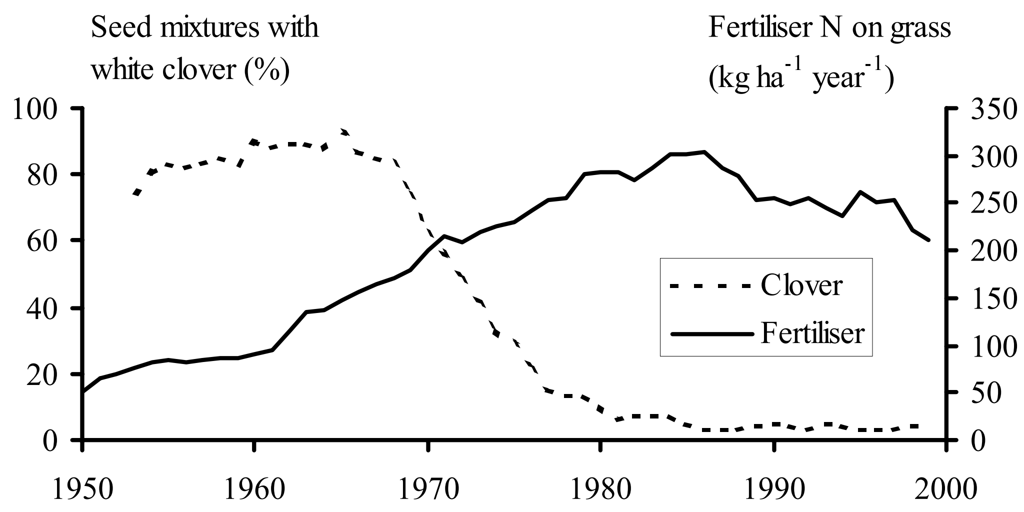

Figure 1. Development in the application of fertiliser nitrogen (Bussink & Oenema, 1998; LEI, 2002) and the proportion of certified grass seed mixtures containing white clover (Bonthuis & Donner, 2001) in the Netherlands.

high for a switch to white clover. Considering the fact that unfertilised grass/white clover swards should be able to yield the same as grass-only swards with N levels of 150 to 250 kg ha^{-1} $year^{-1}$ (e.g. Frame & Newbould, 1986), it is not surprising that there is no strong surge in white clover seed sales. As stated earlier, it has to be taken into account that Figure 1 disregards the use of slurry N. A significant increase in the use of white clover can only be expected after a further reduction in fertiliser N use until below 200 kg ha^{-1} $year^{-1}$, which is the current level of the frontrunners in dairy farming. As more farms will reduce the use of fertiliser N on grass, a greater reliance on white clover may be expected.

Until now, an increased interest in white clover has only been noticed on organic farms. The area of organically managed pastures has increased from 4583 ha in 1991 to 15954 ha in 2000 (CBS, 2002). Some degree of increased interest is noticeable on conventional dairy farms, but it is unclear what the exact motive is. On some farms, the current N level is low enough to consider the switch from fertiliser to white clover. On farms with relatively high N levels, interest in white clover may be encouraged by the fact that biological N fixation by white clover does not have to be taken into account as an N input for MINAS.

White clover research in the Netherlands

The interest in white clover not only diminished in farm practice, but to a large extent also in research and breeding efforts. In 1972, two white clover varieties were added to the Dutch Recommended List of Varieties. It took nearly twenty years before a new variety was added to the list. Since 1990, another seven varieties have been added. The recent Dutch Recommended List of Varieties contains 10 white clover varieties, 3 of which have been bred before 1980, 3 between 1980 and 1990 and 4 after 1990.

In the 1960s and 1970s there was little attention for research on white clover in the Netherlands. Ennik (1960) reported on competition effects between white clover and grass, mainly based on pot experiments. In an eight-year field experiment, Kleter & Bakhuis (1972) compared the yield of old grass/clover swards on a clay soil with a young grass/clover sward on a sandy soil.

From the 1980s onwards, research efforts on white clover increased on several institutes throughout the Netherlands. The experiments reported in this thesis aimed at white clover utilisation in conventional dairy systems. Some years earlier, due to a growing interest in organic farming, trial fields with white clover were established on organically managed swards (e.g. Baars & Van Dongen, 1993). The performance of grass/clover swards within an organically managed dairy farm was reported by Van Der Meer & Baan Hofman (1989). In addition white clover received some attention in a system study aimed to reduce energy use on dairy farms (Snijders, 1981; Bruins, 1988).

The renewed attention for white clover continued into the 1990s, both on issues concerning conventional farming (Elgersma & Schlepers, 1997; Lantinga & Van Bruchem, 1998; Baan Hofman, 1999) and organic farming (Baars *et al*., 1996).

Although N level is the most critical factor for the re-introduction of white clover, there are several other questions concerning the use of white clover. Due to the lack of research and breeding efforts, there is little knowledge of the current yield potential of mixed swards in the Netherlands. The predominant grassland management system consists of rotational grazing of one to four days per paddock, with the inclusion of one or two silage cuts per year. Adoption of mixed swards by dairy farmers will be easier when these swards can be integrated into currently used grassland management systems. Furthermore, it is necessary to evaluate whether grass/clover swards can be a sound basis for a conventional Dutch dairy system. Among farmers, clover has a bad reputation because of its supposed unreliability in production and problems with bloat. Therefore, it is important to demonstrate the potential of implementing white clover in a dairy system.

White clover project at the Waiboerhoeve

The white clover project described in this thesis was initiated in 1987, following a study into new directions for dairy farming. Milk quota had been introduced in 1984 and there was a growing awareness that dairy farming caused environmental problems, especially due to nitrogen and phosphate losses. Therefore, it was anticipated that the upward trend in fertiliser use and milk production per ha was at its end. Furthermore, it was expected that the reduction in the use of fertiliser nitrogen would bring about a renewed interest in the use of white clover.

To facilitate the research on white clover, one of the dairy units at the Waiboerhoeve experimental farm was designated for the new project. In that way, the Waiboerhoeve became the focal point for research and demonstration on white clover. In 1988, the Minister of Agriculture, Nature Conservation and Fisheries opened the new dairy farm building, suitable for the comparison of a traditional grass/fertiliser-N based system with a new white clover based system. Over a period of two years, mixed swards of perennial ryegrass and white clover were established, so that the system comparison could be launched in 1990.

By then, detailed field experiments on white clover had already started. From 1989 to 1998 a range of topics was studied in separate experiments on the Waiboerhoeve. The questions addressed in these experiments were usually linked to developments in the associated white clover based dairy system.

Some experiments were also undertaken at the experimental farm Aver Heino, situated on a sandy soil. At present, Aver Heino has been converted into an organic dairy farm and understandably white clover is now at the centre of attention (Pinxterhuis, 2001).

Besides being a research project, the white clover project at the Waiboerhoeve has received much attention from visitors. Farmers, students, researchers, extension workers and policy makers have taken notice of the on-going experiments during excursions, farm walks or special visitors' days. In addition to the scientific account in this thesis, many results have been passed on through popular publications of the Research Institute for Animal Husbandry or through articles in farmers' magazines.

Problem statement and objectives

At present, white clover plays a minor role in Dutch grasslands, mainly due to the large amounts of slurry and fertiliser N used on these grasslands. Because of increasing efforts by farmers to reduce N losses, there will be a renewed interest in white clover. However, for many dairy farmers it is unclear whether mixed swards of perennial ryegrass and white clover are able to produce enough good quality herbage to be the backbone of their dairy system.

Therefore the general objective of this thesis is to provide a scientifically sound basis for the potential use of white clover on dairy farms in the Netherlands. The main objective is elaborated into more specific objectives for the system experiment and the field experiments. The objectives of the system experiment were to

- design and demonstrate an agronomically, environmentally and economically sound white clover based dairy system,
- identify potential problems in the utilisation of white clover in dairy farming.

The field experiments aimed to quantify the potential herbage yield and herbage quality of mixed swards, under a range of management practices. Attention was paid to nitrogen and phosphate application, and cutting and grazing management. For the field experiments, the following specific aims were formulated:

- to evaluate the potential yield and quality of mixed swards under cutting conditions,
- to determine the yield and herbage quality of mixed swards in a conventional rotational grazing and cutting system,
- to establish the effect of spring application of N on the performance of mixed swards,
- to quantify the combined effect of fertiliser N and P on the herbage yield and quality of mixed swards, and on the change in soil nutrients,
- to increase the understanding of P utilisation in mixed swards and to provide a basis for P recommendations on mixed swards.

Methodological aspects

An integrated system research was chosen to study the whole cycle of events from the inputs of fertiliser, biologically fixed N and concentrates, through the processes such as feed production, grazing, feed intake and slurry application, to the outputs of milk and meat. Specific research questions on processes within the system were addressed in separate experiments.

The comparison of the white clover system with a traditional grass/fertiliser-N system imposes special requirements on the layout of the farm. All unintended factors affecting the outcome of the comparison have to be excluded as much as possible. This means that one farm manager ran both systems. Before the start of the experiment all cows were grouped into pairs of the same age, calving date, milk production and genetic potential and pairs were then randomly split between both systems. Both herds were housed under identical conditions in one building, split down the middle. Furthermore it is essential to separate the flows of fertiliser, slurry, feed, animals and milk as much as possible. Therefore the building was designed with separate feeding passages and separate storages for slurry, silage and milk. Outside, the routing systems for cows were completely separated to prevent the cows from grazing in the fields to which they were not assigned.

Both systems were designed to be self-supporting in silage production. As the DM yield of grass/clover swards was expected to be 15 to 20% lower than that of the grass/fertiliser-N swards, 41 and 34 ha were allocated to the grass/clover and grass/fertiliser-N treatments, respectively. The grassland area was divided into 33 grass/clover and 27 grass/fertiliser-N paddocks with an average area of 1.25 ha. Three large blocks of grassland were available for the experiment. One block of grassland had a lighter soil texture than the other two blocks. Ideally, all individual paddocks would have been randomly allocated to the systems. However, such a strict randomisation met a lot of opposition from a practical point of view. Therefore a lay out was designed in which the proportion of soil types was similar in both systems, but without complete randomisation (Figure 2). In the years preceding the experiment, the old grass-only swards were converted into grass/clover swards. This was partly done by direct drilling into the existing grass sward and by complete reseeding after ploughing. In order to have similar sward ages in both systems, an approximately equivalent proportion of the area was renewed on the grass/fertiliser-N farm as well.

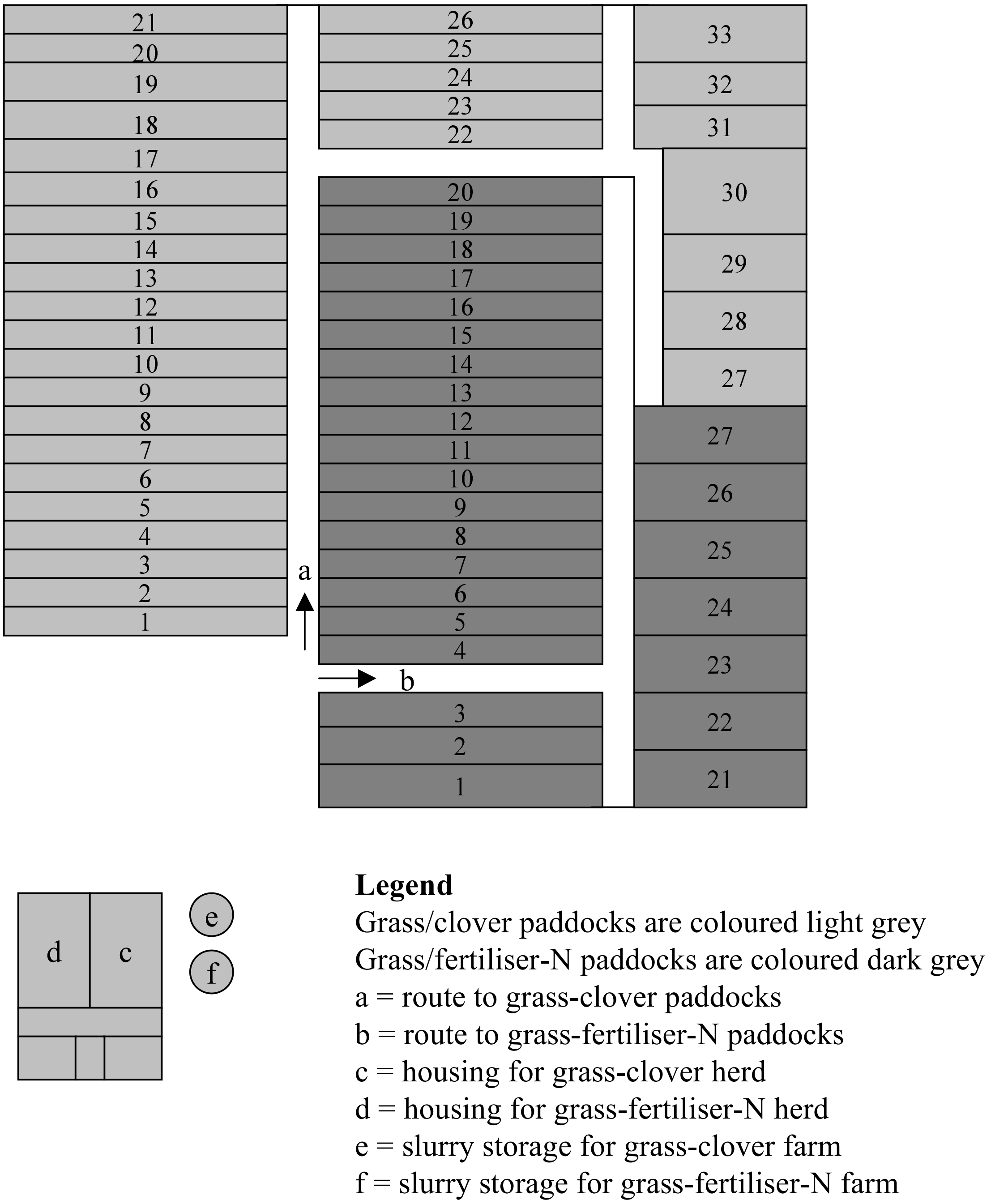

Figure 2. Layout of the comparison of two dairy farm systems at the Waiboerhoeve experimental farm.

Outline of this thesis

This thesis presents the results of the white clover project at the Waiboerhoeve, from the first sowing in August 1988 to the last soil sampling in March 1999. The results are described in six chapters, published earlier or accepted for publication in various scientific journals. Following this general introduction, the first four chapters deal with detailed field experiments, while the fifth and sixth chapter deal with the system study.

Strategic spring application of nitrogen is discussed in Chapter 2. A range of spring N applications, up to 100 kg ha^{-1} $year^{-1}$, was set up in a five-year experiment on clay soil and a three-year experiment on sandy soil. The effects on white clover content, dry matter and nitrogen yield are presented. Chapter 3 deals with the performance of a grass/clover sward under a rotational grazing and cutting management. The effects of intensity of cutting, grassland management system and N application in spring are evaluated in a four-year grazing experiment with dairy cows. Phosphate application on grass/clover swards, and its effect on herbage and soil parameters are discussed in Chapters 4 and 5. On newly established grass-only and grass/clover swards, the combined effects of a range of phosphate and nitrogen applications were studied during five consecutive years. Chapters 6 and 7 report on a systems study, in which a grass/clover and a grass/fertiliser-N based dairy farm were compared during three years. The technical, financial and environmental performances are presented.

The general discussion in Chapter 8 synthesises the results of the individual experiments. Furthermore, it presents a general view on the perspective for white clover based dairy farms in the Netherlands.

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CHAPTER 2

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

Schils, R.L.M., 1997. Effect of a spring application of nitrogen on the performance of perennial ryegrass-white clover swards at two sites in the Netherlands. Netherlands Journal of Agricultural Science 45: 263-275.

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

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 trials 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.

Introduction

At present white clover only plays a minor role in Dutch grasslands, mainly due to the large amounts of slurry and fertiliser nitrogen (N) used on these grasslands. However, since the introduction of milk quota in 1984, there has been a gradual reduction in stocking rates (LEI, 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 (MANMF, 1997). This development will lead to a further reduction in the use of fertiliser 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 fertiliser 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) (PV, 1999).

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 (KNMI, 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 (N0, N25, N50, N75 and N100; 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 tonnes 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 (N0, N50 and N100; i.e. 0, 50 and 100 kg ha^{-1} $year^{-1}$). Fertiliser 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 x 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 content ranged from 26 to 63% (Table 1). Each year, fertiliser N application decreased white clover content significantly. Average (1990-1993) white clover contents were 48 and 36% on N0 and N100 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 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	1989[1]		1990		1991		1992		1993	
(kg ha^{-1} year^{-1})	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		**	
N x cut. freq.	NS		NS		NS		NS		**	
	White clover yield (t DM 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		*	
N x cut. freq.			NS		NS		NS		*	

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

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 fertiliser 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 (N100), while in the other years the DM yield only increased between N0 and N50. At Lelystad the mean apparent N efficiency (ANE) for fertiliser N was 11.3 kg DM per kg N between N0 and N50, whereas the ANE was only 3.5 kg DM per kg N between N50 and N100. Corresponding figures for Heino were 9.5 kg DM per kg N for N0-N50 and 5.3 kg DM per kg N for N50-N100. 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.

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 (%) 1992	1993	1994	White clover yield (t DM ha^{-1} year^{-1}) 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	**	**	***	*	**	***

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

Nitrogen	1989		1990		1991		1992		1993	
(kg ha^{-1} year^{-1})	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	
N x 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		**	
N x cutting frequency			NS		NS		NS		NS	

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). Fertiliser N application had no effect on 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 N0 and N100 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.

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

Nitrogen	DM Yield (kg ha^{-1} year^{-1})			N yield (kg ha^{-1} year^{-1})		
(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

Seasonal white clover content

Figure 1 shows the seasonal variation in white clover content of the HF treatments at Lelystad. For reasons of clarity only the results of N0, N50 and N100 are shown. Each spring white clover content started of higher on the unfertilised plots. On the HF treatments mean white clover contents in the first cut (1990-1993) were 34, 24, 25, 21 and 19% for N0, N25, N50, N75 and N100, 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 fertilised 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 N0, N50 and N100, 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

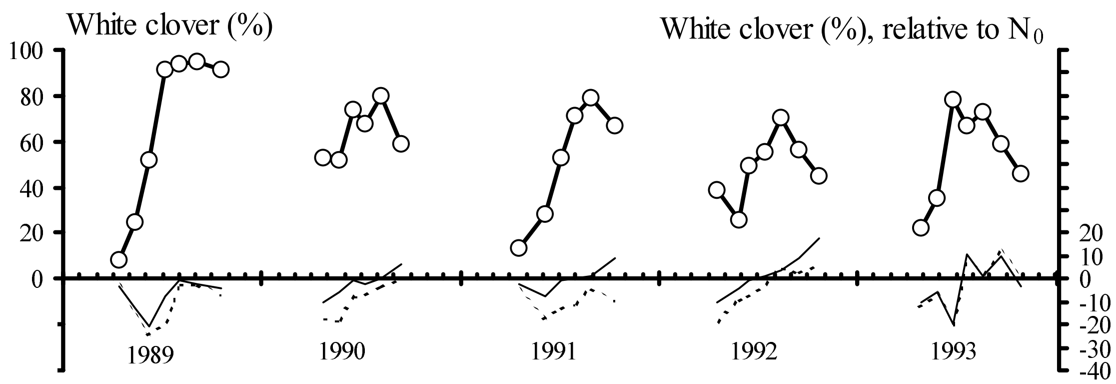

Figure 1. Seasonal white clover content of HF treatments at Lelystad; figures for N0 (—O—) are plotted against left axis and figures for N50 (—) and N100 (----) are relative to N0 and plotted against right axis. Figures for 1989 are ground cover.

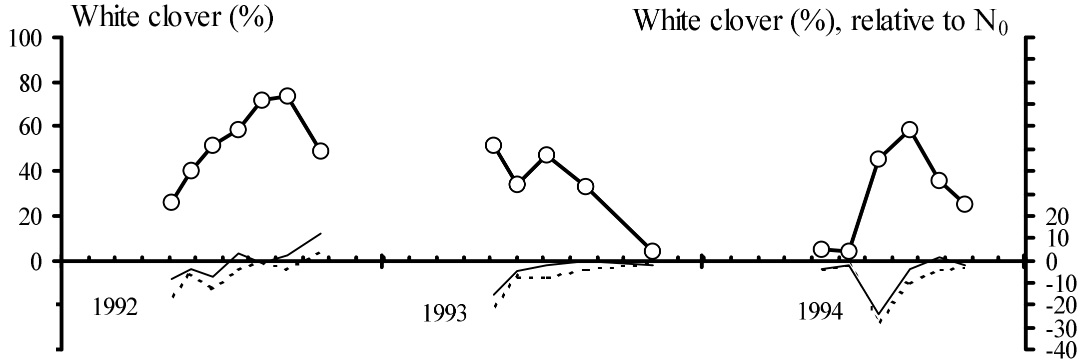

Figure 2. Seasonal white clover content of HF treatments at Heino; figures for N0 (—O—) are plotted against left axis and figures for N50 (—) and N100 (----) are relative to N0 and plotted against right axis.

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 fertiliser N application rate, N yield and DM yield in the 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 N0 and N100, 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 N0 and N100, 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

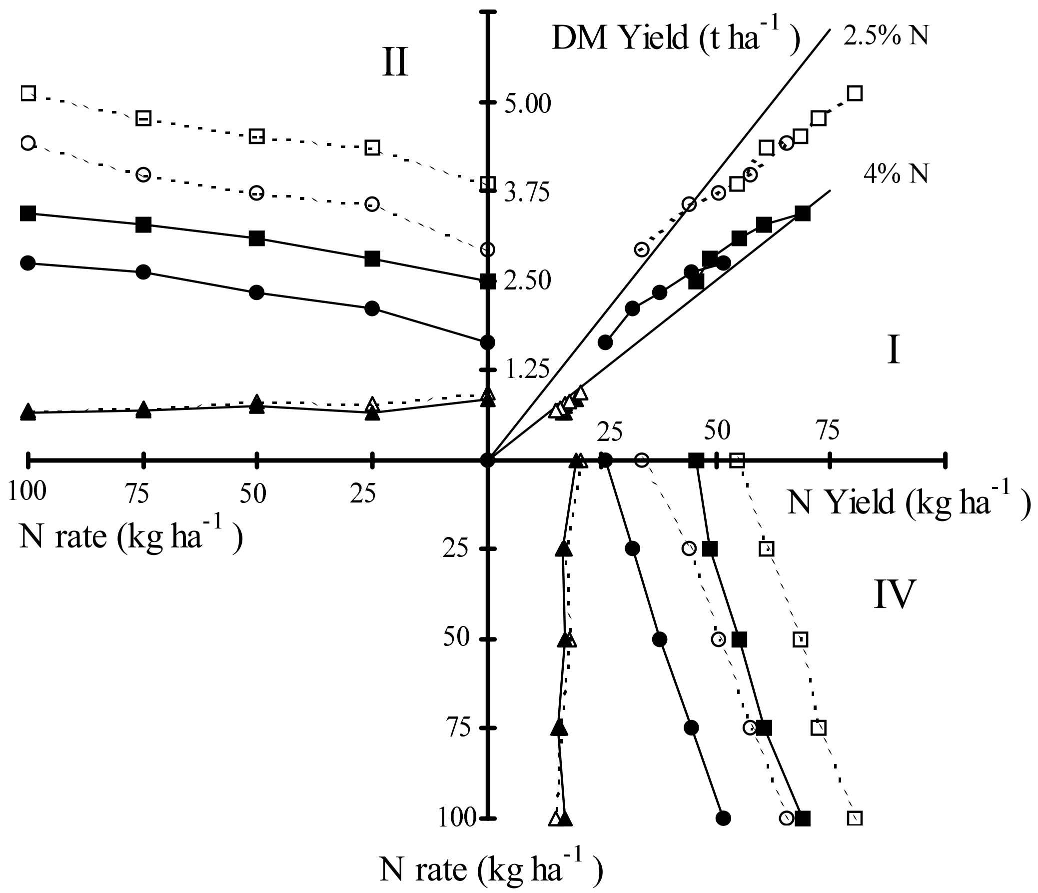

Figure 3. Relationships between N application rate, N yield and DM yield of the first cut at Lelystad (mean data over 1990-1993); grass-HF (—●—), clover-HF (—▲—), mixture-HF (—■—), grass-LF (---○---), clover-LF (---□---), mixture-LF (---Δ---).

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 N0 and N100 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 fertiliser 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 fertiliser N. Increased N rates led to slightly higher grass yields but this was almost

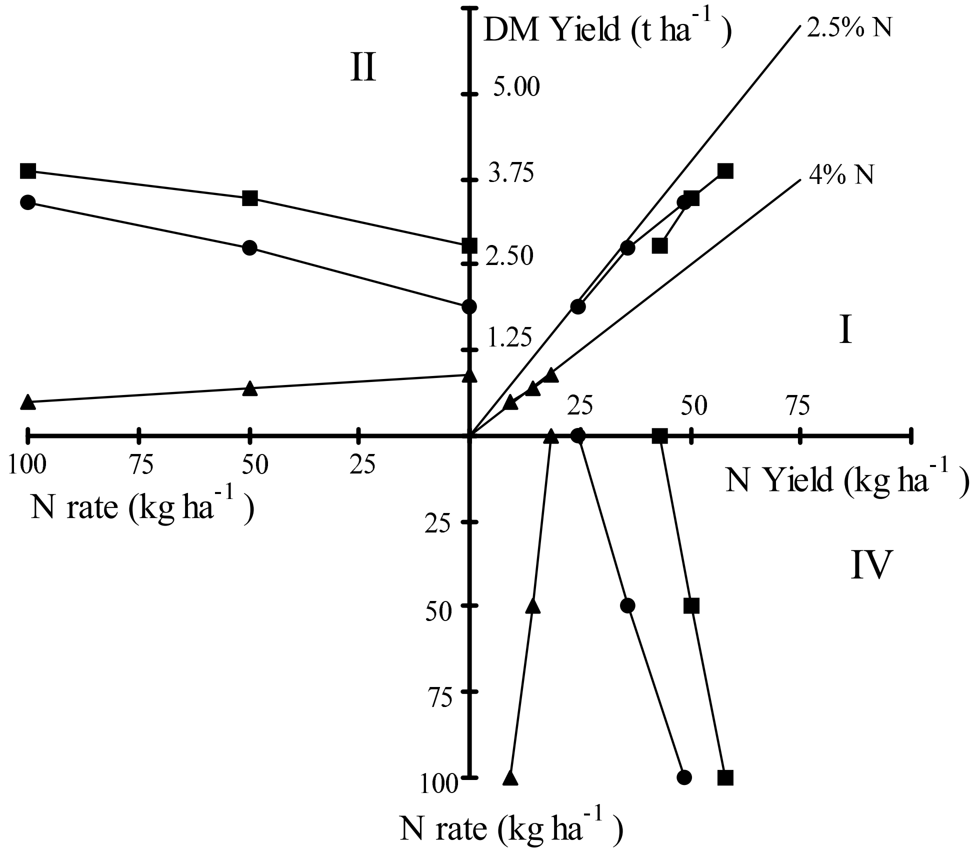

Figure 4. Relationships between N application rate, N yield and DM yield of the first cut at Heino grass (—●—), clover (—▲—), mixture (—■—).

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 fertiliser N. 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 fertiliser 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 fertilised 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 fertilised 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).

Fertiliser 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 N0 - N50 and N50 - N100, 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 fertiliser 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 fertiliser 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.

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CHAPTER 3

Dry matter yield and herbage quality of a perennial ryegrass / white clover sward in a rotational grazing and cutting system

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Dry matter yield and herbage quality of a perennial ryegrass / white clover sward in a rotational grazing and cutting system

Abstract

The expected reduction in the use of fertiliser nitrogen (N) on grassland in the Netherlands has led to renewed interest in white clover. Therefore, the performance of a newly sown perennial ryegrass / white clover sward on clay soil was assessed during four consecutive years. The experiment consisted of all combinations of two defoliation systems, i.e. one or two silage cuts per year (S1, S2), spring N application rate, i.e. 0 or 50 kg ha^{-1} $year^{-1}$ (N0, N50) and management system, i.e. rotational grazing and cutting or cutting only (RGC, CO). The overall mean white clover cover was 30%. All treatments affected white clover cover, which was 8% higher with S2 than with S1, 6% higher with N0 than with N50 and 12% higher with CO than with RGC. The overall mean annual dry matter (DM) yield (13.1 t ha^{-1} $year^{-1}$) was significantly affected only by management system: in two relatively wetter years, the annual DM yield was 1.19 t ha^{-1} higher with RGC than with CO, while there was no difference in two relatively drier years. Nitrogen application increased the DM yield in the first cut by 7.0 kg per kg N applied, but had no significant effect on the annual DM yield. Herbage quality was not affected by the experimental treatments. Average *in vitro* organic matter digestibility was 801 g kg^{-1} organic matter (OM) and average crude protein content was 193 g kg^{-1} DM. With the expected reduction in the use of fertiliser N, perennial ryegrass / white clover swards should be seriously considered as an alternative option to perennial ryegrass swards on these clay soils.

Introduction

To decrease nitrogen (N) losses from Dutch dairy systems, current government policies aim to reduce the N surpluses on dairy farms to a level of 180 kg ha^{-1} by the year 2008 (MANMF, 1997). In the next decade, the prevailing management on grassland will be a gradual reduction in fertiliser N input, creating renewed interest in white clover.

In the Netherlands, the predominant grassland management system consists of rotational grazing of one to four days per paddock, with the inclusion of one or two silage cuts per year. Guidelines for grassland management recommend that grazing with dairy cows takes place at a dry matter (DM) yield of approximately 1700 kg ha^{-1} and that silage is cut at approximately 3500 kg DM ha^{-1} (IKC, 1993). Adoption of mixed perennial ryegrass / white clover swards by dairy farmers will be easier when these swards can be integrated in currently used grassland management systems. In a cutting experiment, Frame & Paterson (1987) simulated different defoliation systems and concluded that mixed swards are suitable for management systems that include one or two silage cuts a year. However, their experiment simulated grazing by cutting at a DM yield of 1 to 2 t ha^{-1}, thereby excluding some important aspects of grazing, such as the return of excreta, treading and selection by the grazing animal. The present experiment tried to simulate the practical farm situation and therefore included grazing with dairy cows. The main objective of this experiment was to determine the DM yield and herbage quality of a mixed sward in a rotational grazing system with the inclusion of either one or two silage cuts a year, in comparison with a cutting only system. On grass only swards on clay soil, under a rotational grazing and cutting management and fertilized with 250 kg N ha^{-1} $year^{-1}$, Boxem (1973) measured an average DM yield of 10.3 t ha^{-1} $year^{-1}$. More recently on a clay soil similar to that in the present experiment, Deenen (1994) found an average DM yield of 13.1 t ha^{-1} $year^{-1}$, with rotational grazing and an N application rate of 250 kg ha^{-1} $year^{-1}$. In order to be competitive with grass only systems, similar DM yields should be obtained with grass / clover swards.

Many experiments have shown the beneficial effect of strategic applications of moderate quantities of fertiliser N in spring, i.e. increased DM yields with only small negative effects on clover content (e.g. Field & Ball, 1978; Frame & Paterson, 1987; Frame & Boyd, 1987; Schils, 1997). An additional objective of this experiment was to establish the response of spring applied fertiliser N under a rotational grazing and cutting management.

Materials and methods

Experimental site

In August 1988, a new sward was established with 20 kg ha^{-1} of perennial ryegrass (*Lolium perenne* L.) seed, cvs. Profit and Magella, mixed with 5 kg ha^{-1} of white clover (*Trifolium repens* L.) seed, cv. Retor, on the Waiboerhoeve experimental station at Lelystad (52° N). It is located on a well drained calcareous marine light clay soil, that had been used as intensive grassland since 1971. In the first year of the experiment, concentrations in the top soil (Table 1) of available phosphate (extracted with 0.1 mol l^{-1} ammonium lactate and 0.4 mol l^{-1} acetic acid) and potassium (extracted with 0.1 mol l^{-1} hydrochloric acid 0.4 mol l^{-1} oxalic acid) were sufficient and high, respectively (IKC, 1994).

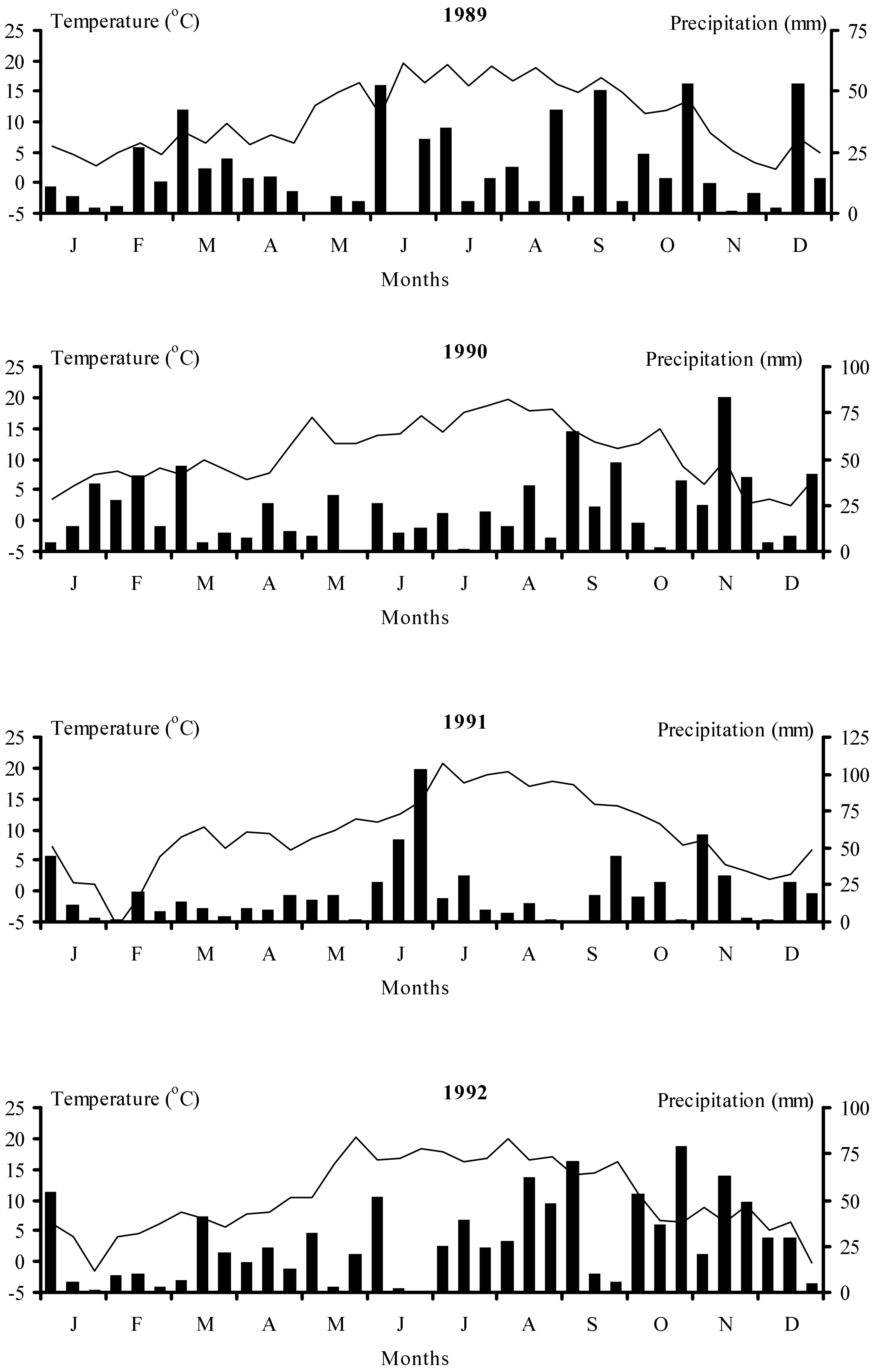

Figure 1. Temperature at 1.5 m (—) and precipitation (■) per decade.

Table 1. Soil characteristics in the first and last year of the experiment (0-5 cm).

	1989	1992
pH-KCl	7.4	6.9
Organic matter (%)	4.0	6.7
P-AL (mg P_2O_5 100 g^{-1})	34	62
K-HCl (mg K_2O 100 g^{-1})	53	72

Weather data (Figure 1) were collected from the nearest weather station, 10 km from the experimental site (KNMI, 1989-1992). The temperature sum was calculated as the sum of the positive average daily temperatures, from the 1st of January onwards. All four harvest years were warmer and sunnier than average. The total precipitation surpluses, i.e. precipitation minus reference evaporation according to Makkink (Hooghart & Lablans, 1988), during the growing season (March to October), from 1989 to 1992 amounted to -105, +4, -83, and +99 mm, for successive years. The experimental field was not irrigated.

Treatments

The experiment consisted of all combinations of (i) two defoliation systems, (ii) two N application rates in spring and (iii) two management systems, laid out in four replicates. The main experimental treatments, defoliation system and N application rate, were randomized within blocks, while management system treatments were randomized within the defoliation system and N application rate plots. Defoliation systems S1 and S2 consisted of a rotational grazing system with the inclusion of either one or two silage cuts, respectively. The silage cuts were planned to be taken at the second cut in system S1 and at the first and fourth cut in system S2. The objective for defoliation system S1 and S2 was to harvest approximately 25 and 50% of the annual DM yield as silage, respectively. Grazing was planned to take place at a DM yield of 1.5 to 2.0 t ha^{-1} and silage cutting was planned at a DM yield of 3.0 to 4.0 t ha^{-1}. Grazing was performed during half a day with lactating Holstein dairy cows at a stocking rate of 150 to 250 cows ha^{-1}, depending on the amount of herbage on offer. This relatively short grazing time was chosen to minimize differences in undisturbed herbage growth between the two management systems. The rejected herbage on the grazing plots was topped twice a year, after two consecutive grazings: in defoliation system S1 after the 4th and 6th defoliation and in defoliation system S2 after the 3rd and 6th defoliation. Fertiliser N (calcium ammonium nitrate) was applied in the third week of March, either 0 or 50 kg ha^{-1} on treatments N0 and N50, respectively. The temperature sum at application was 515, 598,

Table 2. Harvest dates for defoliation systems with one or two silage cuts (S1 or S2); normal font for grazing and **bold** for cutting.

	1989		1990		1991		1992	
Harvest number	S1*	S2	S1	S2	S1	S2	S1	S2
1	**11 Apr**	**20 Apr**	10 Apr	**1 May**	16 Apr	**14 May**	27 Apr	**12 May**
2	1 May	10 May	**9 May**	21 May	23 May	12 Jun	**25 May**	9 Jun
3	16 May	30 May	30 May	13 Jun	**1 Jul**	11 Jul	30 Jun	2 Jul
4	**6 Jun**	**4 Jul**	19 Jun	**20 Jul**	30 Jul	**19 Aug**	11 Aug	**25 Aug**
5	4 Jul	1 Aug	2 Aug	4 Sep	28 Aug	16 Oct	8 Sep	29 Sep
6	1 Aug	6 Sep	12 Sep	5 Oct	16 Oct		20 Oct	
7	6 Sep	9 Oct	10 Oct	8 Nov				
8	9 Oct		8 Nov					

* Two silage cuts, in 1989 only

378 and 450 ^{o}C in the four consecutive years.

Annually, there were 5 to 8 defoliations, depending on year and defoliation system (Table 2). In the first experimental year, cows were available only from the 1st of May onwards. Therefore, the first harvest of S1 was cut for silage, instead of being grazed. To meet the objective of "25% of the annual yield removed as silage", an additional silage cut with a relatively low DM yield was interposed later that year. The management system treatments were included to allow a comparison with a cutting only situation. The two management systems were either rotational grazing and cutting (RGC), as described above or cutting only (CO). The CO treatments were harvested on the same dates as the RGC treatments.

In the third week of March, all plots received 70 kg P_2O_5 ha^{-1} as triple superphosphate. During the rest of the year, each silage cut on the RGC plots received 30 kg P_2O_5 and 60 kg K_2O ha^{-1} as potassium chloride, while the CO plots received a similar application for each cut. The average annual application rate amounted to 100 kg P_2O_5 and 60 kg K_2O ha^{-1} on RGC plots and 235 kg P_2O_5 and 330 kg K_2O ha^{-1} on CO plots.

Measurements

Prior to each harvest, the cover of white clover leaves was estimated visually in 0.25 m^2 quadrates, 5 per RGC plot and 3 per CO plot. The number of measurements per plot was higher on the RGC plots than on the CO plots because of the larger plot size and the higher variation expected on the grazing plots. In 1989, additional herbage samples were taken prior to each harvest. Samples were separated into white clover and grass and dried for 24 hours at 105 ^{o}C, to establish the relationship between visual clover cover and DM clover content. Herbage yields were determined by cutting five strips of 6 m x 0.7 m from the main RGC plots (23 m x 12 m) and one strip of 6 m x 0.7 m from the CO plots

(10 m x 3 m), using an Agria motor cutter at a cutting height of 5 cm. Herbage was weighed, sampled and dried for 48 hours at 70 °C. Data from quadrats and strips were averaged per plot. After drying, herbage samples from the four replicates were bulked into one sample and analysed for crude protein, crude ash, crude fibre and *in vitro* organic matter digestibility (Tilley & Terry, 1963). Crude protein was determined as 6.25 x Kjeldahl-N. Crude fibre was analysed gravimetrically after calcination of the non-soluble residues which remained after cooking in 0.26 N H_2SO_4 and 0.23 N NaOH, respectively. Crude ash was determined gravimetrically after calcination during 4 hours at 550 °C (CVB, 1992). Directly following the grazing of the plots, five new strips were cut and marked. These were used for the next harvest, thereby avoiding overestimation of annual herbage yields through rejected herbage. Analyses of variance and multiple linear regression analyses were performed with GENSTAT 5 software (Genstat 5 committee, 1994).

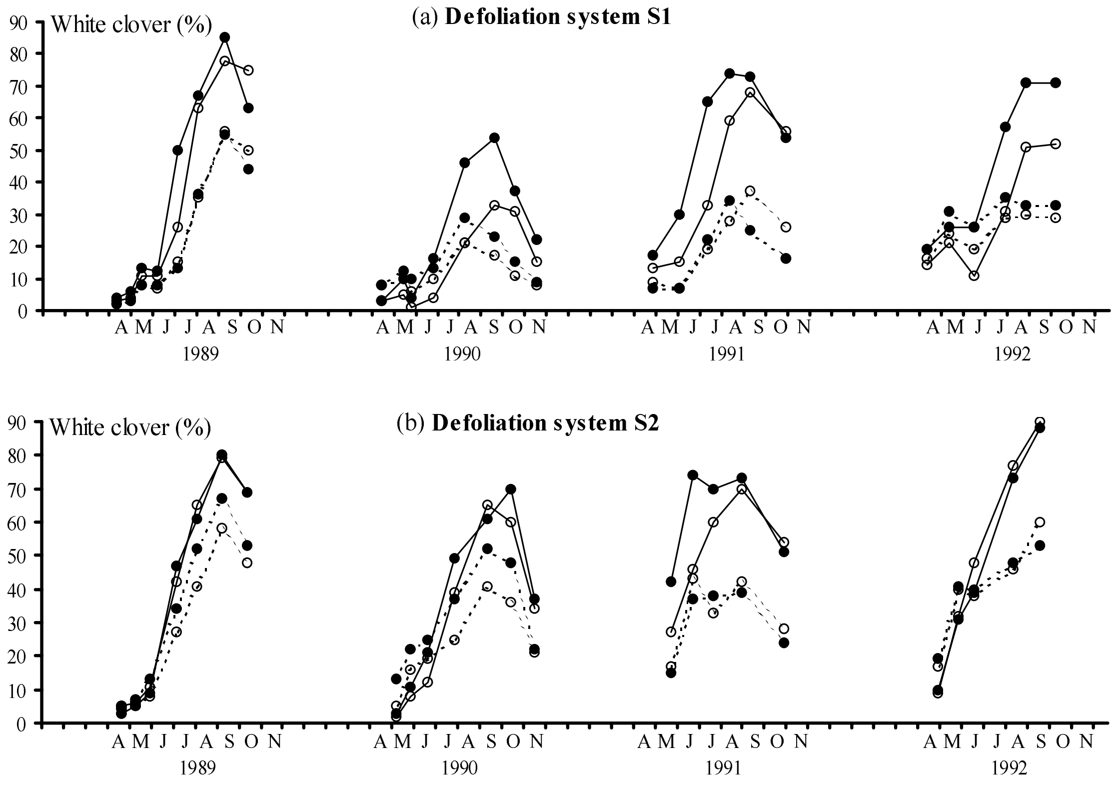

Figure 2. Mean white clover cover for defoliation systems with (a) one or (b) two silage cuts (S1 or S2), N application rates of 0 or 50 kg ha^{-1} (N0 ● or N50 O) and management systems with rotational grazing and cutting (RGC ---) or with cutting only (CO —).

Results

White clover

From the results of the first experimental year the following relationship between dry matter white clover content (CLdm) and white clover cover (CLcov) was derived: CLdm = 0.8214 x CLcov, which accounted for 85.2% of the variation.

Overall mean white clover cover from the first to the fourth year was 28, 20, 39 and 32%, respectively. Averaged over the whole experimental period, all treatments had a significant effect on white clover cover, without any significant interactions (Table 3).

Management system had the most substantial effect on white clover cover, with significant differences in 1989 and 1991. Rotational grazing and cutting (RGC) reduced the average white clover cover by 12%, compared with the cutting control (CO). This negative effect of grazing occurred from July or August onwards (Figure 2). At the end of each growing season, white clover cover was higher in CO treatments, but this

Table 3. Annual white clover cover (%) for defoliation systems with one or two silage cuts (S1 or S2), N application rates of 0 or 50 kg ha^{-1} and management systems with rotational grazing and cutting (RGC) or with cutting only (CO).

Defoliation system	N rate (kg ha^{-1})	Management system	1989	1990	1991	1992	Mean
S1	0	RGC	19	15	21	28	21
		CO	34	23	58	38	38
	50	RGC	19	12	20	23	19
		CO	29	11	38	23	25
S2	0	RGC	29	27	30	35	30
		CO	35	30	64	39	42
	50	RGC	25	18	31	33	27
		CO	36	23	48	39	37
Mean							
S1			25	15	34	28	26
S2			31	25	43	37	34
	0		29	24	43	35	33
	50		27	16	34	30	27
		RGC	23	18	26	30	24
		CO	34	22	52	35	36
			Sign[1]/ LSD[2]	Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD
Defoliation			NS / 6.3	** / 6.0	NS / 11.8	* / 7.3	*** / 3.8
Nitrogen			NS / 6.3	* / 6.0	NS / 11.8	NS / 7.3	*** / 3.8
Management			** / 5.4	NS / 5.3	***/ 7.8	NS / 7.8	*** / 3.3
N x Management			NS / 7.8	NS / 7.5	* / 13.3	NS / 10.1	NS / 5.0

1: NS=not significant; * = P<0.05; **=P<0.01; ***=P<0.001

2: Least Significant Difference (P<0.05) difference was not long-lasting. At the first defoliation of the following year, white clover cover of RGC and CO treatments were down to similar levels, with the exception of defoliation system S2 in 1991.

Average white clover cover was 8% higher in the defoliation system S2 than in S1. Significant differences occurred in years 1990 and 1992. In 1989, the difference between the two defoliation systems was relatively small, possibly because defoliation system S1 consisted of two silage cuts as well, rather than one as in other years (Table 2).

On average, N application reduced annual white clover cover by 6%. Although the average annual effect was fairly consistent and varied from 2 to 9%, white clover cover in single cuts showed a large variation in response to N application. In defoliation system S1, the negative response of white clover cover to N application was more apparent with cutting (CO) than with rotational grazing and cutting (RGC). In defoliation system S2, the average response to N application was somewhat less than in S1, and there were no consistent differences between CO and RGC treatments.

Table 4. Annual dry matter yield (t ha^{-1}) for defoliation systems with one or two silage cuts (S1 or S2), N application rates of 0 or 50 kg ha^{-1} and management systems with rotational grazing and cutting (RGC) or with cutting only (CO).

Defoliation system	N rate (kg ha^{-1})	Management system	1989	1990	1991	1992	Mean
S1	0	RGC	14.89	15.12	10.31	13.56	13.47
		CO	14.74	12.65	9.97	12.29	12.41
	50	RGC	15.18	15.63	11.46	13.31	13.90
		CO	14.05	13.28	10.14	11.41	12.22
S2	0	RGC	13.89	15.37	9.53	12.67	12.87
		CO	14.08	15.01	10.89	11.85	12.96
	50	RGC	14.60	15.21	11.49	12.18	13.37
		CO	15.38	14.58	12.39	12.46	13.70
Mean							
S1			14.72	14.17	10.47	12.64	13.00
S2			14.49	15.04	11.08	12.29	13.23
	0		14.40	14.54	10.18	12.59	12.93
	50		14.80	14.68	11.37	12.34	13.30
		RGC	14.64	15.33	10.70	12.93	13.40
		CO	14.56	13.88	10.85	12.00	12.82
			Sign/ LSD	Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD
Defoliation			NS / 0.99	NS / 1.00	NS / 1.61	* / 0.81	NS / 0.50
Nitrogen			NS / 0.99	NS / 1.00	NS / 1.61	NS / 0.81	NS / 0.50
Management			NS / 0.57	*** / 0.63	NS / 0.48	** / 0.62	*** / 0.32
N x Management			NS / 1.09	* / 1.12	*** / 1.64	* / 0.96	*** / 0.59

Annual dry matter and nitrogen yield

Overall mean annual DM yields from the first to the fourth year were 14.6, 14.6, 10.8 and 12.5 t ha^{-1}, respectively. Averaged over the whole experimental period, DM yield was significantly affected by management system, but only within defoliation system S1 (Table 4). On average, the annual DM yield was 0.6 t ha^{-1} higher under the RGC management than under the CO management, the difference ranging from not significant in 1989 and 1991 to significant differences of 1.5 and 1.0 t ha^{-1} in 1990 and 1992, respectively. In those years, however, the positive effect of management system RGC on annual DM yield was apparent only within defoliation system S1.

Annual DM yield was not significantly affected by N application or defoliation system.

Overall mean annual N yields (results not shown) from the first to the fourth year were 483, 466, 337 and 382 kg ha^{-1}, respectively. Nitrogen application and defoliation system had no effect on N yield. Similar to annual DM yields, annual N yields were higher under RGC management than under CO management. The largest effect was found within defoliation system S1 in 1990 and 1992, when the difference in annual N yield between RGC and CO treatments was 73 and 69 kg ha^{-1}, respectively.

Dry matter yield at the first defoliation

Dry matter yields at the first defoliation showed an average response to fertiliser N of 7.0 kg DM per kg N, varying from not significant in 1989 and 1992 to a significant response of 9.4 kg DM per kg N in 1990 and 1991 (Table 5). There was no significant interaction between management system and nitrogen application.

The average DM yield at the first defoliation of S1 was 3.00 t ha^{-1}. The first cut in

Table 5. Dry matter yield (t ha^{-1}) at the first defoliation for N application rates of 0 or 50 kg ha^{-1} and management systems with rotational grazing and cutting (RGC) or with cutting only (CO).

Management system	N rate (kg ha^{-1})	1989	1990	1991	1992	Mean
RGC	0	3.38	3.85	2.74	4.47	3.61
	50	3.58	4.29	3.14	4.59	3.90
CO	0	3.40	4.01	2.61	4.26	3.57
	50	3.52	4.51	3.15	4.72	3.98
mean	0	3.39	3.93	2.68	4.37	3.59
	50	3.55	4.40	3.15	4.66	3.94
		Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD
Nitrogen		NS / 0.29	* / 0.43	* / 0.38	NS / 0.65	** / 0.24
Management		NS / 0.15	NS / 0.22	NS / 0.24	NS / 0.28	NS / 0.10

Table 6. Mean chemical composition, digestibility and feeding value of harvested herbage for defoliation systems with one or two silage cuts (S1 or S2), N application rates of 0 or 50 kg ha^{-1} and management systems with rotational grazing and cutting (RGC) or with cutting only (CO).

Defoliation system	N rate (kg ha^{-1})	Management system	DM-Yield (t ha^{-1})	Clover (%)	Crude ash (g kg^{-1} DM)	Crude fibre (g kg^{-1} DM)	Crude protein (g kg^{-1} DM)
S1	0	RGC	1.98	21	114	207	194
		CO	1.81	38	116	199	198
	50	RGC	2.02	19	116	206	197
		CO	1.76	29	117	202	196
			Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD
Nitrogen			NS / 0.08	** / 3.6	NS / 2.1	NS / 4.2	NS / 4.5
Management			*** / 0.08	*** / 3.6	NS / 2.1	* / 4.2	NS / 4.5
Nitrogen x Management			NS / 0.11	* / 5.1	NS / 3.0	NS / 5.9	NS / 4.5
S2	0	RGC	2.24	33	114	209	190
		CO	2.21	45	116	204	198
	50	RGC	2.25	29	115	210	190
		CO	2.28	41	116	204	200
			Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD	Sign / LSD
Nitrogen			NS / 0.09	NS / 3.6	NS / 1.8	NS / 3.0	NS / 5.6
Management			NS / 0.09	*** / 3.6	NS / 1.8	** / 3.0	* / 5.6
Nitrogen x Management			NS / 0.13	NS / 5.1	NS / 2.6	NS / 4.3	NS / 7.8

defoliation system S2 was harvested 18 days later and yielded 4.52 t ha^{-1}, on average. There was no interaction between defoliation system and N application rate or management system.

Herbage quality

The experimental treatments had only minor effects on the herbage quality of grass/clover (Table 6). Crude fibre contents were slightly, but significantly, lower on CO treatments than on RGC treatments. Consequently, digestibility of organic matter was higher on CO treatments. The effect of management system on crude fibre content reflected the effect of management system on DM yield and clover content; regression analysis confirmed that crude fibre content was significantly ($P < 0.05$) related with DM yield and clover content (R^2 = 42.6%). However, harvest date was by far the most important factor for herbage quality (Figure 3). Each year, IVOMD and CP showed a fairly consistent seasonal pattern. Until June, IVOMD values ranged from 820 to 870 g kg^{-1} OM. In July and August, IVOMD values fell to 680 to 770 g kg^{-1} OM, but from September onwards, they recovered to values around 800 g kg^{-1} OM. For CP contents, a similar consistent pattern was observed, with high values in spring and autumn and low values in summer, with a more than twofold difference between lowest and highest values.

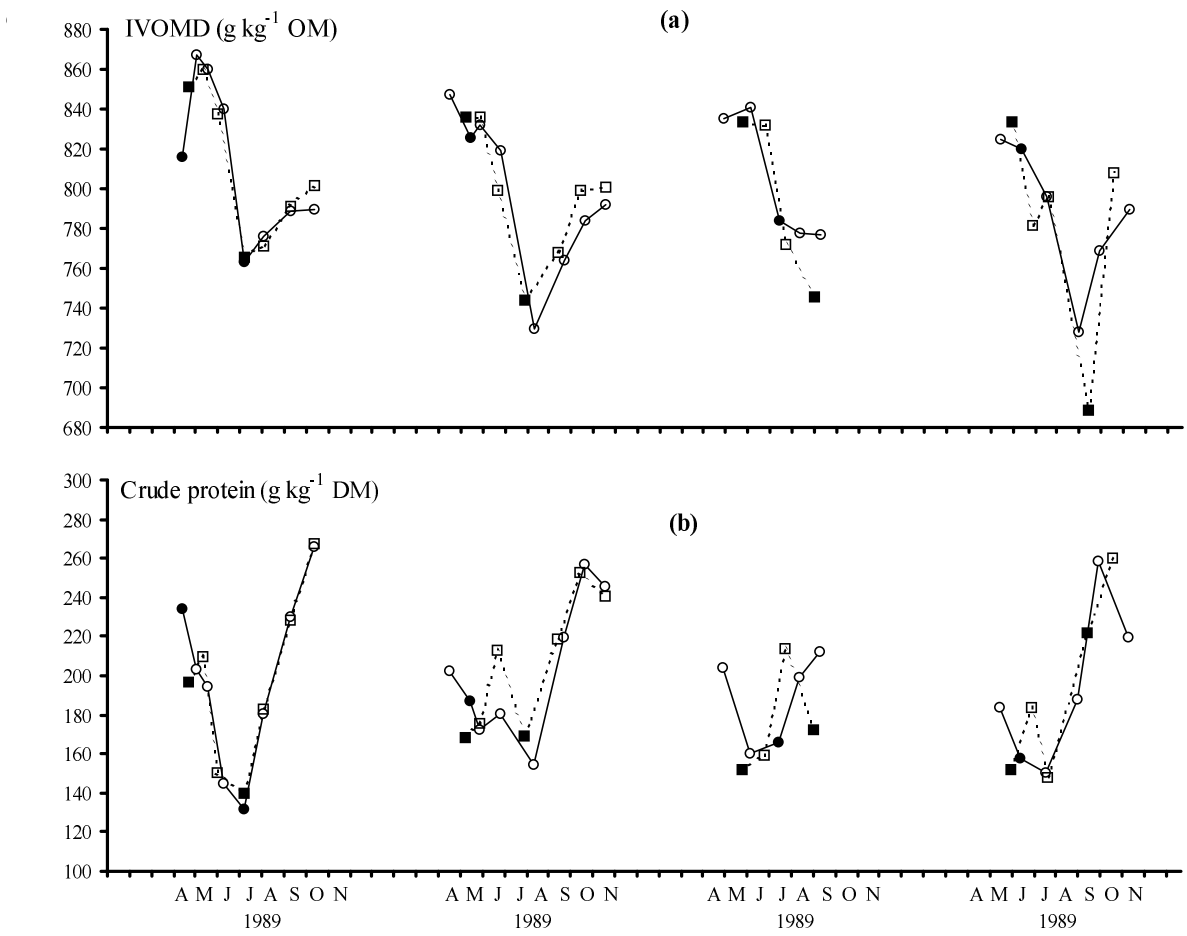

Figure 3. Seasonal pattern of (a) *in vitro* organic matter digestibility (IVOMD) and (b) crude protein of grass/clover for defoliation systems with one or two silage cuts (S1●—O— or S2 ■---□---), averaged over management system and N application rate. Open markers represent harvests at grazing stage and filled markers represent silage cuts.

Discussion and conclusions

Average DM yields at individual harvests were 1.71 t ha^{-1} for grazing and 3.21 t ha^{-1} for silage cuts, which was in line with targets. However, there was considerable variation between harvests, ranging from 0.60 to 4.28 t ha^{-1} at grazing and from 1.27 to 5.54 t ha^{-1} at silage cutting. Yields above the targets occurred mainly in spring, due to underestimation of herbage growth rates. In summer and autumn, target yields could not always be achieved within a reasonable regrowth period and therefore harvests took place below the target yield. At grazing, the DM yields in the high end of the range increased the amounts of rejected herbage, but regular topping and inclusion of the silage cuts prevented the accumulation of rejected herbage.

White clover

The lower white clover cover under grazing, as observed in the RGC system, compared with the CO system, is well documented (e.g. Evans & Williams, 1997; Swift *et al.*, 1992). The negative effect of grazing on the proportion of white clover in mixed swards is mainly associated with return of urinary N (Ledgard *et al.*, 1982; Baars & Van Dongen, 1993). Although an effect of treading can not be eliminated, it is unlikely that this was of major importance in our experiment, as the grazing periods in this experiment did not coincide with very wet conditions. It is not probable that selective grazing of clover has contributed to the lower clover contents in the grazed plots. The sward structure in this experiment, with no distinct spatial separation of clover and grass, is unlikely to have allowed selective grazing (Cosgrove *et al.*, 1996.). In the present experiment, the observed reduction in white clover cover was a short term effect. At the start of each grazing season, there were generally no differences in white clover cover, but as the grazing season progressed, differences in clover cover increased.

The average white clover cover in the rotational grazing and cutting system was 24%. Between years it varied from 18 to 30%, but within-year variation was substantially greater, with lowest values in April (2 to 17%) and the highest values, in July and August (21 and 67%). Using the relationship between white clover cover and DM white clover content, as found in the first year, these figures correspond with an overall average DM white clover content of 20%, with a variation of 2 to 55%. Based on four criteria, i.e. herbage yield, animal performance, bloat risk and nitrogen losses, Pflimlin (1993) suggested an optimal clover content between 25 and 50%, for rotational grazing systems without supplementation of dry forages. The amount of white clover present in the rotational grazing and cutting plots in this experiment was slightly lower than those targets, especially in spring. Although it would be possible to increase the amount of clover by choosing other white clover varieties (Ebskamp & Bonthuis, 1996; Elgersma & Schlepers, 1997), the use of more competitive white clover varieties increases the risk of clover dominance, thereby increasing the risk of unacceptable N losses (Jarvis, 1992).

Dry matter yield

The overall average annual DM yield of 13.1 t ha^{-1} indicates that, assuming a prospective reduction in the use of fertiliser N below a level of 250 to 300 kg ha^{-1} year^{-1}, perennial ryegrass - white clover swards can be considered as an alternative option on this soil type. In a cutting experiment from 1990 to 1992, average DM yields of grass-only swards for this soil type were 4.7, 11.1 or 15.0 t ha^{-1} year^{-1} with applications of 0, 160 or 320 kg N ha^{-1} year^{-1}, respectively (Schils *et al.*, 1998), compared with 12.2 t ha^{-1} year^{-1} in corresponding years on CO treatments of the present experiment. In an experiment with rotational grazing and cutting on grass-only swards on the same site in 1992, Hofstede *et* *al*. (1995) found a DM yield of 12.6 t ha^{-1} year^{-1} after application of 277 kg N ha^{-1} year^{-1}. In that year, the average DM yield on the RGC treatments of this experiment was 12.9 t ha^{-1} year^{-1}.

Average annual DM yields varied from 10.8 to 14.6 t ha^{-1}, with no obvious relationships with annual white clover cover or annual precipitation surplus.

Despite a lower white clover cover, the DM and N yields on RGC treatments were equal to, or higher than, those of CO treatments. This suggests that the reduced input of biologically fixed N, arising from the lower proportion of white clover and a reduction in N fixation per unit clover (Ledgard *et al*., 1982; Marriott *et al*., 1987), was more than compensated by the N input through urine. The most substantial positive effects of grazing on DM and N yields were obtained in 1990 and 1992, when the DM yield on the RGC treatments was increased by 1.2 t ha^{-1} year^{-1} and the N yield by 39 kg N ha^{-1} year^{-1}, compared with the CO treatments. As 1990 and 1992 were relatively wet years within this experiment, the increased DM and N yields might be connected with an increased N utilisation from urine. Based on the daily milk protein production of 874 g cow^{-1} day^{-1} (Schils, 1996), an N utilisation (N in milk * 100% / N intake) of 22.2% for clover based diets (Remmelink, 2000) and an average of 435 cow grazing days ha^{-1} year^{-1}, the amount of N returned through faeces and urine is estimated at 210 kg ha^{-1} year^{-1}. Assuming 75% of excreted N is in urine (Lantinga *et al*., 1987) and weather induced variations in apparent N recoveries are from 11%, under warm dry conditions, to 55%, under cool moist conditions (Ball & Keeney, 1981), the herbage N derived from urine could vary from 17 to 86 kg N ha^{-1} year^{-1}.

Fertiliser N increased the DM yield at the first defoliation by 7 kg DM kg^{-1} N, which is in the low end of the range found in other experiments (Morrison *et al*., 1983; Frame & Paterson, 1987; Frame & Boyd, 1987; Schils, 1997). The weather data do not suggest that water availability or temperature were limiting factors. There were no major differences between the two management systems in the DM response to fertiliser N.

Herbage quality

The nutritional characteristics of white clover and its feeding value for dairy cattle have been reported thoroughly (Thomson, 1984; Søegaard, 1993; Remmelink, 2000). In the present experiment, the average OMD values were satisfactory (Søegaard, 1993). Relatively low OMD values were obtained in July and August, coinciding with white clover flowering. White clover inflorescence and flower stem have a lower digestibility than leaves and petioles (Wilman & Altimimi, 1984; Søegaard, 1993). Crude protein concentrations were generally lowest between June and August. From August onwards, CP values showed a sharp increase towards the end of the growing season. Such high amounts of CP increase the risk of undesired N losses in the rumen (Steg *et al*., 1994).

Under Dutch conditions, supplementation with forage maize is an effective way to reduce the potential N losses (Remmelink, 2000). It has to be considered that in this experiment, herbage was always harvested on areas from which rejected herbage had been removed. Under practical farm conditions, subsequent grazings might increase the accumulation of rejected herbage, depending on the frequency of topping, and consequently reduce the OMD and CP values.

Conclusions

- The results of the present experiment demonstrated the potential of mixed swards of perennial ryegrass and white clover in a rotational grazing and cutting system. Average annual DM yields were 13.40 t ha^{-1} with rotational grazing and cutting, compared with 12.82 t ha^{-1} with cutting only. With rotational grazing and cutting, average values of IVOMD and CP were 801 g kg^{-1} OM and 193 g kg^{-1} DM, respectively.
- Inclusion of a second silage cut in a rotational grazing system increased white clover cover by 8%, but did not affect annual DM yields.
- A spring application of 50 kg N ha^{-1} increased the DM yield at the first defoliation by 7.0 kg DM kg^{-1} N applied, with no difference between RGC and CO treatments. Nitrogen application had no effect on annual DM yields.

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CHAPTER 4

The combined effect of fertiliser nitrogen and phosphorus on a grass/clover and grass-only sward. I. Nutrient uptake and herbage production

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Chapter 4

The combined effect of fertiliser nitrogen and phosphorus on a grass/clover and grass-only sward. I. Nutrient uptake and herbage production

Abstract

The combined effect of reduced nitrogen (N) and phosphorus (P) application on the production of grass-only and grass/clover swards was studied in a cutting experiment on a marine clay soil. The experiment was established on newly sown swards and lasted for five years. The treatments included specific combinations of four P levels (0, 35, 70 and 105 kg P ha^{-1} $year^{-1}$), three N levels (0, 190 and 380 N kg ha^{-1} $year^{-1}$) and two sward types (grass-only and grass/clover).

Nitrogen was the main factor determining the yield and quality of the harvested herbage. On the grass-only swards, N application increased the DM yield with 28 or 22 kg DM kg^{-1} N, after application of 190 or 380 kg N ha^{-1} $year^{-1}$, respectively. The average apparent N recovery of applied N was 0.78 kg kg^{-1}. On the grass/clover swards N application increased grass production at the cost of white clover production. The average proportion of white clover decreased from 41 to 16% following an N application of 190 kg ha^{-1} $year^{-1}$.

The average apparent P efficiency after application of 34, 68 or 100 kg P ha^{-1} $year^{-1}$ was 13.0, 9.0, and 9.1 kg DM kg^{-1} P, respectively. Phosphorus application did not increase clover yield. The results suggested a negative effect of P application on clover proportions in mixed swards.

A positive interaction between N and P applications was observed. However, the consequences of this interaction for the optimal N application were only minor, and of little practical relevance.

Introduction

Over the last 40 years, production grasslands in the Netherlands have been fertilised with increasing amounts of nitrogen (N) and phosphorus (P). In 1990, the fertiliser application on specialised dairy farms was at a level of 304 kg N and 19 kg P ha^{-1} $year^{-1}$. In the following 10 years, fertiliser use decreased to a level of 210 kg N and 11 kg P ha^{-1} $year^{-1}$ in 1999 (LEI, 2001). Next to fertiliser, grasslands have received N and P from animal excreta, either directly during grazing or through application of slurry or farmyard manure. For a typical dairy farm on sandy soil in the early eighties, Aarts *et al.* (1992)

estimated an additional input of 164 kg N and 25 kg P ha^{-1} $year^{-1}$ through animal excreta during grazing and 120 kg N and 30 kg P ha^{-1} $year^{-1}$ through slurry application.

The amounts of N and P applied to grasslands exceed the uptake, causing environmental problems like nitrate leaching to ground water (Fraters *et al*., 1997; Oenema *et al*., 1998) and N and P eutrophication of surface water (Oenema & Roest, 1998). Therefore, from 1985 onwards, the Dutch government has introduced a series of measures that aim to reduce the N and P losses from farming (VROM, 1989). In 1998, the Mineral Accounting System (MINAS) was introduced, which is an N and P accounting system on farm level (MANMF, 1997). In the year 2003, the allowed levy-free surpluses on grassland will be 180 kg N and 9 kg P ha^{-1} $year^{-1}$. These measures will lead to a further reduction in the use of fertiliser N and P on grassland and a substitution of fertiliser N by biologically fixed N (Schils *et al*., 2000a; Schils *et al*., 2000b), the latter mainly through the increased use of mixtures of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.).

Although much is known about the individual effects of N and P on grassland production (e.g. Agterberg & Henkens, 1995; Vellinga & André, 1999), there has been little attention for the combined effects of N and P, especially in field trials. The majority of fertiliser N experiments has been carried out with ample fertiliser P and vice versa. Furthermore, P application on grass/clover swards and its interaction with N application has not received any attention in the Netherlands.

The objectives of the present experiment are to (i) quantify the combined effect of fertiliser N and P on herbage production, herbage quality and soil P of grass and grass/clover swards, (ii) increase the understanding of P utilisation in grass/clover swards and (iii) provide a basis for P recommendations on grass/clover swards.

This experiment is presented in two parts. This first paper focuses on N and P utilisation by the grass and grass/clover crop. A second paper (Schils & Snijders, 2002) deals with soil nutrients and N and P budgets of the plant-soil system.

Materials and methods

Site

The experiment was established at Lelystad (52 ^{o}N) on a well drained sedimentary calcareous light marine clay soil, reclaimed from the IJssel Lake in 1957. The site has been used for dairy farming since 1973, first with amply fertilised perennial ryegrass dominated swards, later with moderately fertilised perennial ryegrass / white clover mixtures.

In January 1994, the experimental site was ploughed to a depth of 25 cm. In April, all

Table 1. Soil characteristics at the start of the experiment (April 1994).

	Sampling depth (cm)					
	0-5	5-10	10-15	15-20	20-25	25-30
Density (kg l^{-1})	0.97	1.17	1.23	1.26	1.15	1.29
Particles < 16 μm (%)	37	38	40	38	37	38
Organic matter (%)	3.4	3.4	3.6	4.0	4.6	3.6
pH-KCl	7.3	7.2	7.2	7.2	7.2	7.2
K-HCl (mg K 100 g^{-1})	22	24	27	31	31	24
P-AL (mg P_2O_5 100 g^{-1})	12	11	14	15	19	13
Total P (mg P 100 g^{-1})	54	55	58	61	66	58
Total N (mg N 100 g^{-1})	151	155	168	187	203	165
Organic C (mg C 100 g^{-1})	1857	2077	2103	2167	2430	1953
C_{org}/N ratio	12.3	13.4	12.5	11.6	12.0	11.8

plots were sown with 20 kg ha^{-1} of perennial ryegrass cvs. Herbie and Exito (50/50). Additionally, the grass/clover plots were sown with 5 kg ha^{-1} of white clover cvs. Alice and Retor (50/50).

As a result of ploughing, the nutrient availability in the soil tended to increase with depth, up to 25 cm (Table 1). According to the Dutch fertiliser recommendations (PR, 1998), the potassium values were very high and the P-AL values low. To prevent any negative effect of the low P-AL values on plant establishment, the whole field received a P starter dressing of 4.4 kg P ha^{-1} as triple superphosphate.

Weather data were obtained from the nearest weather stations (KNMI, 1993-1999). The precipitation surplus was calculated as the difference between precipitation and reference evaporation, according to Makkink (Hooghart & Lablans, 1988). The temperature sum, at one meter above soil level, was calculated from the first of January onwards, as the sum of the average of daily maximum and minimum temperatures, if the average was above 0 ^{o}C. During the experiment, all growing seasons were warmer than normal and, with the exception of the last season, also drier than normal (Table 2). The autumn and winter periods were generally warmer and equally wet or wetter than normal. Only the autumn/winter period of 1995/1996 was drier and colder than normal. The experimental field was not irrigated.

Treatments

The experiment was a randomised block trial with three replicates of combinations of two sward types (Grass and Grass/clover), three N levels (0, 200 and 400 kg ha^{-1} $year^{-1}$, designated as N0, N1 and N2, respectively) and four P levels (0, 35, 70 and 105 kg ha^{-1} $year^{-1}$, designated as P0, P1, P2 and P3, respectively). Grass swards were combined with all three N levels, while grass/clover swards were only combined with 0 and 200 kg N

Table 2. Mean values of daily minimal, mean and maximal temperatures and total precipitation surplus (precipitation - reference evaporation) per period of six months (KNMI, 1993 - 1999).

	April - September				October - March			
	Temperature (°C)			Surplus	Temperature (°C)			Surplus
	min	mean	max	(mm)	min	mean	max	(mm)
30 year mean	*9.0*	*13.6*	*18.6*	*-35*	*1.7*	*4.9*	*8.1*	*282*
1993/1994					2.1	5.1	8.0	363
1994/1995	9.9	14.7	19.4	-83	3.5	6.8	10.0	521
1995/1996	10.1	15.0	20.1	-98	0.3	3.7	6.9	40
1996/1997	8.5	13.8	18.5	-115	1.8	5.0	8.2	278
1997/1998	9.6	14.8	19.7	-154	3.4	6.7	9.7	273
1998/1999	10.3	14.7	19.1	131	2.6	5.7	8.6	480

ha^{-1} $year^{-1}$. The five resulting sward type x N level treatments were combined with the four P levels, resulting in 20 treatment combinations all together.

Nitrogen was applied as calcium ammonium nitrate (27% N) and P as triple superphosphate (20% P). The distribution of the annual application over the first 6 cuts was 25, 20, 20, 15, 10 and 10% for N, and 25, 15, 15, 15, 15 and 15% for P. In the establishment year, the first fertiliser was applied at sowing and in the following years between the 16th and 24th of March at a temperature sum of 514, 253, 521 and 578 °C, in the consecutive years. Throughout the experiment, the whole field was fertilised with 42 kg K ha^{-1} cut^{-1} as potassium chloride (50% K).

Harvests were planned to take place when the fastest growing plots yielded approximately 3.5 t DM ha^{-1} for the first cut, and approximately 2.5 t DM ha^{-1} for later cuts. All treatments were harvested on the same day. In each year, five cuts were taken, except in 1995, when seven cuts were taken. As a result, the average annual applications rates are somewhat lower than the planned application rates. Excluding the establishment year, the first cut was harvested between the 20th April and 21st May. The following cuts were harvested after an average growing period of 34 days, with a range of 20 to 56 days. In 1998, some harvests were delayed due to wet weather, which increased the DM yield at cutting.

Measurements and data analysis

Herbage was harvested with a Haldrup forage harvester from an area of 6 m x 1.5 m, leaving a stubble of 4 - 5 cm. Yields were recorded and a sample was taken for analyses of DM, total N (oxidation at 1050 °C) and P (destruction with Fleischmann acid). On grass/clover plots, an additional sample was taken for manual separation of grass and white clover. The grass fraction also contained small proportions of not sown species like annual meadowgrass (*Poa annua* L.), smooth stalked meadowgrass (*Poa pratensis* L.) and dandelion (*Taraxacum officinale* Web. s.l.). Grass and white clover fractions were analysed for DM, and from 1996 onwards, also for total N and P.

The apparent N and P recoveries were calculated as: {(N or P yield of fertilised plot – N or P yield of unfertilised plot) / fertiliser N or P application}. The apparent N and P efficiencies were calculated as: {(DM yield of fertilised plot – DM yield of unfertilised plot) / fertiliser N or P application}. The N and P use efficiencies were calculated as the DM yield per kg of N or P uptake. Biological N fixation by white clover was calculated as the difference between the N yield of grass/clover plots and grass plots with a similar N application. The apparent N transfer from white clover to perennial ryegrass was calculated as the difference in N yield of the grass component in the mixture and the unfertilised grass plots.

Data were analysed with GENSTAT 5 (GENSTAT, 1998).

Results

Dry matter yield

The overall mean DM yield was 10.0, 12.1, 9.6, 11.4 and 14.5 t ha^{-1} year^{-1}, in consecutive years (Table 3). The DM yield of the grass-only plots receiving no N ranged from 3.9 to 10.0 t ha^{-1} year^{-1}.

In each year, the annual DM yield was significantly affected by N input and N level (Table 3). On the grass-only swards, the average N efficiency was 28 and 22 kg DM kg^{-1} N after application of 190 or 380 kg N ha^{-1} year^{-1}, respectively. The N-efficiency was considerably lower in the establishment year than in the following four years. The effect

Table 3. Annual DM yield (t ha^{-1}) in relation to N input, sward type and N level.

Sward type	N level	1994		1995		1996		1997		1998	
Grass	N0	6.82		5.63		3.88		5.28		10.04	
	N1	10.93		11.56		9.28		10.78		15.46	
	N2	12.48		16.14		12.89		14.61		17.34	
Grass/Clover	N0	8.59		13.97		10.83		12.84		14.11	
	N1	11.18		13.12		10.95		13.31		15.57	
Mean		9.98		12.08		9.57		11.36		14.50	
Significance/ LSD (P≤0.05)											
Sward type		*	.16	***	.29	***	.28	***	.35	***	.27
Sward type*N level		***	.26	***	.44	***	.44	***	.54	***	.42

NS Not Significant; * P≤0.05; ** P≤0.01; *** P≤0.001

of a N application of 190 kg ha^{-1} year^{-1} on the grass/clover plots was only 4 kg DM kg^{-1} N on average, but varied from 13 kg DM kg^{-1} N in the establishment year to –4 kg DM kg^{-1} N in 1995.

Phosphorus application had a significant positive effect on the DM yield in four out of five years (Table 4). The effect of P on the DM yield was observed in two to four cuts, but not consistently in the same cuts. The occurrence of a positive P effect in the individual cuts could not be related to monthly weather data. The average apparent P efficiency after application of 34, 68 or 100 kg P ha^{-1} year^{-1} was 13.0, 9.0, and 9.1 kg DM kg^{-1} P, respectively.

The average response of DM yield to P application increased considerably with increasing N application (Figure 1, quadrant II). The average P efficiency was 1.5, 11.3 and 21.3 kg DM (kg P)$^{-1}$ after application of 0, 190 and 380 kg N ha^{-1} year^{-1}, respectively. On the other hand, the average N efficiency increased from 23 to 26 kg DM (kg N)$^{-1}$ from the lowest to the highest P application, respectively. However, this interaction between N and P application was never statistically significant. The average P efficiency on the grass/clover plots was 8.1 and 10.0 after application of 0 or 190 kg N ha^{-1} year^{-1}, respectively.

White clover

The average annual white clover content was 12, 36, 32, 41 and 23% in the consecutive years (Table 5). In each year, N application had a significant negative effect on white clover content. The overall mean white clover content was reduced from 41 to 16% following N application. On average, application of 190 kg N ha^{-1} year^{-1} increased the grass DM yield with 3.64 t ha^{-1} year^{-1}, but decreased the white clover DM yield with 3.06 t ha^{-1} year^{-1}.

Phosphorus application had no significant effect on either grass DM yield, white clover DM yield or white clover content. In 1995, the white clover content and white

Table 4. Annual DM yield (t ha^{-1}) in relation to P level.

P level	1994	1995	1996	1997	1998
P0	9.61	11.77	8.91	10.99	13.90
P1	9.91	11.91	9.45	11.44	14.46
P2	10.03	12.19	9.84	11.35	14.70
P3	10.44	12.46	10.06	11.68	14.94
Mean	9.98	12.08	9.57	11.36	14.50
Significance	***	**	***	NS	***
LSD (P≤0.05)	.23	.40	.39	.48	.37

clover DM yield were significantly lower with increasing P application, but only in combination with N application. Although not significant in individual years, this interaction between N and P application was also observed in 1996 and 1997.

The average annual N fixation was 176 kg ha^{-1}, but ranged from 67 to 253 kg ha^{-1} (Table 6). Application of N reduced the average N fixation from 257 to 95 kg ha^{-1} year^{-1}. Without N application, P application tended to increase N fixation, whereas with N application, P application tended to reduce N fixation.

The average apparent N transfer (1996-1998) was 63 kg N kg ha^{-1} year^{-1} without N application and nil with N application. Phosphorus application had a minor positive effect on N transfer.

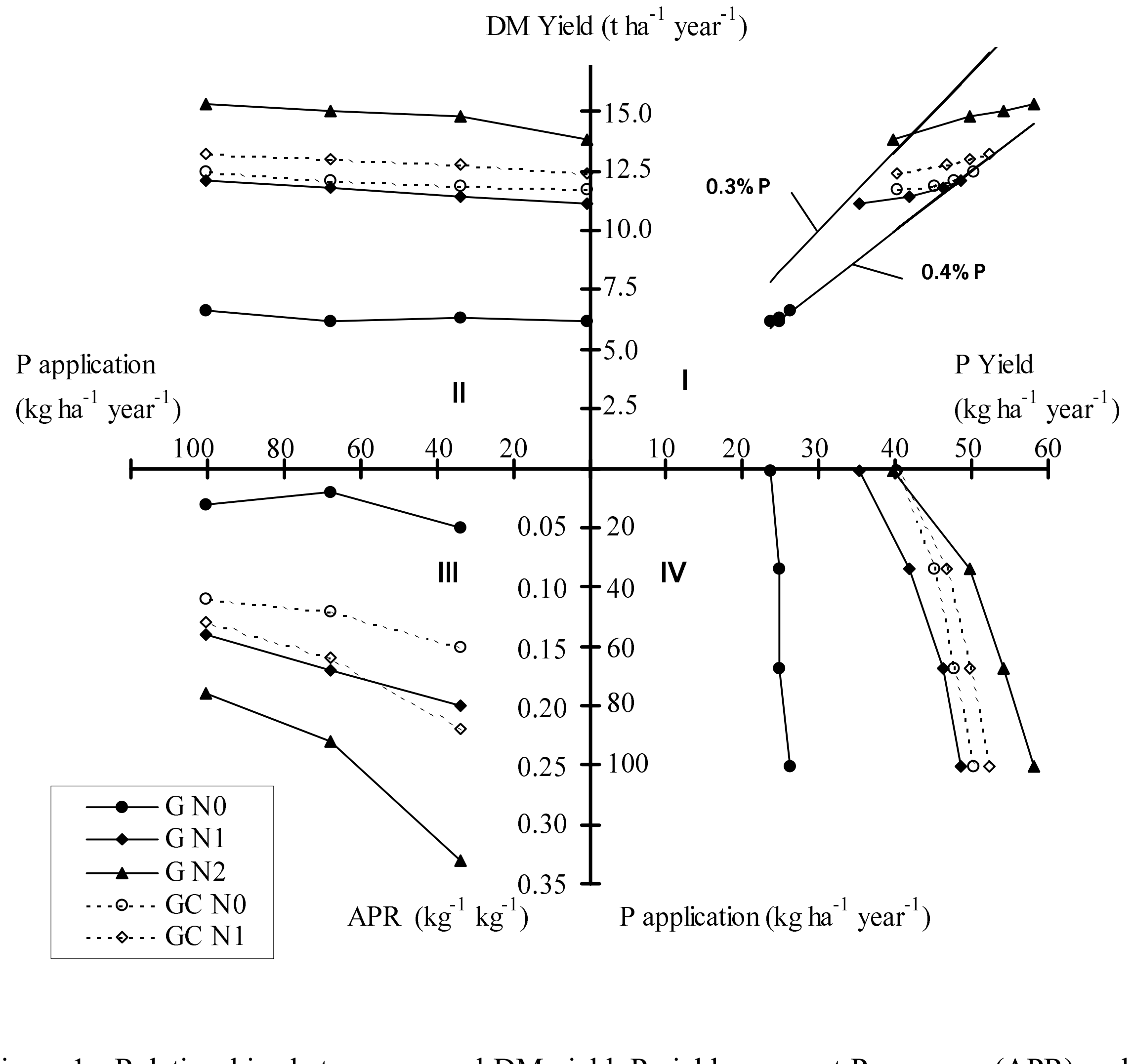

Figure 1. Relationships between annual DM yield, P yield, apparent P recovery (APR) and P application, for grass-only (G) and grass/clover (GC); mean of five years.

Table 5. Annual white clover content (%) of Grass/Clover swards in relation to N level and P level.

	1994			1995			1996			1997			1998		
P level	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
P0	16	7	11	60	15	37	46	22	34	53	32	42	38	20	29
P1	17	6	12	61	11	36	47	18	32	55	30	43	34	14	24
P2	18	7	13	62	13	37	43	17	30	48	30	39	25	17	21
P3	20	8	14	63	6	34	48	11	30	52	27	39	24	15	20
Mean	18	7	12	61	11	36	46	17	32	52	30	41	30	17	23
Significance/ LSD (P≤0.05)															
N level		***	1.7		***	2.6		***	4.2		***	5.4		***	5.2
P level		NS	2.4		NS	3.7		NS	6.2		NS	7.6		NS	7.3
N level * P level		NS	3.4		*	3.2		NS	8.8		NS	10.8		NS	10.3

Table 6. Annual N fixation (kg ha^{-1} $year^{-1}$) on grass/clover swards in relation to N level and P level.

	1994			1995			1996			1997			1998		
P level	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
P0	67	48	58	312	100	206	266	125	196	325	154	240	237	99	168
P1	63	37	50	325	64	195	289	106	198	332	170	251	253	108	181
P2	79	28	54	351	71	211	265	100	183	341	189	165	254	110	182
P3	109	24	67	357	52	205	308	77	193	374	137	256	231	105	168
Mean	80	34	57	336	72	204	282	102	192	343	163	253	244	106	175

Nitrogen yield

The overall mean N yield was 320, 333, 262, 316 and 370 kg ha^{-1} year^{-1}, in consecutive years (Table 7). The N yield of the grass plots receiving no N, also indicated as the Soil Nitrogen Supply (SNS), varied from 76 to 183 kg ha^{-1} year^{-1}.

In each year, the annual N yield was significantly affected by N input and N level (Table 7). On the grass-only swards the average N recovery was 0.75 and 0.81 kg kg^{-1}, after application of 190 or 380 kg N ha^{-1} year^{-1}, respectively. In the establishment year, N application increased the N yield of the grass/clover plots, resulting in a N recovery of 0.53 kg kg^{-1}. In the next three years, N application had a significant negative effect on the N yield of the grass/clover plots, while in the fifth year the N yield was not affected by N application. Overall, the average N recovery on the grass/clover plots was –0.11 kg kg^{-1}.

Phosphorus application had a positive effect on the N yield, although this was only sigificant in the first two years (Table 8). The average response of N yield to P application increased with increasing N application, but this interaction was only statistically significant in the establishment year.

Nitrogen use efficiency

On the grass-only plots, the N use efficiency decreased with increasing N application, on average from 48 to 32 kg DM kg^{-1} N. On the grass/clover plots, the N use efficiency was 31 kg DM kg^{-1} N without N application and 35 kg DM kg^{-1} N with N application.

The N use efficiency was not affected by P application, not on the grass-only plots, nor on grass/clover plots.

On the grass-only plots, the average annual N concentrations in the harvested herbage increased from 21 g kg^{-1} DM without N fertilisation to 30 g kg^{-1} DM after application of

Table 7. Annual N yield (kg ha^{-1}) in relation to sward type and N level.

Sward type	N level	1994		1995		1996		1997		1998	
Grass	N0	183		117		76		102		182	
	N1	334		273		203		228		329	
	N2	451		476		365		411		480	
Grass/Clover	N0	263		453		358		445		426	
	N1	368		345		305		391		435	
Mean		320		333		262		316		370	
Significance/ LSD (P≤0.05)											
Sward type		*	6	***	12	***	11	***	16	***	12
Sward type*N level		***	9	***	18	***	17	***	24	***	18

Table 8. Annual N yield (kg ha^{-1}) in relation to P level.

P level	1994	1995	1996	1997	1998
P0	310	321	252	301	357
P1	318	329	258	316	373
P2	324	337	268	321	379
P3	328	344	268	325	373
Mean	320	333	262	316	370
Significance	***	*	NS	NS	NS
LSD ($P \leq 0.05$)	8	16	15	21	16

380 kg N ha^{-1} $year^{-1}$. The lowest N concentrations were observed on the grass-N0-P3 plots, and varied from 18 g kg^{-1} DM in 1998 to 26 g kg^{-1} DM in 1994. On the grass/clover plots, the average N concentration was 32 g kg DM^{-1} without N application and 29 g kg DM^{-1} with N application.

Phosphorus yield

The overall mean P yield was 34, 46, 33, 42 and 56 kg ha^{-1} $year^{-1}$, in consecutive years (Table 9). The average P yields on the plots receiving no fertiliser P varied from 27 to 44 kg ha^{-1} $year^{-1}$, but showed no consistent trend over the years. In each year, the P yield increased significantly with increasing P level. The average apparent P recoveries after application of 34, 68 or 100 kg P ha^{-1} $year^{-1}$ were 0.19, 0.14 and 0.12 kg kg^{-1}, respectively. The fertiliser P effect consistently increased during consecutive years. The average apparent P recovery at the lowest P level increased from 0.08 kg kg^{-1} in 1994 to 0.35 kg kg^{-1} in 1998.

Nitrogen application increased the P yield significantly in all years. On the grass-only plots the average P yield was 25, 43 and 50 kg ha^{-1} $year^{-1}$ after application of 0, 190 and 380 kg N ha^{-1} $year^{-1}$, respectively. On the grass/clover plots, N application increased the P yield only in two out of five years (Table 9).

On the grass-only plots, N level interacted significantly with the effect of P level (Table 9 and Figure 1, quadrant IV). The response of the annual P yield to P application increased with increasing N level. The average P recoveries at the lowest P level were 0.05, 0.20 and 0.33 kg kg^{-1}, for N0, N1 and N2, respectively (Figure 1, quadrant III).

Table 9. Annual P yield (kg ha^{-1}) in relation to sward type, N level and P level.

		1994					1995					1996					1997					1998				
Sward type	N level	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean
Grass	N0	23	25	24	25	24	22	25	24	27	24	14	14	14	14	14	20	21	21	22	21	38	40	41	44	41
	N1	33	36	38	40	37	39	44	48	49	45	25	30	34	37	32	34	40	42	47	41	46	59	69	70	61
	N2	36	40	41	43	40	49	57	61	66	58	31	38	45	48	41	37	52	55	57	50	45	62	69	76	63
Grass/Clover	N0	29	30	31	35	31	48	51	54	57	52	34	40	42	46	41	44	49	51	55	50	46	54	61	59	55
	N1	35	37	38	40	38	48	49	52	54	51	31	38	42	42	38	41	51	54	55	50	46	58	63	71	60
Mean		31	34	34	37	34	41	45	48	50	46	27	32	35	38	33	35	43	45	47	42	44	54	61	64	56
Significance/ LSD (P≤0.05)																										
P level				***	0.9			***	1.5					***	2.0				***	2.5				***	2.1	
Sward type				*	0.6			***	1.1					***	1.4				***	1.8				**	1.5	
Sward type*P level				NS	1.4			NS	2.3					NS	3.2				NS	4.0				NS	3.3	
Sward type*N level				***	1.0			***	1.7					***	2.2				***	2.8				***	2.3	
Sward type*N level*P level				**	2.0			**	1.4					***	4.5				**	5.6				***	4.6	

Grass/clover plots showed a response to fertiliser P that was different from the response on grass-only plots. Without P fertilisation, the average P yield of the grass/clover plots was equal to that of grass-N2 plots (Figure 1, quadrant IV). However, P fertilisation increased the P yield of grass/clover plots not as much as the P yield of the grass-only plots. The average apparent P recoveries of grass/clover at the lowest P level were 0.15 and 0.21 kg kg^{-1}, for N0 and N1, respectively. The lower response to P fertilisation of the grass/clover plots can be attributed to the clover component of the mixture. White clover P yield showed no response to fertiliser P, while the grass component showed a response similar to the one in the grass-N1 plots (Figure 2, quadrant IV).

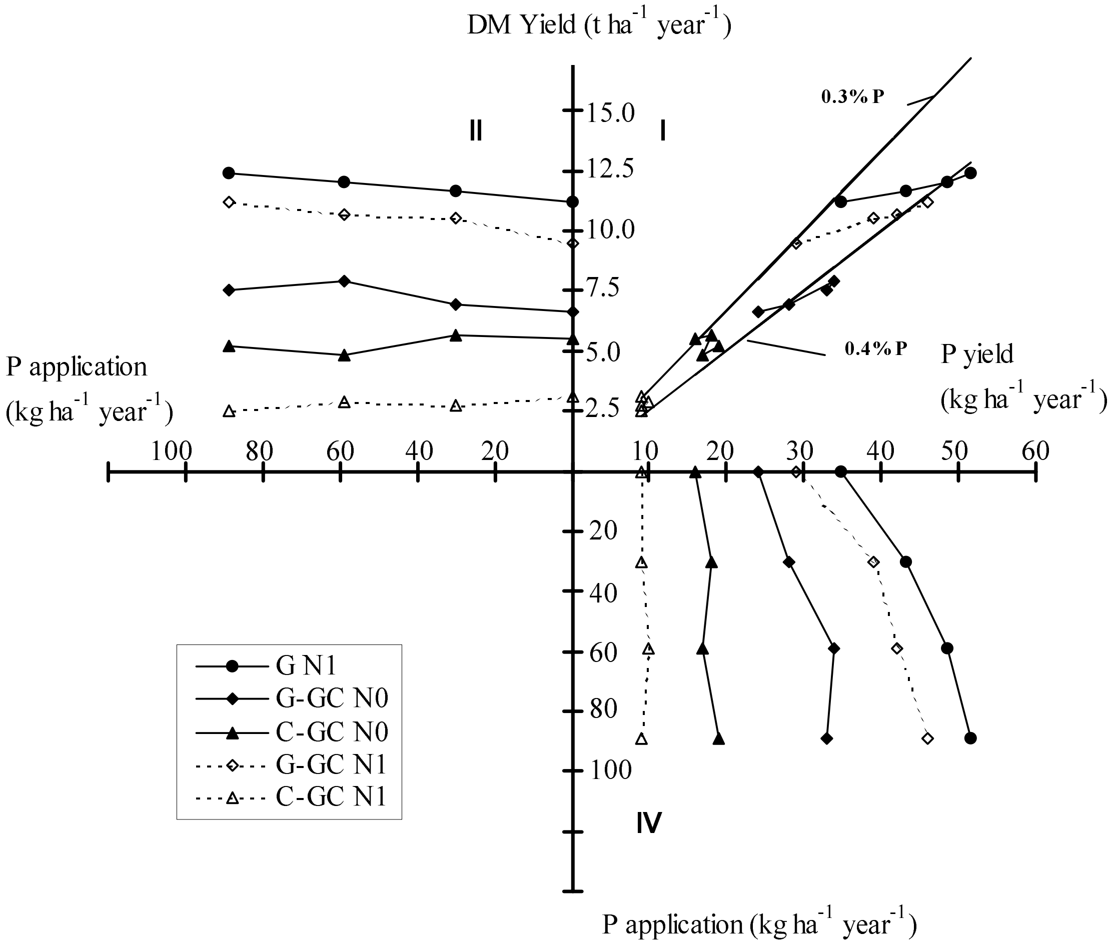

Figure 2. Relationships between annual DM yield, P yield and P application, for grass (G-GC) or clover (C-GC) from grass/clover plots, and gras-only (G) as a reference; mean of three years (1996-1998).

Phosphorus use efficiency

The P use efficiency decreased with increasing P application, on average from 310 to 252 kg DM kg^{-1} P. However, on the grass-N0 plots the P use efficiency was almost unaffected by P application, with an average value of 255 kg DM kg^{-1} P (Figure 1, quadrant I). On the grass-only plots, N application increased the P use efficiency to 269 kg DM kg^{-1} P (N1) and 292 kg DM kg^{-1} P (N2). Nitrogen application on grass/clover plots only increased the P use efficiency of the grass component, whilst the P use efficiency of the clover component remained unchanged.

The average annual P concentrations in the harvested herbage increased from 3.2 g kg^{-1} DM without P fertilisation to 4.0 g kg^{-1} DM after application of 100 kg P ha^{-1} $year^{-1}$. On the grass-only plots the average P concentration decreased from 3.9 g kg^{-1} DM without N fertilisation to 3.4 g kg^{-1} DM after application of 380 kg N ha^{-1} $year^{-1}$. On the grass-only swards the minimum P concentrations, observed on the N2-plots, varied from 2.6 to 3.2 g kg^{-1} DM.

On the grass/clover plots, the P concentrations of the grass component were consistently higher than those of the clover component. The minimum P concentrations found in the grass and clover components of the mixture were 3.1 and 2.9 g kg^{-1} DM, respectively.

Discussion

General

In this experiment, all plots were harvested on the same date. Therefore the faster growing plots were harvested at a higher DM yield than the slower growing plots. In farming practice, a faster herbage growth will not lead to a higher yield at cutting, but will lead to an earlier harvest at the same target DM yield. For the slower growing plots, the "fixed date" method will lead to an underestimation of the annual DM yield and an overestimation of the N and P concentrations in the herbage (Prins *et al*., 1980). The average DM yield at cutting was 1.18, 2.16 and 2.72 t ha^{-1} on the grass-only N0, N1 and N2 treatments, respectively, and 2.25 and 2.39 t ha^{-1} on the grass/clover N0 and N1 treatments, respectively. Considering the N response, only the DM yield per cut on the grass-N0 treatment is out of range with the other treatments. With respect to the P response the "fixed date" method only has a minor effect, because the average DM yields at cutting were 2.05, 2.13, 2.17 and 2.21 for P0, P1, P2 and P3, respectively.

The present experiment only studied the effect of fertiliser N and P. The recent Dutch policy will lead to an increased use of nutrients from slurry at the cost of nutrients from fertiliser. Especially the P fertilisation on dairy farms will be almost completely done through cattle slurry. With the current methods of slurry injection, slurry is placed at a depth up to 10 cm below soil surface and in rows, 15 to 20 cm apart. The pattern of availability of P from injected slurry is different from fertiliser (Den Boer *et al*., 1995).

Furthermore, most grasslands in the Netherlands are used for cutting and grazing. In this experiment the potential effects of the return of N and P through animal excreta, animal treading and selective grazing have been disregarded.

Nitrogen response

Nitrogen was the driving factor with respect to the performance of the grass-only swards. The effect of nitrogen on the performance of perennial ryegrass is well-documented (Vellinga & André, 1999). In the Netherlands, the annual N requirements are based on a marginal response of 7.5 kg DM (kg N)$^{-1}$ (Unwin & Vellinga, 1994). The marginal N response of the grass-only treatments was derived from a simple regression of DM yield on N level: $Y = -0.02874*X^2 + 33.0*X + 6348$ (R^2=94.2%), where Y = DM yield (kg ha^{-1} year^{-1}) and X = N application (kg ha^{-1} year^{-1}). From this response curve it can be calculated that the marginal N response at the highest N application of 380 kg ha^{-1} year^{-1} was 11.2 kg DM (kg N)$^{-1}$. This means that the optimal N application, according to the current recommendations, for this experiment was higher than 380 kg ha^{-1} year^{-1}. Therefore it has to be realised that the range of N rates studied in this experiment is possibly lower than the currently applied N rates in practical farming on this soil type (Reijneveld *et al*., 2000).

The N-recovery and especially the N-efficiency of the grass-only plots was markedly lower in the establishment year than in the other years. Although a comparison with an unploughed sward in the same year is not present, it may be hypothesised that mineralisation from the old stubble and roots increased the soil N supply (Davies *et al*., 2001).

On the grass/clover plots, N application led to an increased grass production at the cost of white clover, as reported earlier by Frame & Newbould (1986). In relation to the target marginal N response of 7.5 kg DM (kg N)$^{-1}$, N application was only advisable in the establishment year. In that year the increased grass DM yield was 3.10 t ha^{-1} year^{-1}, while the clover DM yield was only reduced by 0.74 t ha^{-1} year^{-1}. In the following four years, the increased grass DM yield was nearly completely offset by the decreased clover DM yield, resulting in an average N efficiency of only 1.6 kg DM (kg N)$^{-1}$. Considering the N yield of the grass/clover mixture, a positive effect of N application was only observed during the establishment year. In all other years, the increased N yield due to N application was completely offset by the reduced N fixation.

Phosphorus response

The phosphorus response, measured in this experiment, is a joint effect of fertiliser and soil P. During the experimental years the P-AL value increased with increasing fertiliser P level (Schils & Snijders, 2002). Therefore, the calculated apparent P efficiencies and P recoveries were increasingly overestimated as the experiment progressed. The highest apparent P recovery observed in the fifth year of the experiment was 0.56 kg kg^{-1} on the grass-N2-P1 treatment, indicating that a substantial proportion of the applied P was still accumulating in the soil.

The observed P response of the grass/clover swards was different from that of the grass-only swards. The grass component of the mixed swards showed a positive response of DM yield, P concentration and P yield to P application, similar to the responses observed in the grass-only swards. In contrast, the clover component of the mixed sward showed no response in P yield. However, a lower P use efficiency with increased P application meant that the DM yield decreased and the P concentration increased. This corresponds with the view that white clover is generally a weaker competitor for nutrients when grown in association with grass, due to its thicker and less branched root system (Dunlop & Hart, 1987). On the other hand, others reported a stronger P response for white clover than for perennial ryegrass (Sinclair *et al.*, 1996). The observed P concentrations measured in the white clover component on the P0-plots were lower than the lower end of the range of reported critical values of 3.0 to 4.0 g kg^{-1} DM (Dunlop & Hart, 1987; Morton *et al.*,1998; Whitehead, 2000). Taking the optimal ratio between P and N concentration of 0.074 (Morton *et al.*, 1998) as an indicator for balanced nutrient supply, no suboptimal P/N-ratios were observed in white clover. The minimum P/N-ratio observed in white clover varied from 0.071 to 0.081.

Nitrogen x phosphorus response

Interactions between N and P application have only been observed to a limited extent. Especially if a practical range of applications is considered, i.e. approximately 150 to 400 kg N ha^{-1} $year^{-1}$ and 40 to 100 kg P ha^{-1} $year^{-1}$, the implications for management practices are relatively small. This can be illustrated by the calculation of the marginal N efficiencies at different P application levels. Regression of DM yield, restricted to grass-only plots, on N and P application resulted in the following model. $Z = -0.02944*X^2 + 31.85*X + 3.66*Y + 0.0272*X*Y + 6159$ (R^2=95.1%), where Z = DM yield (kg ha^{-1} $year^{-1}$), X = N application (kg ha^{-1} $year^{-1}$) and Y = P application (kg ha^{-1} $year^{-1}$). With a P application of 40 and 100 kg ha^{-1} $year^{-1}$, a marginal N efficiency of 12.5 kg DM kg^{-1} N is attained at an N application of 347 and 374 kg kg ha^{-1} $year^{-1}$, respectively.

The negative effect of P application on white clover yield appeared to increase with N application. This suggests that the competitive ability of grasses intensifies after N application, which was also noted in several other studies (Dunlop & Hart, 1987). Furthermore, an overview of Harris (1987) indicated that the competitive effect of grasses for P can also be developed by an increased availability of fixed N. Although not significant, the observations on the grass/clover-N0 plots are in agreement with that hypothesis. The response of the white clover content from the lowest to the highest P application was +4, +3, +2, -1 and -14% in the consecutive years.

Conclusions

- Nitrogen was the main factor determining the yield and nutrient content of the harvested herbage.
- A positive interaction between N and P application was observed. However, the consequences for the optimal N application are only minor, and of little practical relevance.
- Phosphorus application did not increase clover yield. The results indicated a possible negative effect of P application on clover proportions in mixed swards. Further research has to show whether this is valid under other conditions, e.g. other soil types and P statuses, as well. For the moment it can be advised at least not to exceed the P recommendations for grass-only swards.

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CHAPTER 5

The combined effect of fertiliser nitrogen and phosphorus on a grass/clover and grass-only sward. II. Changes in soil nutrients

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Submitted to Nutrient Cycling in Agroecosystems.

The combined effect of fertiliser nitrogen and phosphorus on a grass/clover and grass-only sward. II. Changes in soil nutrients

Abstract

The combined effect of reduced nitrogen (N) and phosphorus (P) application on the accumulation of soil N, P and carbon (C) under grass-only and grass/clover swards was studied in a cutting experiment on a marine clay soil. The experiment was established on newly sown swards and lasted for five years. The treatments included specific combinations of four P levels (0, 35, 70 and 105 kg P ha^{-1} $year^{-1}$), three N levels (0, 190 and 380 kg N ha^{-1} $year^{-1}$) and two sward types (grass-only and grass/clover).

Both the P-AL-value and total soil P showed a positive response to P application and a negative response to N application. Furthermore, the positive effect of P application decreased with increasing N application. The annual changes in P-AL-value and total soil P were closely related to the soil surface balance, which in turn was determined by the level of N and P application and their interaction. The observed effects were most evident in the top soil layer of 0-5 cm. Balanced P application did not lead to lower P-AL values.

The accumulation of soil N on the grass-only was positively affected by N application, but was unaffected by P application and sward type. The accumulation of organic C was unaffected by N or P application, but was lower under grass/clover than under grass-only.

Introduction

During the last 40 years, production grasslands in the Netherlands have been fertilised with increasing amounts of nitrogen (N) and phosphorus (P), both from fertilisers and animal slurries. (Aarts *et al.*, 1992; LEI, 2001). In order to reduce the associated environmental problems for ground water (Fraters *et al.*, 1997; Oenema *et al.*, 1998) and surface water (Oenema & Roest, 1998), the Dutch government has introduced a series of measures that aim to reduce the N and P losses from farming systems (VROM, 1989). The introduction of the Mineral Accounting System (MINAS), an N and P accounting system on farm level (MANMF, 1997), will lead to a reduction in the use of fertiliser N and P on grassland and a substitution of grass-only by grass/clover swards (Schils *et al.*, 2000).

The individual effects of N and P on grassland production have been studied extensively (e.g. Agterberg & Henkens, 1995; Vellinga & André, 1999), but there has been little attention for the combined effects of N and P, especially in field trials.

Furthermore, there is a lack of knowledge regarding the changes of soil P, following reduced P application. Amongst farmers there is concern that reduced P surpluses on grassland will lead to sub-optimal P levels in the soil, which in turn leads to a reduced herbage yield and quality. In an earlier study, using data from dairy farm monitoring projects, it was estimated that a P surplus of 20 to 25 kg ha^{-1} $year^{-1}$ was necessary to maintain soil P levels at an agriculturally optimal value (Oenema & Van Dijk, 1994). On the other hand, the same study indicated that environmentally acceptable P surpluses are as low as 0.5 kg ha^{-1} $year^{-1}$.

The objectives of the present experiment are to (i) quantify the combined effect of fertiliser N and P on herbage production, herbage quality and changes in soil P of grass and grass/clover swards, (ii) increase the understanding of P utilisation in grass/clover swards and (iii) to provide a basis for P recommendations on grass/clover swards.

The first paper (Schils & Snijders, 2002) on this experiment described the nutrient uptake and herbage production of grass-only and grass/clover plots under a range of combinations of fertiliser N and P levels. It was concluded that N was the main factor determining herbage yield and quality, and clover proportions in the swards. A positive interaction between N and P application was observed, but only with minor consequences for optimal fertiliser application levels. Furthermore the results indicated a possible negative effect of P application on clover proportions in mixed swards.

In this second paper the changes in soil nutrients are described and related to the nutrient uptake of the herbage.

Materials and methods

Site

The experiment was established at Lelystad (52°N) on a well drained sedimentary calcareous light marine clay soil, reclaimed from the IJssel Lake in 1957. The site has been used for dairy farming since 1973. In spring 1994, the experimental area was ploughed and plots were established with grass-only or grass/clover swards. As a result of ploughing, the nutrient availability in the soil tended to increase with depth, up to 25 cm. For instance, the organic matter content increased from 3.4% in the top 5 cm to 4.6% in the soil layer of 20-25 cm. At the start of the experiment, in April 1994, the total amount of soil N and P, to a depth of 30 cm, was 6080 and 2020 kg ha^{-1}, respectively. Further details on soil characteristics, sward establishment and weather data are described in Schils & Snijders (2002).

Treatments

The experiment was a randomised block trial with three replicates of combinations of two sward types (Grass and Grass/clover), three N levels (0, 200 and 400 kg ha^{-1} $year^{-1}$, designated as N0, N1 and N2, respectively) and four P levels (0, 35, 70 and 105 kg ha^{-1} $year^{-1}$, designated as P0, P1, P2 and P3, respectively). Grass swards were combined with all three N levels, while grass/clover swards were only combined with 0 and 200 kg N ha^{-1} $year^{-1}$. The five resulting sward type x N level treatments were combined with the four P levels, resulting in 20 treatments all together.

Nitrogen was applied as calcium ammonium nitrate (27% N) and P as triple superphosphate (20% P). The distribution of the annual application over the first to the sixth cut was 25, 20, 20, 15, 10 and 10% for N, and 25, 15, 15, 15, 15 and 15% for P. In the establishment year, the first fertiliser was applied at sowing and in the following years between the 16th and 24th of March at a temperature sum of 514, 253, 521 and 578 ^{o}C, in the subsequent years. Throughout the experiment, the whole field was fertilised with 42 kg K ha^{-1} cut^{-1} as potassium chloride (50% K).

Harvests were planned to take place when the fastest growing plots yielded approximately 3.5 t DM ha^{-1} for the first cut, and approximately 2.5 t DM ha^{-1} for later cuts. All treatments were harvested on the same day. Each year, five cuts were taken, except in 1995, when seven cuts were taken. As a result, the average annual applications rates were somewhat lower than the planned application rates.

Measurements

Details on herbage measurements and data handling are presented in Schils and Snijders (2002). In short, herbage was harvested from an area of 6 m x 1.5 m, and analysed for DM, N and P. Biological N fixation by white clover was calculated as the difference between the N yield of grass/clover plots and grass plots with a similar N application.

Soil samples were taken at the time of sowing to a depth of 30 cm, in layers of 5 cm each. Samples were bulked per replicate and analysed for pH-KCl, texture (particles < 16 μm), K-HCl, P-AL (Egner *et al*., 1960), total P (destruction with Fleischmann acid), total N (oxidation at 1050 ^{o}C), organic matter (loss on ignition at 550 ^{o}C, corrected for clay particles and $CaCO_3$) and organic C (oxidation at 600 ^{o}C). The methods are conform those described by Houba *et al*. (1997). Additionally, undisturbed soil samples were taken from the same layers to calculate soil density.

To obtain information about soil compaction after sowing, metal plates (20 cm x 20 cm) were placed at a depth of 30 cm on each corner of the trial field. To prevent disturbance of the soil profile, the plates were inserted laterally from a hole, dug at the side of the marked place. The depth of the metal plates was measured prior to each soil sampling. In March 1995, the depth of the metal plates was 28 cm, and therefore the sampling depths for the following years were adjusted to 0-5, 5-10, 10-23 and 23-28 cm.

In the following years, soil samples were taken in March, prior to the first fertiliser applications. Samples were bulked per treatment and analysed for P-AL, total P, total N, organic matter and organic C. Only at the final sampling date, March 1999, soil samples were analysed per plot. Soil density was also measured at the sampling dates in 1996, 1997 and 1999.

Data were analysed with GENSTAT 5 (GENSTAT, 1998).

Results

Soil phosphorus

The P-AL value and total soil P showed a positive response to P application, and a negative response to N application. The positive effect of P-application on soil P contents decreased with increasing N application. The responses of the P-AL value and total soil P decreased with increasing depth.

Phosphorus application had the largest effect on the P-AL value, even down to a depth of 23-28 cm (Figure 1, Table 1). At the end of the experiment, annual application of 100 kg P ha^{-1} had increased the P-AL value in the soil layers of 0-5, 5-10, 10-23 and 23-28 cm with 63, 17, 7 and 3 mg P_2O_5 100 g^{-1}, respectively, compared to the P0 plots.

The negative effect of N application on P-AL value was visible down to the soil layer of 10-23 cm. On the grass-only plots, the average P-AL value in the soil layers of 0-5, 5-10, 10-23 and 23-28 cm was decreased by 20, 8, 1 and 0 mg P_2O_5 100 g^{-1}, respectively, after five years of application of 380 kg N ha^{-1} $year^{-1}$. Within the grass/clover plots, N application had no effect on the P-AL value. After five years, the P-AL value of the grass/clover plots was in the same range as the P-AL value of the grass plots with N application.

The development of total soil P was in line with the development of the P-AL value, but was more restricted to the upper soil layers (Table 2). At the end of the experiment, annual application of 100 kg P ha^{-1} had increased total soil P in the soil layers of 0-5, 5-10, 10-23 and 23-28 cm with 44, 13, 5 and 2mg P 100 g^{-1}, respectively, compared to the P0 plots. A good relationship (R^2 = 97.7%) was found between P-AL value and total soil P, namely: P-AL = -1.65 – 0.3669*(total P) + 0.011017 * $(\text{total P})^2$.

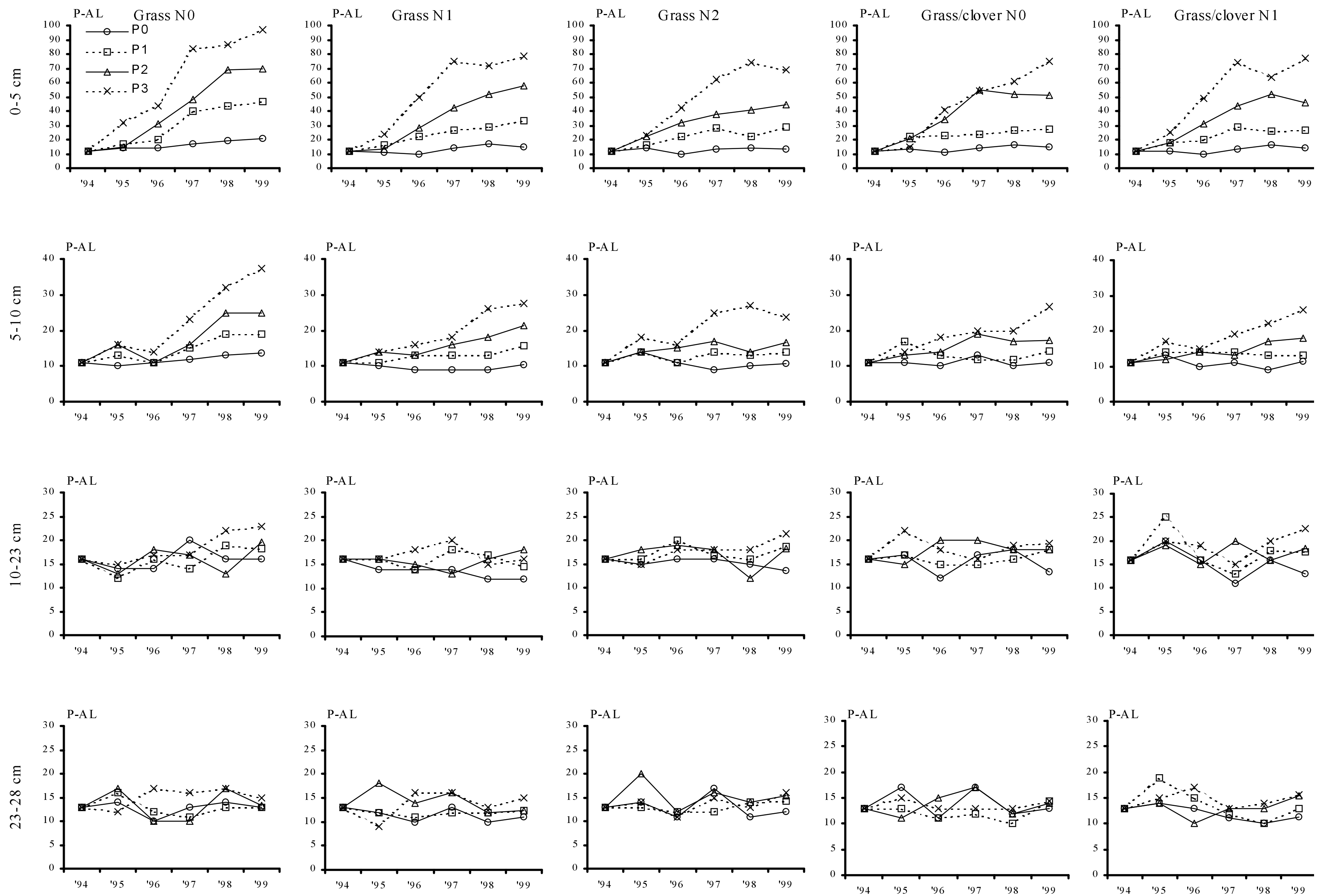

Figure 1. Development of P-AL value (mg P_2O_5 100 g^{-1} dry soil) in relation to P application, for all combinations of sward type and N application, and for all soil layers. (top-down: 0-5, 5-10, 10-23 and 23-28 cm) (left-right: grass N0, N1, N2 …grass/clover N0, N1).

Table 1. P-AL value (mg P_2O_5 100 g^{-1} dry soil) at the end of the experiment in relation to sward type, N level and P level, measured in four soil layers.

		0 - 5 cm					5 – 10 cm					10 – 23 cm					23 – 28 cm				
Sward type	N level	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean
Grass	N0	21	47	70	97	59	14	19	25	37	24	16	18	20	23	19	13	13	13	15	14
	N1	15	33	58	78	46	10	16	21	28	19	12	15	18	16	15	11	12	12	15	13
	N2	13	29	45	69	39	11	14	17	24	16	14	19	18	21	18	12	14	15	16	14
Grass/Clover	N0	15	28	51	75	42	11	14	17	27	17	13	19	18	19	17	13	14	14	14	14
	N1	14	27	46	77	41	11	13	18	26	17	13	18	18	23	18	11	13	15	16	14
Mean		16	33	54	79	45	11	15	20	28	19	14	17	18	20	18	12	13	14	15	14
Significance/ LSD (P≤0.05)																					
P level				***	2.3			***	1.4					***	2.1				***	1.2	
Sward type				***	1.6			***	1.0					NS	1.4				NS	0.8	
Sward type*P level				**	3.6			NS	2.3					NS	3.4				NS	1.9	
Sward type*N level				***	2.5			***	1.6					*	2.4				NS	1.3	
Sward type*N level*P level				***	5.1			**	3.2					NS	4.8				NS	2.7	

NS Not Significant; * P≤0.05; ** P≤0.01; *** P≤0.001

Table 2. Total P (mg P 100 g^{-1} dry soil) at the end of the experiment in relation to sward type, N level and P level, measured in four soil layers.

		0 - 5 cm					5 – 10 cm					10 – 23 cm					23 – 28 cm				
Sward type	N level	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean
Grass	N0	66	84	97	115	90	57	63	66	75	65	60	63	65	65	63	55	55	55	56	55
	N1	61	75	91	105	83	55	59	64	66	61	56	59	62	59	59	53	55	55	55	54
	N2	59	72	84	100	79	56	60	61	66	61	58	62	64	64	62	55	56	58	58	57
Grass/Clover	N0	62	73	85	100	80	55	61	69	69	62	58	62	61	62	61	58	56	56	55	56
	N1	60	71	85	104	80	56	58	68	68	61	58	62	62	65	62	54	56	57	59	56
Mean		61	75	88	105	82	56	60	63	69	62	58	62	63	63	61	55	56	56	57	56
Significance/ LSD (P≤0.05)																					
P level				***	1.5			***	1.4					***	2.3				NS	1.6	
Sward type				***	1.1			NS	1.0					NS	1.6				NS	1.1	
Sward type*P level				*	2.3			NS	2.3					NS	3.6				NS	2.5	
Sward type*N level				***	1.6			***	1.6					*	2.5				*	1.7	
Sward type*N level*P level				**	3.3			*	3.2					NS	5.1				NS	3.5	

Table 3. Total N (mg 100 g^{-1} dry soil) at the end of the experiment in relation to sward type and N level, measured in four soil layers.

Sward type	N level	0-5 cm		5-10 cm		10-23 cm		23-28 cm	
Grass	N0	235		178		202		173	
	N1	247		176		183		169	
	N2	253		186		203		185	
Grass/Clover	N0	244		183		193		177	
	N1	248		184		201		174	
Mean		245		181		196		176	
Significance/ LSD ($P \leq 0.05$)									
Sward type		NS	4.4	NS	5.6	NS	9.0	NS	7.5
Sward type*N level		***	6.9	NS	8.7	NS	13.9	NS	11.7

Soil nitrogen and carbon

During the experiment, total soil N in the top layer (0-5 cm) increased from 151 to 245 mg 100 g^{-1} dry soil. The N accumulation in the top soil of the grass-only plots was significantly increased by N application (Table 3), but was not affected by P application. The soil N content of the grass/clover plots was similar to that of the grass-only plots with fertiliser N. In the deeper soil layers the N content was not affected by N application, P application or sward type. On average, the increases in soil N content in the layers 5-10, 10-23 and 23-28 cm were 26, 10 and 11 mg 100 g^{-1} dry soil, respectively.

Similar to soil N, organic C in the top layer (0-5 cm) increased during the experiment, from 1857 to 2581 mg 100 g^{-1} dry soil. The C accumulation in the top soil of the grass-only plots was not affected by N or P application, but was significantly higher in the

Table 4. Organic C (mg 100 g^{-1} dry soil) at the end of the experiment in relation to sward type and N level, measured in four soil layers.

Sward type	N level	0-5 cm		5-10 cm		10-23 cm		23-28 cm	
Grass	N0	2573		1907		2144		1960	
	N1	2682		1935		1967		1888	
	N2	2625		1937		2107		2018	
Grass/Clover	N0	2473		1936		2030		1940	
	N1	2554		1889		2085		1975	
Mean		2581		1921		2067		1956	
Significance/ LSD ($P \leq 0.05$)									
Sward type		**	65	NS	54	NS	92	NS	80
Sward type*N level		NS	101	NS	83	NS	142	NS	123

grass-only plots than in the grass/clover plots (Table 4). In the deeper soil layers, the C content was not affected by N application, P application or sward type. On average, the changes in soil C content in the layers 5-10, 10-23 and 23-28 cm were +159, +163 and –6 mg 100 g^{-1} dry soil, respectively.

As the C content increased less than the N content, the C/N ratio decreased during the experiment. In the top soil, the average C/N ratio decreased from 12.3 to 10.5. At the end of the experiment, the C/N ratio was significantly lower in the grass/clover plots than in the grass-only plots. Within the grass-only plots, the C/N ratio decreased significantly with increasing N application. In the soil layer of 5-10 cm, the C/N ratio decreased from 13.4 to 10.6, and was significantly lower in the grass/clover plots than in the grass-only plots. The mean changes in the C/N ratio in the layers 10-23 and 23-28 cm were –1.5 and –0.7, respectively.

Phosphorus balances

The average soil surface balance, i.e. fertiliser input minus removed herbage,was –35, –8, +23 and +53 kg P ha^{-1} $year^{-1}$ after a fertiliser P application of 1, 34, 68 or 100 kg P ha^{-1} $year^{-1}$, respectively. This positive effect of application rate on soil surface balance was consistent throughout the experiment, but the absolute value of the soil surface balance showed some variations between years (Table 5). The soil surface balance for total P was also affected by N application rate. Increasing N rates increased the P uptake and hence decreased the soil surface balance.

Each year, the accumulation of total soil P, measured to a depth of 28 cm, increased with increasing P application (Table 5). The average accumulation of total soil P, measured to a depth of 28 cm, was –10, +25, +50 and +80 kg ha^{-1} for P0 to P3, respectively. There were large fluctuations between years. In 1994, an overall average increase of 157 kg P ha^{-1} was measured, whereas in 1995 an overall average decrease of 54 kg P ha^{-1} was measured. The total soil balance, i.e. the soil accumulation minus the soil surface balance, was not affected by any of the experimental treatments. The average total soil balance varied from –75 to +138 kg P ha^{-1} $year^{-1}$. Negative values indicate an unaccounted loss of P from the studied soil-crop system, and positive values indicate an unaccounted input. Considering the whole five-year experimental period, an unaccounted accumulation of 138 kg P ha^{-1} occurred. Exclusion of the establishment year (1994) improved the balance of the experiment considerably.

Table 5. Soil surface balance (fertiliser input – herbage removal), soil accumulation and the total balance of P (kg ha^{-1} year^{-1}) in relation to P level, measured to a depth of 28 cm.

	Soil surface balance					Change in soil P (0-28 cm)					Balance				
Year	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean	P0	P1	P2	P3	Mean
1994	-27	3	35	65	19	79	176	160	213	157	105	174	124	148	138
1995	-41	-2	44	83	21	-105	-108	-29	24	-54	-64	-106	-72	-59	-75
1996	-27	0	30	60	16	79	78	165	158	119	107	78	135	98	103
1997	-35	-16	9	32	-3	-49	-29	-79	-28	-46	-14	-13	-87	-60	-43
1998	-44	-24	-1	25	-11	-56	8	34	33	5	-12	33	35	8	16
Total	-174	-40	116	266	42	-52	126	251	399	181	122	166	134	134	138
1995-1998	-147	-37	81	261	23	-131	-50	91	186	24	17	-8	10	-14	0

Table 6. Soil surface balance (fertiliser input – herbage removal), soil accumulation and the total balance of N (kg ha^{-1} year^{-1}) in relation to sward type and N level, measured to a depth of 28 cm.

	Soil surface balance						Change in soil N (0-28 cm)						Balance					
	Grass			Gr/Cl			Grass			Gr/Cl			Grass			Gr/Cl		
Year	N0	N1	N2	N0	N1	Mean	N0	N1	N2	N0	N1	Mean	N0	N1	N2	N0	N1	Mean
1994	-183	-135	-51	-183	-135	-137	426	639	709	845	1226	768	609	774	760	1028	1361	871
1995	-117	-56	-36	-117	-56	-76	-184	-436	-187	-450	-570	-364	-67	-380	-151	-333	-514	-410
1996	-76	-22	-5	-76	-22	-40	565	787	706	852	231	628	641	809	711	928	253	554
1997	-102	-57	-72	-102	-57	-78	106	-106	-240	-133	416	9	208	-49	-168	-31	473	-64
1998	-182	-148	-120	-182	-148	-156	-215	-433	-35	-430	-485	-320	-33	-285	85	-248	-337	-270
Total	-660	-418	-284	-660	-418	-488	698	451	953	684	818	721	1358	869	1237	1344	1236	681
1995-1998	-477	-283	-233	-477	-283	-351	272	-188	244	-161	-408	-47	749	95	477	316	-125	-190

Regression analysis showed that the soil surface balance had a significant effect on the changes in the amount of soil P in the soil layers of 0-5 and 5-10 cm, whereas changes in the deeper soil layers could not be related to the soil surface balance. The accumulation of total soil P in the top layer of 0-5 cm, as found in 1994 (Figure 2), is most probably caused by compaction in the establishment year. This assumption is supported by the relationship between total soil P concentrations and the soil surface balance, for which the establishment year is in line with the other experimental years (Figure 3).

Changes in the P-AL value were affected to a depth of 10 cm by the soil surface balance. The following relationships were found for the soil layers of 0-5 cm and 5-10 cm.

Δ(P-AL value)$_{0\text{-}5\ cm}$ = 6.43 + 0.179 * Psoil surface balance , $R^2 = 66.1\%$
ΔP-AL value)$_{5\text{-}10\ cm}$ = 1.75 + 0.0581 * Psoil surface balance , $R^2 = 44.7\%$

As indicated by these relationships, a balanced P application, i.e. a soil surface balance of zero, resulted in an annual increase of the P-AL value by 6.43 mg P_2O_5 100 g^{-1} in the layer of 0-5 cm (Figure 4).

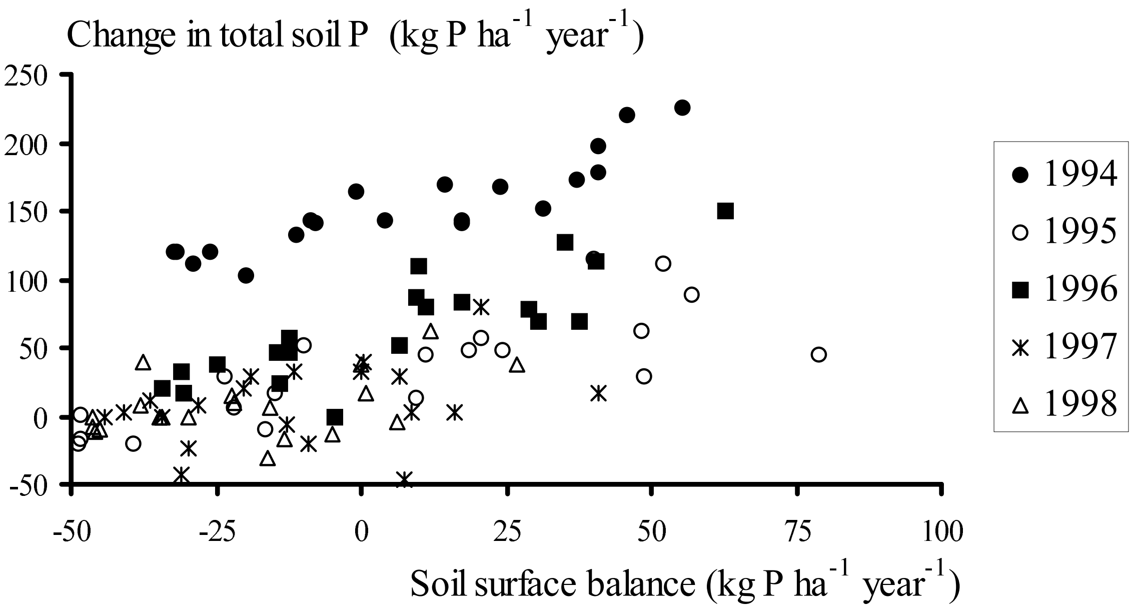

Figure 2. Relationship between change in the amount of total soil P (0-5 cm) and the soil surface balance.

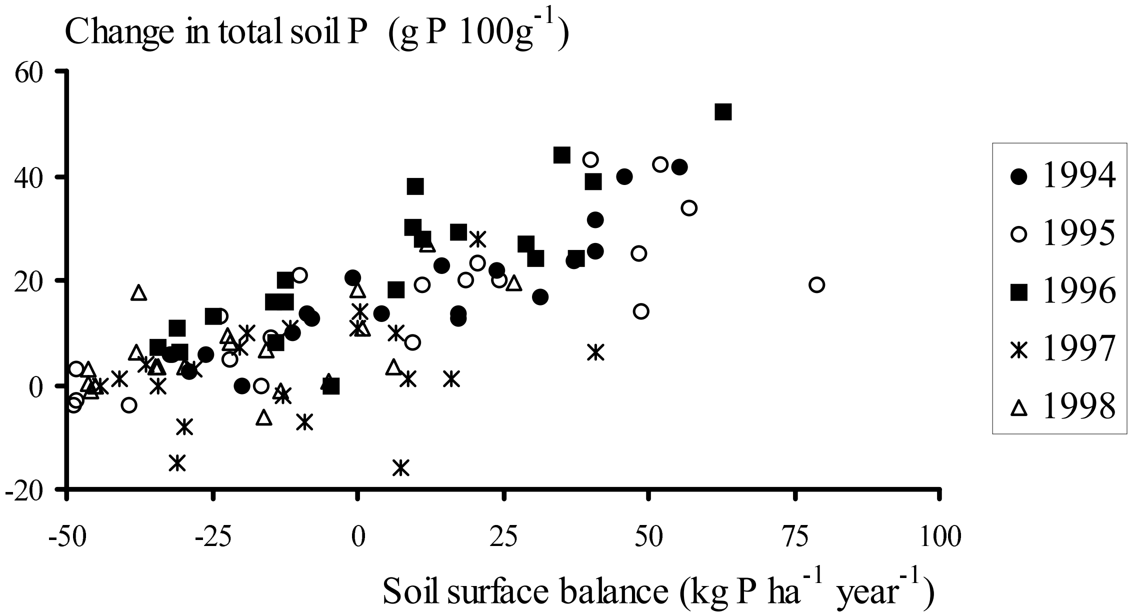

Figure 3. Relationship between change in the concentration of total soil P (0-5 cm) and the soil surface balance.

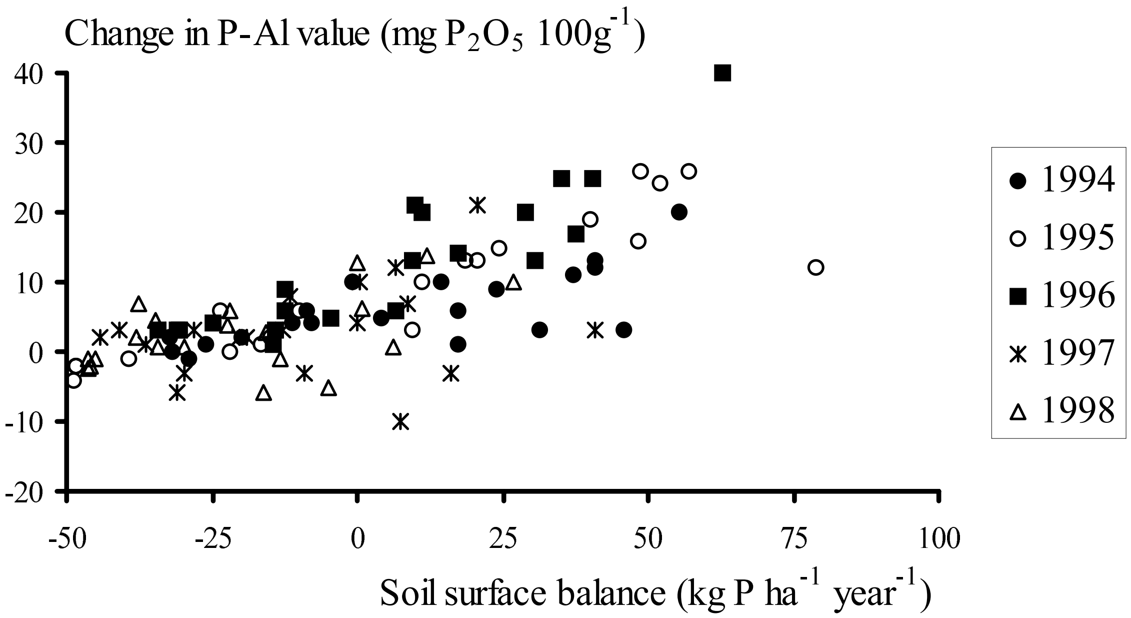

Figure 4. Relationship between change in P-AL value (0-5 cm) and the soil surface balance.

Nitrogen balances

The average soil surface balance for N was –132, -84 and -57 kg ha^{-1} year^{-1} on grass-only plots after a fertiliser N application of 0, 190 or 380 kg ha^{-1} year^{-1}, respectively. The soil surface balance of the grass/clover plots is exactly equal to those of the grass-only plots with corresponding N levels, due to the method used to calculate the biological N fixation. Similar to the findings with P, the absolute value of the soil surface balance for N showed some variations between years (Table 6). The soil surface balance for total N was also affected by P application rate. Increasing P rates increased the N uptake and hence decreased the soil surface balance.

There was no consistent relationship between N application rate or sward type and the accumulation of total soil N, measured to a depth of 28 cm (Table 6). The average accumulation of total soil N, measured to a depth of 28 cm, varied from –364 kg ha^{-1} in 1995 to +768 kg ha^{-1} in 1994. The fluctuation between years followed the same pattern as that of the accumulation of soil P.

The total soil balance showed a wide variation, but was not affected by any of the experimental treatments. The average total soil balance varied from –410 to +871 kg P ha^{-1} year^{-1}. Considering the whole five-year experimental period, an unaccounted accumulation of 681 kg N ha^{-1} occurred. Exclusion of the establishment year (1994) resulted in an unaccounted loss of 190 kg N ha^{-1}.

Discussion

Soil phosphorus

The P-AL-value of the soil showed a large response to the experimental treatments. At the end of the experiment the P-AL-values in the top soil layer (0-5 cm) ranged from 13 to 97. At the low end of the range, the P-AL-values, in all soil layers, seemed to stabilise around a level of 10.

The observed responses of the P-AL value and total soil P were related to the soil surface balance for P, which in turn was determined by N and P application rates and their interaction. Although a significant effect of sward type on P-AL-value and total P was measured, it is more likely that this is an indirect effect related to the level of N, either through fixation or fertiliser application. This hypothesis is supported by the fact that sward type had no effect on the relationship between soil surface balance and change in either P-AL-value or total P.

The changes in soil P values were closely related to the soil surface balance for P. A general concern of farmers, that balanced P application will lead to a reduction of P-AL-values, was not justified by the results of this experiment. Balanced P application did not lead to reduced P-AL values. At a negative surplus of 36 and 30 kg P ha^{-1} year^{-1} the P-AL value remained unchanged in the soil layers of 0-5 and 5-10 cm, respectively. Similar results were obtained for the relationship between changes in total soil P and the soil surface balance, indicating an enrichment of the top soil. Upwards P transport occurs either through capillary rise or through root uptake in deeper soil layers (Willigen & Van Noordwijk, 1987). In a monitoring study of dairy farms, Den Boer *et al.* (2001) showed that fields with higher P-AL-values in the soil layer of 5 to 20 cm required a lower soil surface balance to maintain the P-AL-value in the top soil layer at a constant level.

On the other hand, the observed enrichment could be a measurement inaccuracy that falls within the margin of error. The observed enrichment of 28 kg P ha^{-1} year^{-1}, in the soil layer of 0-28 cm, is only 1% of the total amount of P found in that layer. Furthermore, the observed enrichment occurred mainly in the establishment year. This is unexpected, as the amount of P taken up for the development of roots and stubbles is not accounted for in the total soil-plant balance. Assuming a total root and stubble weight of 6 to 8 t DM ha^{-1} (Sibma & Ennik, 1988) and a P content between 0.2 and 0.5% (De Willigen & Van Noordwijk, 1987; Whitehead, 2000), the total amount of P in roots and stubbles would be between 12 and 40 kg ha^{-1}.

The present experiment only studied the effect of fertiliser inputs under a cutting management. Recent Dutch policy will lead to an increased use of nutrients from slurry at the cost of nutrients from fertiliser. Phosphorus on grassland will be almost completely applied through shallowly injected cattle slurry. Furthermore, in practical farming, a considerable amount of P is not removed by cutting, but heterogeneously returned to the sward by the faecal excreta of the grazing animal. Preliminary data of currently ongoing experiments (Van Middelkoop *et al.*, 2002), in which the aspects of cattle slurry and grazing are accounted for, indicate a slightly higher required soil surface balance to maintain a constant P-AL-value.

The experiments of Van Middelkoop *et al.* (2002) are carried out on marine clay soil, in the vicinity of the present experiment, on peat soil and on sandy soil. The preliminary results indicate that the results on the marine clay soil are not typical for all grassland soils in the Netherlands. The required soil surface balance for a constant P-AL-value was near zero on the peat location and around +20 kg P ha^{-1} year^{-1} on the sand location.

Soil nitrogen and carbon

The accumulation of total soil N was similar under both sward types. After five years, only the unfertilised grass-only plot had a significantly lower soil N content in the layer of 0-5 cm. Similar to the findings with the P balance, an unaccounted accumulation of soil N occurred. Including the input of atmospheric deposition of 35 kg N ha^{-1} year^{-1} (IKC, 1993), leaves an unaccounted N accumulation of 101 kg ha^{-1} year^{-1}, which is only

1.5% of the total amount of soil N in the layer of 0-28 cm.

The accumulation of organic C, in the top soil layer of 5 cm, was significantly lower on the grass/clover swards than on the grass-only swards. At comparable levels of aboveground DM production, 1030 kg C ha^{-1} $year^{-1}$ accumulated in the layer of 0-5 cm of the grass-only-N1 sward, compared to 761 kg C ha^{-1} $year^{-1}$ for the grass/clover-N0 sward. It may be assumed that the lower C/N-ratio under grass/clover increases the N mineralisation. This is confirmed by earlier work of

Elgersma & Hassink (1997), in which the potential N mineralisation under unfertilised grass/clover swards was higher than under unfertilised grass-only swards. Alvarez *et al.* (1998) suggested that the higher N mineralisation under white clover can be attributed to the high organic N contents and low C/N-ratio of the organic inputs.

Conclusions

- There were no differences in accumulation of soil N and P under grass-only and grass/clover swards. Due to a lower C accumulation, the C/N-ratio was lower under grass/clover swards.
- Changes in total soil P and P-AL value were closely related to the soil surface balance, which in turn was determined by the level of N and P application and its interaction.
- Balanced P application did not lead to lower P-AL values.

Acknowledgements

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CHAPTER 6

The performance of a white clover-based dairy system in comparison with a grass/fertiliser-N system. I. Botanical composition and sward utilisation

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The performance of a white clover-based dairy system in comparison with a grass/fertiliser-N system. I. Botanical composition and sward utilisation

Abstract

The performance of a white clover-based dairy system in comparison with a grass/fertiliser-N system was studied during three years. Mixed swards of perennial ryegrass and white clover were established successfully through reseeding or sodseeding. Both systems had 59 dairy cows and a milk quota of 450 tonnes per year. The allocated areas of 41 ha for the grass/clover system and 34 ha for the grass/fertiliser-N system were based on an expected yield difference of 15 to 20% in favour of the grass/fertiliser-N swards. The grassland management consisted of a rotational grazing system with one to three silage cuts per paddock, depending on herbage growth.

The average white clover ground cover was 31, 30 and 26% in the three subsequent years, but with a large variation between seasons and paddocks. Season, clover variety and sward age x clover variety explained 28% of the variance in clover cover, but 72% remained unexplained.

Grass/clover and grass/fertiliser-N swards received 69 and 275 kg N ha^{-1} $year^{-1}$, respectively, including the inorganic N from applied cattle slurry, but excluding animal excreta during grazing. The average annual net DM yield from grass/fertiliser-N swards was 10.8 t ha^{-1} and from grass/clover swards 10.1 t ha^{-1}. The yield difference occurred mainly in spring, but was smaller than expected, causing a relative silage surplus for the grass/clover system. The OMD of grass/clover was slightly, but consistently, higher than that of grass-only, while the CP concentration of grass/clover was consistently higher from July onwards. It is concluded that mixed swards of perennial ryegrass and white clover can function as a sound basis to produce good quality herbage for a dairy system.

Introduction

From the 1950's onwards, dairy production systems in the Netherlands have become increasingly dependent on imports of fertilisers and concentrates (Van Der Meer, 1994). Concurrently, until the early 1980's interest in white clover disappeared, both in farm practice and, to a large extent, also in research. Since the middle of the 1980's developments such as the introduction of milk quota, a growing interest in organic farming and concern about nitrogen (N) losses (Aarts *et al.*, 1992) have caused a gradual decrease in the use of fertiliser N (Bussink & Oenema, 1998). In 1997, the average amount of fertiliser N applied to grassland on specialised dairy farms was 252 kg ha^{-1} $year^{-1}$ (LEI, 1999). To reduce the N losses, government policies aim to reduce the annual N surpluses of dairy farms, according to the Mineral Accounting System (MINAS), to a level of 180 kg ha^{-1} for grassland by the year 2003 (MANMF, 1997; MANMF, 1999). As the use of fertiliser N will gradually be reduced, a greater reliance on white clover may be expected, especially since N fixation by legumes does not have to be accounted for in MINAS so far.

Many studies with mixtures of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) concentrated on agronomic aspects (e.g. Frame & Newbould, 1986; Baker & Williams, 1987), animal nutritional aspects (e.g. Thomson, 1984; Beever & Thorp, 1996) or environmental aspects (Jarvis, 1992). Studies on the entire white clover-based dairy system are scarce. System studies in the Netherlands have been restricted to organic farm types (Van Der Meer & Baan Hofman, 1989) and integrated farms (Lantinga & Van Bruchem, 1998). In other countries in Northwest Europe, white clover-based systems have been compared to fertiliser N based systems (Ryan, 1989; Weissbach & Ernst, 1994; Leach *et al*., 2000). The white clover-based systems in these three studies carried 21 to 40% fewer cows per ha and produced 16 to 40% less milk per ha than the fertiliser N based systems. However, some aspects in these comparisons are not applicable to the Dutch situation, for instance the use of a two-sward system, a set-stocking grazing system or relatively low yielding dairy cows.

The present experiment studied the performance of white clover in a conventional Dutch dairy system, i.e. non-organic, with rotational grazing and cutting and a high yielding dairy herd. The objectives were (i) to compare the agronomic, environmental and economic performance of a white clover-based dairy system with a moderately intensive grass/fertiliser-N system, (ii) to identify potential problems in the utilisation of white clover in dairying, and (iii) to design an agronomically, environmentally and economically sound white clover-based dairy system.

This experiment is presented in two parts. This first paper focuses on sward utilisation and botanical composition, while a second paper (Schils *et al*., 2000) deals with animal production and the overall system performance.

Materials and methods

Site

The experiment was conducted at the Waiboerhoeve experimental station at Lelystad (52^oN, 5^oE). The soil was a young calcareous marine light clay, reclaimed from the sea in

Table 1. Soil characteristics of grass and grass/clover paddocks, determined in spring to a depth of 5 cm, before the start and at the end of the experiment.

	Grass/fertiliser-N		Grass/clover	
	1989	1993	1989	1993
Sampled paddocks (n)	25	27	18	33
pH-KCl	7.0	7.0	7.1	7.0
Organic matter (%)	7.7	9.5	6.3	7.4
P-AL (mg P_2O_5 100 g^{-1} soil)	28	57	28	40
K-HCl (mg K_2O 100 g^{-1} soil)	46	55	48	55

1957 and under grass since 1971. Until the start of the experiment, in 1990, the site had been used for intensive dairying on perennial ryegrass dominated swards with N application rates of 300 to 500 kg ha^{-1} $year^{-1}$, including inorganic N from slurry. Soil samples taken in 1989 (Table 1), showed that the top soil (0-5 cm) had a sufficient phosphate status and a high potassium status (PR, 1998).

During the three experimental years, the April-September periods were generally warmer and drier than average (Table 2). From October to March, temperatures were higher as well, with the total precipitation surpluses ranging from 233 to 412 mm.

Sward establishment

On a total area of 40.6 ha, 33 paddocks were established with mixed swards of perennial ryegrass and white clover between August 1988 and June 1991, with 7, 15, 10 and 1 paddocks being sown in 1988, 1989, 1990 and 1991, respectively (Table 3). Approximately two thirds of the paddocks were ploughed, cultivated and sown successfully with a seed mixture of 20 kg (diploid) or 30 kg (tetraploid) perennial

Table 2. Mean values of daily minimum, mean and maximum temperatures at De Bilt and total precipitation surplus (precipitation - reference evaporation) at Swifterbant per period of six months (KNMI, 1990 - 1993).

	April – September				October - March			
	Temperature (°C)			Surplus	Temperature (°C)			Surplus
	min	mean	max	(mm)	min	mean	max	(mm)
Average[1]	9.0	13.6	18.6	-35	1.7	4.9	8.1	282
1990/1991	9.0	14.4	19.4	-111	2.2	5.7	9.0	259
1991/1992	8.9	13.9	18.5	-41	2.5	5.7	8.7	233
1992/1993	10.5	15.2	20.1	-21	2.4	5.4	8.7	412

[1] Average = 30 year mean 1961-1990

Table 3. Number of paddocks (n) per sowing date, sowing method, perennial ryegrass varieties and white clover varieties in the grass/clover system.

Sowing date	n	Sowing method	n	Perennial ryegrass varieties	n	White clover varieties	n
Aug 1988	7	Cultivated	21	Profit, Magella	11	Retor	21
Apr 1989	1	Direct drill	12	Trani, Barlet	2	Alice	5
Jun 1989	4			Tresor, Parcour, Kerdion, Magella, Edgar	2	Milkanova	2
Aug 1989	10			Texas, Heraut, Magella	2	Menna	1
Mar 1990	1			Profit, Phoenix	2	Retor, Alice, Pertina, Merwi, Milkanova*	1
Apr 1990	3			Condesa, Madera	2	Alice, Pertina, Menna, Retor*	3
Jun1990	2			Unknown	12		
Jul 1990	2						
Sep 1990	2						
Jun 1991	1						

* Paddocks were drilled two to three times with different clover mixtures

ryegrass and 5 kg white clover per ha. The other paddocks were direct-drilled, using a disc type drill (Vredo), with 5 kg white clover seed per ha. The results of direct drilling were very variable due to problems with drought, the high density of the old sward and machine calibration. Therefore, paddocks had to direct-drilled 2.4 times on average to obtain a satisfactory clover establishment. The composition of seed mixtures of the old swards, sown around 1980, into which clover was direct-drilled is unknown, but perennial ryegrass was the dominant component. This practice resulted in a series of paddocks with a wide variation in sward age, sward composition, perennial ryegrass variety and white clover variety at the start of the study.

In order to have similar sward ages in both systems, an approximately equivalent proportion of the area was renewed on the grass/fertiliser-N farm. A total of 4, 7 and 4 paddocks were reseeded in 1988, 1989 and 1990, respectively. These paddocks were ploughed and sown with 25 kg (diploid) or 40 kg (tetraploid) perennial ryegrass of the same varieties as in the mixed swards.

Systems layout

The experiment consisted of a comparison between a grass/clover and grass/fertiliser-N dairy system, from May 1990 until April 1993 (Table 4). One farm manager ran both herds, which were housed under one roof, but in independent units with separated silage clamps and slurry storage facilities, cubicles, feeding passages and milk tanks. A more extensive description of the farm buildings was given earlier (Schils *et al.*, 1995). Both systems had milk quota of 450 tonnes and were planned to be self-supporting in silage

Table 4. System layout of grass/clover and grass/fertiliser-N dairy systems.

	Grass/fertiliser-N	Grass/clover
Milk quota (kg)	450,000	450,000
Pasture area (ha)	34.4	40.6
Forage maize area (ha)	-	-
Dairy cows	59	59
Stocking rate[1] (LU ha^{-1})	2.2	1.9
Milk (10^3 ton ha^{-1})	13.1	11.1
Nitrogen application[2] (kg ha^{-1})	300	< 100

1 LU = Livestock Unit: 0-1 year = 0.3, 1-2 year = 0.6 and cow = 1.0
2 including inorganic N from slurry

production. As the dry matter (DM) yield of grass/clover swards was expected to be 15 to 20% lower than that of grass fertilised with 300 kg N ha^{-1} $year^{-1}$, 41 and 34 ha were allocated to grass/clover and grass/fertiliser-N, respectively. The grassland area was divided into 33 grass/clover and 27 grass/fertiliser-N paddocks with an average area of 1.25 ha.

Each spring, cattle slurry was applied with a shallow disk injector at a rate of 20 m^3 ha^{-1}. Some paddocks received a second application during summer. On grass/clover swards, fertiliser N was only applied in spring at a rate of 20 kg ha^{-1} in 1990 and 1991 on all paddocks, and in 1992 only on the paddocks planned to be cut for silage. Grass/fertiliser-N swards received fertiliser N in 5 to 7 dressings, depending on the number of grazings and silage cuts. All paddocks received additional fertiliser P_2O_5 depending on available P_2O_5 in the soil and the number of silage cuts. Additional fertiliser K_2O was not necessary because of the high K_2O status of the soil (PR, 1998).

A rotational grazing system was applied with planned grazing periods of two days by dairy cows, followed by two days by young stock together with dry cows. Ideally, dairy cows were turned into a paddock at a DM yield of approximately 1700 kg ha^{-1} above 5 cm. On many occasions throughout the experiment, target yields could not be achieved, due to differences in expected and realised herbage growth. The first priority was to have enough herbage for grazing, whilst surplus herbage was cut for silage. Silage cuts were planned to be taken at a DM yield of 3500 kg ha^{-1} above 5 cm, and silage was wilted for about 24 hours to obtain a DM content of approximately 35 to 40%. Calves grazed on the aftermath of silage cuts.

Measurements and data analysis

Each year between January and March, soil samples were taken to a depth of 5 cm and analysed for organic matter, pH-KCl, P-AL and K-HCl.

Between autumn 1990 and spring 1993, the botanical composition of the swards was determined on eight occasions by a visual estimation of the ground cover of all plant species in the whole field. Throughout the experiment, these observations were carried out by the same person. A Residual Maximum Likelihood (REML) analysis (GENSTAT, 1998) was carried out on the white clover ground cover, after logit transformation (Log (X / (100 – X)).

A farm management system was used to record all events occurring on the paddocks, i.e. fertiliser use, grazing management, silage production and miscellaneous. Slurry was sampled at the time of application, and subsequently analysed for DM, NH_3-N, total-N, P_2O_5 and K_2O. Each silage clamp was sampled and analysed for DM, crude ash, crude fibre, crude protein and NH_3, from which the organic matter digestibility (OMD) was calculated (CVB, 1992). Prior to each grazing, the herbage of five randomly selected paddocks per system was sampled by taking approximately 40 clippings per paddock at a stubble height of 4 to 5 cm, randomly distributed across the field. The 40 clippings were bulked into one sample of 500 to 750 g fresh weight. The sample was split into two fractions. The first fraction was analysed on DM, crude ash, crude fibre, crude protein, *in vitro* organic matter digestibility (IVOMD), sodium, potassium, magnesium, calcium and phosphorus. The second fraction was separated into white clover and other species. The separated fractions were dried and the white clover content in the dry matter was assessed.

The net DM silage yield was determined by weighing and sampling every silage load. The net DM yield under grazing was calculated from the number of grazing days per ha, assuming that one grazing day equals a net DM yield of 14, 7 or 3.5 kg for dairy cows, heifers or calves, respectively (Hijink & Meijer, 1987; PR, 1997).

Results

Sward composition

The average white clover ground cover of the grass/clover swards, determined in the autumn of 1990, 1991 and 1992 was 31, 30 and 26%, respectively (Figure 1). The white clover ground cover tended to be lowest in spring and highest in summer. The perennial ryegrass cover decreased from 51% in the autumn of 1990 to 37% in the autumn of 1992. Meanwhile the ground cover of other species, such as rough-stalked meadowgrass (*Poa trivialis*), annual meadowgrass (*Poa annua*) and dandelion (*Taraxacum officinale* Web. s.l.) increased slightly. Although the average ground cover of these species generally remained below 10%, some paddocks had a ground cover of up to 30% of rough-stalked meadowgrass or annual meadowgrass, or up to 10% of dandelion.

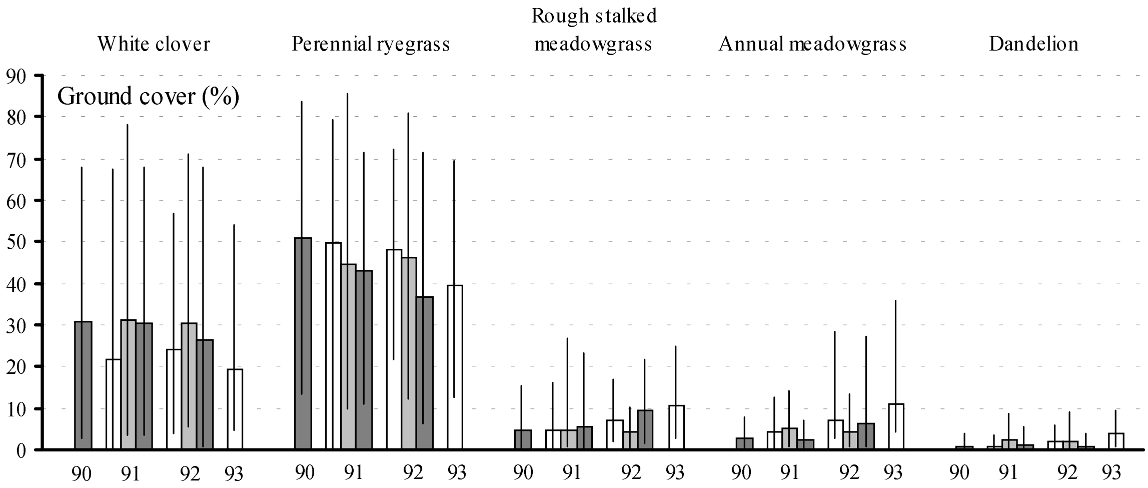

Figure 1. Mean ground cover of the most important species, determined on the grass/clover swards in spring (□), summer (■) or autumn (■); vertical line indicates range between minimum and maximum cover.

The species ground cover showed a wide variation between paddocks. Variance components analysis of the white clover ground cover showed that 28% of the variation could be explained by clover variety ($P<0.01$), season ($P<0.05$) and sward age x clover variety ($P<0.001$). The observed white clover ground cover of the paddocks sown with variety Alice was 42, 51 and 52% in the autumn of the three subsequent years, compared to 32, 27 and 25% for paddocks sown with Retor. Further attempts to explain the variance by soil nutrient status, fertiliser applications, grass varieties and grassland management were unsuccessful.

The swards on the grass/fertiliser-N farm were dominated by perennial ryegrass (71%), with rough-stalked meadow grass (6%) and annual meadowgrass (4%) as the main other species. The average perennial ryegrass ground cover decreased from 75% in the autumn of 1990 to 66% in the autumn of 1992.

Table 5. Fertiliser application, sward utilisation and herbage quality of grass/fertiliser-N and grass/clover swards, averaged over year and season.

	Mean		Grass/Fertiliser-N			Grass/Clover			Grass/Fertiliser-N			Grass/Clover		
	Grass / Fertiliser	Grass / Clover	'90/'91	'91/'92	'92/'93	'90/'91	'91/'92	'92/'93	Start-Jun	July-Aug	Sep-End	Start-Jun	July-Aug	Sep-End
Fertiliser and slurry application (kg ha^{-1})														
$N_{inorganic}$	275	69	279	268	277	43	91	74	203	62	10	66	2	1
P_2O_5	116	112	137	109	102	138	98	100	91	17	8	85	22	5
K_2O	250	193	227	237	287	93	253	233	230	13	7	184	7	2
Sward utilisation														
Grazings per paddock	4.9	4.5	4.9	4.6	5.1	4.5	4.3	4.7	1.5	1.4	2	1.7	1.2	1.6
Total grazing days (10^3 LU)	14.75	15.34	14.17	15.09	14.99	15.32	15.76	14.95	5.72	4.95	4.07	5.8	5.23	4.31
Silage cuts per paddock	1.9	2.4	2.0	1.7	2.1	2.3	2.2	2.6	1.3	0.5	0.1	1.4	0.7	0.3
Total silage yield (10^3 kg DM)	196	226	196	179	213	195	211	272	145	46	5	150	59	17
Herbage at grazing														
DM yield at grazing (t ha^{-1})	2.00	1.82	2.02	2.00	1.99	1.60	1.99	1.86	2.38	2.12	1.72	2.28	2.00	1.28
Crude protein (g kg^{-1} DM)	187	198	182	177	203	201	174	219	190	174	197	192	188	222
IVOMD (g kg^{-1} OM)	766	785	751	767	780	773	791	791	797	750	738	814	775	760
Herbage at cutting														
DM yield at cutting (t ha^{-1})	2.9	2.4	2.9	3.1	3.0	2.1	2.4	2.6	3.2	2.7	1.5	2.6	2.1	1.4
Dry matter (g kg^{-1})	434	434	452	414	435	465	409	429	400	527	573	411	499	417
Crude protein (g kg^{-1} DM)	168	178	175	157	171	172	177	186	169	162	185	170	192	201
OMD (g kg^{-1} OM)	733	750	698	757	745	721	770	758	748	705	584	760	743	692

Sward utilisation

Swards in the grass/fertiliser-N system received 275 kg N ha^{-1} year^{-1} (Table 5), of which 67 kg originated from slurry. Swards in the grass/clover system received 69 kg N ha^{-1} year^{-1}, of which 52 kg came from slurry. There were no major differences in slurry composition between the two systems and the average concentrations per m^3 slurry were 2.8 kg organic N, 2.1 kg inorganic N, 1.6 kg P_2O_5 and 7.8 kg K_2O. In 1990, newly sown grass/clover swards (autumn 1989 / spring 1990) received no N, neither from inorganic fertiliser nor from slurry. Therefore, the annual N application in 1990 was only 43 kg ha^{-1}. The slurry surplus of 1990 was carried over to 1991, resulting into an annual application of 91 kg ha^{-1} in that year. In order to improve the low phosphate status (Table 1), the phosphate application was relatively high in the first year. As there was no need for potassium fertiliser, the potassium application reflects the amounts of slurry given each year. During the experiment, the phosphate, potassium and organic matter contents of the soil increased in both systems.

In each year, the dairy cows of both systems were turned out on the same day, in the second week of April (Figure 2). In August of the first year and September and October of the second year, a drought period caused a shortage of grass in the grass/fertiliser-N system, during which the dairy cows were kept indoors at night and supplemented with silage. Due to excessive rainfall in the third year, the cows in both systems were kept indoors at night from September onwards, and again, were supplemented with silage. The dairy cows were housed permanently in the last week of October of the first and third year, and in the second week of November in the second year. These events resulted

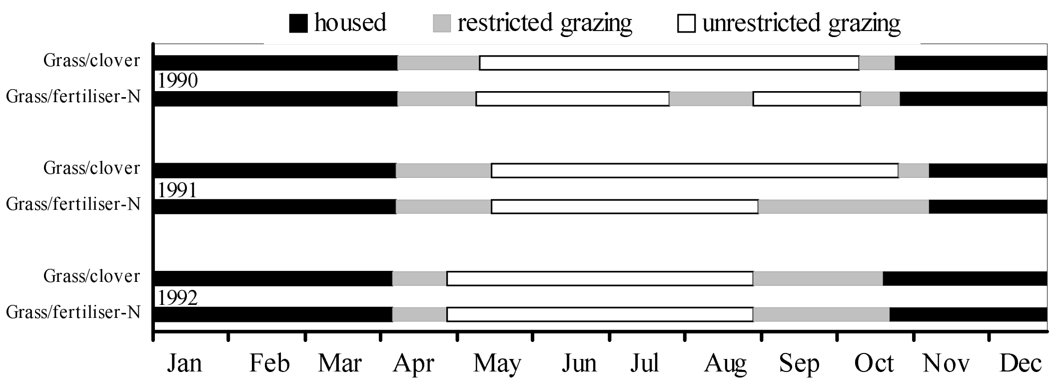

Figure 2. Overview of periods during which the dairy cows were housed, grazed day and night-time without supplementation of silage (unrestricted grazing) or grazed day-time with supplementation of silage (restricted grazing).

in fewer grazing days (Table 5) and a higher silage supplementation (Schils *et al*., 2000) in the grass/fertiliser-N system, especially in the summer and autumn of the first and second year.

Each grass/fertiliser-N paddock was grazed on average 4.9 times and each grass/clover paddock 4.5 times a year, with an average grazing time for the dairy cows of 1.6 and 1.4 days, respectively. The difference in grazing time is reflected in the DM yield at grazing of the sampled paddocks, which was 0.2 t ha^{-1} higher on the grass/fertiliser-N swards. During the grazing season, the DM yield at which cows were turned in decreased from 2.3 to 1.5 t ha^{-1}. The sampled paddocks showed a higher crude protein concentration and IVOMD for herbage from grass/clover swards than from grass/fertiliser-N swards. The crude protein concentrations were mainly higher from July onwards, whilst the difference in IVOMD was consistent throughout the grazing season. There were no major differences between herbage from grass/fertiliser-N or grass/clover swards in the concentrations of sodium (1.0 g kg DM^{-1}), potassium (33.3 g kg DM^{-1}), magnesium (1.7 g kg DM^{-1}) and phosphorus (4.2 g kg DM^{-1}). The calcium concentration in grass/clover herbage was 9.2 g kg DM^{-1}, compared to 6.4 g kg DM^{-1} in grass/fertiliser-N herbage.

The shortage of grass in the grass/fertiliser-N system is also reflected in the mean lower total silage yield than in the grass/clover system, 196 compared to 226 t DM

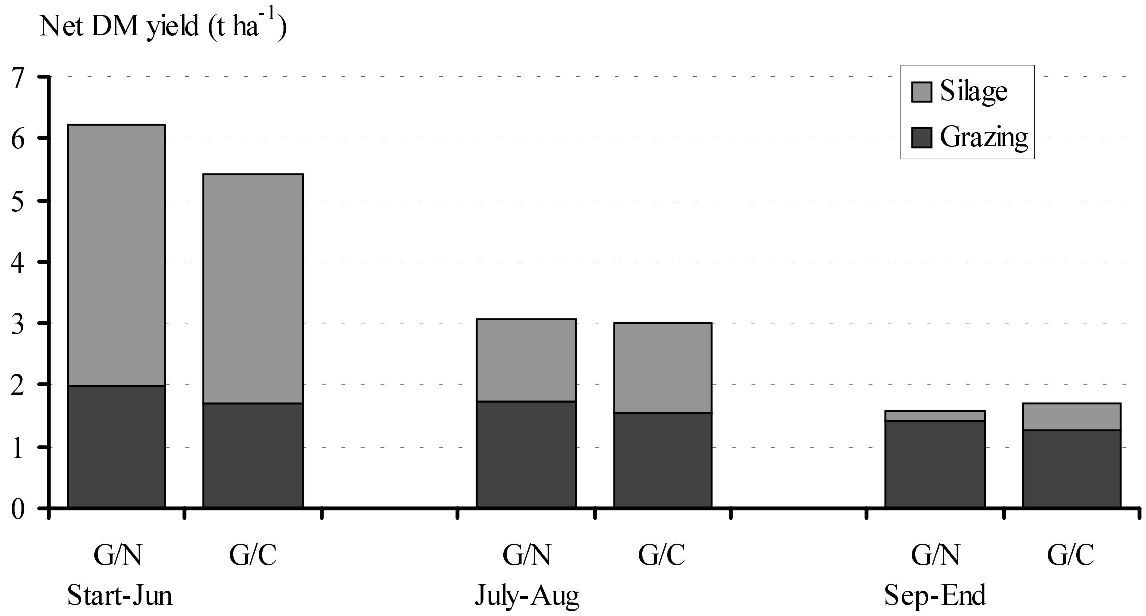

Figure 3. Average seasonal net DM yield during grazing (intake) and cutting (silage) for grass/fertiliser-N (G/N) and grass/clover (G/C).

year^{-1}, respectively. The differences occurred in the second and third year, and mainly from July onwards. Grass/clover paddocks were cut 0.3 to 0.5 times per year more often than grass/fertiliser-N paddocks. This was not only a result of the total higher silage yield of grass/clover, but also of the lower DM yield per cut for grass/clover. Although not planned, grass/clover paddocks were cut for silage at 2.4 t ha^{-1}, compared to 2.9 t ha^{-1} for grass/fertiliser-N paddocks. Similar to the trend at grazing, the DM yield at cutting decreased during the season. The average DM content of silages was 43% in both systems. The average crude protein concentration and OMD of grass/clover were higher than those of grass/fertiliser-N. The difference in crude protein concentration occurred from July onwards. The OMD of silage decreased considerably during the season. Especially the silage in September had a poor quality.

The average annual net DM yield on grass/fertiliser-N was 10.6, 10.5 and 11.4 t ha^{-1} in the three subsequent years, compared to 9.3, 9.9 and 11.1 t ha^{-1} on grass/clover. The average yield deficit of 0.7 t DM ha^{-1} year^{-1} on grass/clover swards occurred completely in the first part of the grazing season (Figure 3). From July onwards, grass/fertiliser-N and grass/clover swards showed similar DM yields.

The more frequent cutting of grass/clover resulted in a higher proportion of aftermath grazing for cows in the grass/clover system. Between July and October, 19% of the grazings on grass/fertiliser-N was on aftermath compared to 37% on grass/clover swards. Therefore, in that period grass/fertiliser-N paddocks had to be topped more often to clean areas with rejected herbage, i.e. 1.1 times per paddock compared to 0.6 times per paddock in the grass/clover system.

In both systems, young stock and dry cows grazed day and night from the last week of April to the second or last week of November, while calves grazed from between the third week of May or second week of June until the third week of September or the third week of October.

Discussion

As biologically fixed N is the driving force for a clover-based system, the white clover content in the sward has to be maintained at an appropriate level. Based on four criteria, i.e. herbage yield, animal performance, bloat risk and N losses, Pflimlin (1993) suggested an optimal annual clover content between 25 and 50%, for rotational grazing systems without supplementation of dry forages. Although the average white clover ground cover was generally within these target values, there was a substantial range between the lowest and highest values of clover ground cover. Although some variation between years and seasons is inevitable, the variation between paddocks could have been reduced by a more uniform variety choice. The poorer performance of clover variety Retor compared to Alice, as shown in cutting experiments by Elgersma & Schlepers (1997) and Baars *et al.* (1995), was confirmed by the present experiment for a practical dairy husbandry situation. Experiences with clover-based dairy systems in United Kingdom (Leach *et al.*, 2000; Bax & Browne, 1995) and more recently in the Netherlands (Lantinga & Van Bruchem, 1998) suggest that it is easier to maintain a more stable clover content in set-stocked grazing systems than in rotational grazing systems.

Strategic N fertilisation in spring is essential to achieve early herbage growth (Frame & Boyd, 1987; Schils, 1997) and thus an early turn-out date for the dairy cows. In the grass/clover system the bulk of inorganic N was applied through slurry, and only 17 kg N ha^{-1} year^{-1} was applied by inorganic fertiliser. Despite the relatively low sugar and high protein concentrations of grass/clover (Frame & Newbould, 1986), there was no evidence of a poor fermentation of grass/clover silages. The silage DM content of 43% has probably caused higher field losses in the grass/clover system. Experiments on the same site (Corporaal, 1993) have shown that the average DM field losses were 8.8% for grass/clover silages and 3.9% for grass-only silages. Furthermore the losses of grass/clover increased from 2.9% at DM contents below 35% to 15.2% at DM contents higher than 50%, whilst the losses of grass-only silages were almost unrelated to the DM content.

The results showed that the overall herbage quality of the grass/clover system resembled that of the grass/fertiliser-N system. The crude protein concentration of fresh and ensiled herbage was 6% higher in the grass/clover system and OMD was 2% higher. It is unclear whether the higher nutritive value can be attributed to clover alone or whether it is also an effect of a lower DM yield per cut. The average DM yields per cut were 9 and 17% lower in the grass/clover system for grazing and cutting, respectively. Søegaard (1993) reported no difference in IVOMD when comparing grass and white clover, cut at the same DM yield.

The applied stocking rate in the systems was based on the assumption that the grass/clover swards would yield 15 to 20% less than the grass/fertiliser-N swards. However, the realised DM yields of the grass/clover swards were only approximately 7% lower. Therefore, it can be put forward that the grass/clover system has been relatively understocked in comparison to the grass/fertiliser-N system. Obviously, a direct result was the silage shortage in the grass/fertiliser-N system and the silage surplus in the grass/clover system. Less obvious, but perhaps more important are the implications with respect to grassland management. In the understocked grass/clover system, it was possible to achieve 2.4 silage cuts on a total of 6.9 cuts, while in the overstocked grass/fertiliser-N system only 1.9 silage cuts were achieved on a total of 6.8 cuts. The higher cutting ratio might have stimulated clover content (Schils *et al.*, 1999) and increased the proportion of aftermath grazing. If the grass/clover system had been stocked to capacity, the performance of the system might have been poorer.

The grassland management on the grass/clover swards was not very different from the grass/fertiliser-N swards. In both systems, the same principles were applied regarding grazing and cutting strategy, phosphate and potassium fertilisation and slurry application. This similar approach makes it easier for farmers to adopt a grass/clover system in phases, because there needs to be no difference in grassland management on the existing grass-only swards and the newly established grass/clover swards.

Conclusions

In a dairy farm system, mixed swards of perennial ryegrass and white clover had satisfactory but highly variable clover contents in the swards. The variation in clover was partly explained by season, clover variety and sward age x clover variety, but 72% of the variation remained unexplained. The mixed swards, fertilised with 69 kg inorganic N ha^{-1} $year^{-1}$, produced 90 to 95% of the DM yield on grass-only swards, fertilised with 275 kg inorganic N ha^{-1} $year^{-1}$. The OMD of grass/clover was marginally, but consistently, higher than that of grass-only, whilst the CP concentration of grass/clover was consistently higher than of grass-only from July onwards. Overall, the experiment demonstrated that mixed swards of perennial ryegrass and white clover can function as a sound basis to produce good quality herbage for a dairy system.

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CHAPTER 7

The performance of a white clover-based dairy system in comparison with a grass/fertiliser-N system. II. Animal production, economics and environment

Schils, R.L.M., Tj. Boxem, C.J. Jagtenberg & M.C. Verboon, 2000. The performance of a white clover-based dairy system in comparison with a grass/fertiliser-N system. II. Animal production, economics and environment. Netherlands Journal of Agricultural Science 48: 305-318.

The performance of a white clover-based dairy system in comparison with a grass/fertiliser-N system. II. Animal production, economics and environment

Abstract

The performance of a white clover based dairy system in comparison with a grass/fertiliser-N system was studied during three years. Both systems had 59 cows, plus young stock, on an area of 40.6 ha for grass/clover and 34.4 ha for grass/fertiliser-N.

During the grazing season, the cows in both groups were supplemented with 3.5 kg concentrates day^{-1}. The daily Fat and Protein Corrected Milk (FPCM) production was 25.7 and 26.5 kg cow^{-1} for grass/fertiliser-N and grass/clover, respectively. The difference in milk production occurred from July onwards. Despite preventive measures in the grass/clover system, bloat occurred several times between August and October. During the housing season, cows received *ad libitum* grass or grass/clover silage with 6 kg concentrates cow^{-1} day^{-1}. Although the intake of grass/clover silage was consistently higher, there were no differences in milk production.

The grass/clover system had a lower N surplus, but this was related to the lower intensity of the system. The overall N utilisation was 25% in both systems. The average nitrate concentration in drain water, measured on a selection of fields, was 26 and 28 mg l^{-1} for grass/fertiliser-N and grass/clover, respectively. The nitrate concentrations in drain water from grass/clover fields were positively related with the clover content in the sward. The energy use of the grass/clover system was 15% lower than that of the grass/fertiliser-N system, with the fertiliser use as the main source of difference. Compared to the grass/fertiliser-N system, the gross margin per cow was slightly higher for grass/clover, but the gross margin per ha was 10% lower for grass/clover.

Considering agronomic and environmental aspects only, white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t FPCM ha^{-1} year^{-1} or less.

Introduction

In the Netherlands, developments such as the introduction of milk quota, concern about N losses (Aarts *et al*., 1992) and growing interest in organic farming have reduced the use of fertiliser N since the early 1980's (Bussink & Oenema, 1998). Consequently, there is renewed interest in the use of mixed swards of perennial ryegrass and white clover.

Most experiments with grass/clover swards have considered only certain aspects like agronomic factors or animal nutrition factors, while only few experiments studied whole farm systems. In the Netherlands, system studies with grass/clover have been restricted to organic farms (Van Der Meer & Baan Hofman, 1989) and integrated farms (Lantinga & Van Bruchem, 1998). In other countries in Northwest Europe, convential clover based farming types have been compared to fertiliser N based systems. Ryan (1989) reported a comparison of five grazing seasons between a grass/fertiliser-N system, stocked at 3.2 cows ha^{-1} and fertilised with 361 kg N ha^{-1} $year^{-1}$ and a grass/clover system, stocked at 2.52 cows ha^{-1} and fertilised with 122 kg N ha^{-1} $year^{-1}$. The milk production per cow was 6% higher, but the milk production per ha was 16% lower in the grass/clover system. Leach *et al.* (2000) presented whole-year comparisons between a grass/fertiliser-N system with 350 kg N ha^{-1} $year^{-1}$ and a grass/clover system with no fertiliser N. Initially, both systems had the same stocking rate of 1.9 cows ha^{-1} and the same target milk yield of 5700 l cow^{-1} $year^{-1}$. The target yields in the grass/clover system could only be realised with an additional input of approximately 300 kg concentrate cow^{-1} $year^{-1}$. In the third year, the stocking rate of the grass/clover system was reduced to 1.5 cows ha^{-1} and the target yields per cow could be achieved with similar concentrate inputs. However, the milk yield per ha was 21% lower in the grass/clover system. Weissbach & Ernst (1994) reported a six-year comparison between a grass/fertiliser-N system (392 kg N ha^{-1} $year^{-1}$) and a grass/clover system (44 kg N ha^{-1} $year^{-1}$). They also found similar milk yields per cow but a 40% lower milk yield per ha for the grass/clover system.

In the present experiment the performance of white clover was studied in a conventional Dutch dairy system, i.e. non-organic, alternating rotational grazing and cutting for silage and a high yielding dairy herd. The objectives were (i) to compare the agronomic, environmental and economic performance of a white clover-based dairy system with a moderately intensive grass/fertiliser-N system, (ii) to identify potential problems in the utilisation of white clover in dairying, and (iii) to design an agronomically, environmentally and economically sound white clover-based dairy system.

The first paper on this experiment (Schils *et al.*, 2000) described the botanical composition and sward utilisation in both systems. The average white clover ground cover was 31, 30 and 26% in the three subsequent years, but with a large variation between years, seasons and paddocks. Grass/clover and grass/fertiliser-N swards received 69 and 275 kg N ha^{-1} $year^{-1}$, respectively, including the inorganic N from cattle slurry. The average annual net dry matter yield on grass/fertiliser-N was 10.8 t ha^{-1} compared to 10.1 t ha^{-1} on grass/clover. The yield difference was smaller than expected, causing a silage surplus for grass/clover. The organic matter digestibility of grass/clover was marginally, but consistently, higher than that of grass-only, while the crude protein concentration was consistently higher from July onwards.

In this second paper the animal production data and overall system performance is presented

Materials and methods

Systems layout

The experiment consisted of a comparison between a grass/clover and grass/fertiliser-N dairy system (Table 1), conducted on the Waiboerhoeve experimental station at Lelystad, from May 1990 until April 1993. One farm manager ran both herds, which were housed under one roof, but in independent units with separated silage clamps and slurry storage facilities, cubicles, feeding passages and milk tanks. Further details about the history of the site, soil characteristics, weather data, the establishment of swards, grassland management and fertiliser policy are described in Schils *et al*. (2000).

The dairy herds consisted of Holstein-Friesian cows, calving from October to April. In 1989/1990, these cows produced 7297 kg milk cow^{-1} year^{-1} with 4.38% fat and 3.37% protein. Before the start of the experiment all cows were grouped into pairs of the same age, calving date, milk production and genetic potential and pairs were then randomly split between both systems. In spring, dairy cows were turned out as soon as there was enough grass to start grazing. A rotational grazing system was applied with planned grazing periods of two days by dairy cows, followed by two days by young stock together with dry cows. The first priority was to have enough herbage for grazing, while surplus herbage was cut for silage. During the first two to four weeks at the beginning and during the last weeks at the end of the grazing season, the herds grazed only grass or grass/clover during daytime and were housed at night, where they were supplemented

Table 1. System layout of grass/clover and grass/fertiliser-N dairy systems.

	Grass/fertiliser-N	Grass/clover
Milk quota (kg)	450,000	450,000
Pasture area (ha)	34.4	40.6
Forage maize area (ha)	-	-
Dairy cows	59	59
Stocking rate[1] (LU ha^{-1})	2.2	1.9
Milk (10^3 ton ha^{-1})	13.1	11.1
Nitrogen application[2] (kg ha^{-1})	300	< 100

1 LU = Livestock Unit: 0-1 year = 0.3, 1-2 year = 0.6 and cow = 1.0
2 including inorganic N from slurry

with approximately 5 kg silage DM cow^{-1} day^{-1}. During the grazing season, cows were fed 1 to 6 kg concentrates cow^{-1} day^{-1} in the milking parlour, depending on the milk production level. Furthermore, in 1990 and 1991 the cows in the grass/clover system were supplemented daily with 1 kg of a concentrate containing 10 mg Centralene® kg^{-1}, a bloat preventing agent containing 60% polyoxypropylene and 40% polyoxyethylene. From 1992 onwards, the use of Centralene® in concentrates was no longer permitted and therefore, the proportion of unsaturated fat in concentrates was increased during the grazing season of 1992 by inclusion of toasted soybean (15%). This modified concentrate was fed to cows in the grass/clover system as well as the grass/fertiliser-N system. During the housing season, cows were on an *ad libitum* silage diet with supplementation of concentrates to a level of 1 to 12 kg cow^{-1} day^{-1}, depending on the level of milk production.

Measurements and data analysis

A farm management system was used to record the animal data, i.e. feed intake, milk production, milk sales, milk quality, animal weights, animal health and fertility.

Nitrogen fixation by white clover was estimated as follows. Data from herbage samples and the botanical composition observed on the grass/clover paddocks (Schils *et al*., 2000) were used to predict the white clover content in the dry matter ($CL_{dm,i}$) on day i (day number after 1st of January) from the autumn white clover cover (CL_{cov}) as follows: $CL_{dm,i} = 0.39{*}CL_{cov} - 0.316{*}i + 0.0330{*}i^2 - 0.00000746{*}i^3 + 0.00283{*}CL_{cov}{*}i$ (R^2=75.9%). The net DM yield per ha was calculated from the silage yield and the number of grazing days. It was assumed that one grazing day equals a net DM yield of 14, 7 or 3.5 kg for dairy cows, heifers or calves, respectively (Hijink & Meijer, 1987; PR, 1997). The net DM yields and clover contents in the sward were combined to calculate the annual clover yield. With the assumption that each tonne of clover DM is equivalent to a N fixation of 54 kg/ha (Van Der Meer & Baan Hofman 1989; Elgersma & Hassink, 1997) the total fixation was estimated.

From October to April, drain water was sampled once per week from a random selection of 10 grass/fertiliser-N paddocks and 14 grass/clover paddocks and analysed for NO_3-N, using a Nitracheck reflectometer and Merckoquant test strips (Elles *et al*., 1987; Berry & Thicoipe, 1993).

The energy use of both systems was calculated with the energy module of a farm budgeting program (Hageman & Mandersloot, 1995), in which the total energy use is derived by multiplying the amount of energy carriers, products and services with their respective energy contents.

Results

Milk production

During the grazing season, the cows in the two systems were supplemented with a similar average amount of concentrates, approximately 3.7 kg cow^{-1} day^{-1} (Table 2). The silage supplementation was higher in the grass/fertiliser-N system, due to occasional grass shortage from July onwards, as described earlier in Schils *et al*. (2000). On average, the cows in both herds produced 25 kg milk cow^{-1} day^{-1}. Generally, daily milk production decreased throughout the grazing season, from approximately 29 to 21 kg cow^{-1}, in line with the herd's calving patterns. Average daily milk production and fat concentration were slightly higher in the grass/clover system than in the grass/fertiliser-N system, but these differences were not consistent throughout the years. However, average fat and protein corrected milk production (FPCM) on grass/clover was always equal to or higher than that on grass/fertiliser-N. Higher daily milk productions occurred mainly from July onwards, while higher fat concentrations occurred throughout the whole grazing season.

During the housing season, cows were supplemented with approximately 6 kg cow^{-1} day^{-1} (Table 3). Although the intake of grass/clover silage was almost 1 kg DM cow^{-1} day^{-1} higher than that of grass/fertiliser-N silage, the milk production in both systems was similar. The fat concentration of the milk was consequently higher in the grass/fertiliser-N system, and therefore FPCM was somewhat higher as well. With a similar milk protein production, the higher intake in combination with a higher N concentration resulted in a lower N utilisation in the grass/clover system.

The annual fat and protein corrected milk production (FPCM) was 8294 kg cow^{-1} in the grass/clover system and 8095 kg cow^{-1} in the grass/fertiliser-N system.

Animal fertility and health

There were no relevant differences in fertility parameters of the two herds. The average number of inseminations per conception was 1.8, with a score of 48% pregnancy to first serve and a final result of 83% pregnancy of all cows served. The calving index was 382 days and there were 74 days between calving and first serve.

In the grass/clover system bloat occurred each year, but with varying frequency. In the establishment year 1989, 25 cows had to be treated for bloat, of which two died. In 1990 and 1991, when the cows were supplemented with bloat preventing means through concentrates, 9 cows were treated. In 1992, when bloat prevention was implied through a higher proportion of unsaturated fat, 7 cows were treated. All incidences of bloat occurred during night-time between August and October.

Table 2. Daily concentrate and silage supplementation and milk production during the grazing season.

	Mean		Grass/Fertiliser-N			Grass/Clover			Grass/Fertiliser-N			Grass/Clover		
	Grass / Fertiliser	Grass / Clover	'90/'91	'91/'92	'92/'93	'90/'91	'91/'92	'92/'93	Start-Jun	July-Aug	Sep-End	Start-Jun	July-Aug	Sep-End
Dairy cows	54	53	52	53	56	51	51	56	56	54	51	57	54	47
Concentrate (kg DM cow^{-1} day^{-1})	3.7	3.6	3.8	3.9	3.4	3.7	3.8	3.2	4.4	3.1	3.5	4.2	2.9	3.4
Silage (kg DM cow^{-1} day^{-1})	2.1	1.4	1.9	2.5	2.0	1.2	1.2	1.9	1.9	0.7	3.6	1.9	0	2.0
Milk (kg cow^{-1} day^{-1})	24.7	25.2	23.4	25.1	25.4	24.9	25.2	25.6	28.9	23.9	20.8	28.6	24.7	21.6
Fat (g kg^{-1})	4.27	4.36	4.33	4.31	4.22	4.28	4.32	4.45	4.18	4.12	4.55	4.26	4.19	4.68
Protein (g kg^{-1})	3.47	3.47	3.55	3.45	3.43	3.46	3.52	3.43	3.44	3.4	3.58	3.41	3.39	3.65
FPCM[1] (kg cow^{-1} day^{-1})	25.7	26.5	24.6	26.2	26.2	25.9	26.4	27.1	29.7	24.4	22.5	29.6	25.4	23.7

[1] Fat (4%) and Protein (3.32%) Corrected Milk production

Table 3. Daily feed intake and milk production during the housing season.

	Mean		Grass/Fertiliser-N			Grass/Clover		
	Grass / Fertiliser	Grass / Clover	'90/'91	'91/'92	'92/'93	'90/'91	'91/'92	'92/'93
Dairy cows	45	47	42	44	50	44	45	52
Concentrate (kg DM cow^{-1} day^{-1})	6.1	5.8	5.9	5.8	6.7	5.3	5.5	6.6
Grass silage (kg DM cow^{-1} day^{-1})	13.5	14.4	14.8	13.0	12.7	15.5	14.7	13.1
Milk (kg cow^{-1} day^{-1})	26.0	25.9	26.8	24.8	26.3	26.0	25.6	26.2
Fat (g kg^{-1})	4.75	4.62	4.67	4.83	4.76	4.58	4.62	4.65
Protein (g kg^{-1})	3.47	3.45	3.46	3.55	3.43	3.43	3.46	3.46
FPCM (kg cow^{-1} day^{-1})	28.5	28.0	29.1	27.5	28.8	27.9	27.7	28.4
N utilisation[1] (%)	26.6	24.5	25.2	28.4	26.6	24.4	24.5	24.8

[1] (N in milk / N in feed) *100%

There were no significant differences in the incidence, i.e. number of treated animals divided by the total number of animals, of other illnesses between the two herds. The most important illnesses, averaged over both herds, were lameness, with an incidence of 70%, sole ulcer (36%), irregular heat (27%), hypocalcemia (27%) and mastitis (23%). The reasons for culling were mainly fertility (42%), udder (18%) and production (13%).

Nitrogen budget

The higher intensity of the grass/fertiliser-N system is reflected in the annual N budget (Table 4). The higher N input through concentrates and the higher N output through milk

Table 4. Average nitrogen budget of the grass/fertiliser-N and grass/clover system (kg N ha^{-1} $year^{-1}$).

	Grass/fertiliser-N	Grass/clover
Concentrates	76	65
Fertiliser	208	16
Fixation	0	176
Silage	9	-18
Deposition	35	35
Other	5	5
Total input	**333**	**279**
Milk	70	61
Cattle	10	8
Total output	**80**	**69**
Surplus	**253**	**212**

and meat are associated with its 15% higher stocking rate. Obviously, the most striking difference is the substitution of fertiliser-N in the grass/fertiliser-N system by biologically fixed N in the grass/clover system. The amount of fixed N was estimated at 170, 182 and 175 kg ha^{-1} $year^{-1}$, in the three consecutive years. In the grass/fertiliser-N system, there was a net N input through silage that had to be bought to compensate for shortages, while the grass/clover system had a net silage surplus, which was sold. In the three consecutive years, the balance for silage was -13, -26 and +2 t DM $year^{-1}$ on grass/fertiliser-N, and -2, +27 and +63 t DM $year^{-1}$ on grass/clover. In this region of the Netherlands the atmospheric deposition of NH_3-N is estimated at 35 kg N ha^{-1} $year^{-1}$ (IKC, 1993). Other inputs consist of litter (1 kg ha^{-1} $year^{-1}$) and an estimated fixation by free living soil bacteria (4 kg ha^{-1} $year^{-1}$).

The N surplus was 41 kg ha^{-1} $year^{-1}$ higher on grass/fertiliser-N than on grass/clover, which is again related to the higher stocking rate. In terms of N efficiency there was no difference between the systems. Approximately 25% of the N input was recovered in the N output.

The similar N efficiency is illustrated by the weekly nitrate concentrations in drain water (Figure 1). The overall average nitrate concentration from grass/fertiliser-N and grass/clover paddocks was 26 and 28 mg l^{-1}, respectively, but there was a considerable variation between years, weeks and paddocks. The variation between paddocks could be partly explained by variation in annual N application on grass/fertiliser-N paddocks, and by variation in white clover cover on grass/clover paddocks. Each year, the nitrate concentration increased consistently with increasing white clover cover. For paddocks with an autumn clover cover of <20%, 20 - 50% and >50%, the average nitrate concentration was 20, 35 and 41 mg l^{-1}, respectively. The effect of N application on grass/fertiliser-N paddocks was clear in the first year, but not in the second and third year, in which years there was too little variation in N application rate between paddocks. For paddocks with an N application of < 280 and >280 kg ha^{-1} $year^{-1}$, the average nitrate concentration was 23 and 29 mg l^{-1}, respectively.

Energy use

The total energy use of the grass/clover system was 15% lower than that of the grass/fertiliser-N system, with the fertiliser energy use as the main difference (Table 5). In both systems, the indirect energy consumption through concentrates made the greatest contribution to the total energy consumption. The higher number of silage cuts in the grass/clover system gave a higher energy use through services, e.g. from contractors. The difference in silage shortage/surplus is included in other sources. The direct energy use was similar on both farms. The total energy use per 100 kg of milk was 440 and 374 MJ for grass/fertiliser-N and grass/clover, respectively.

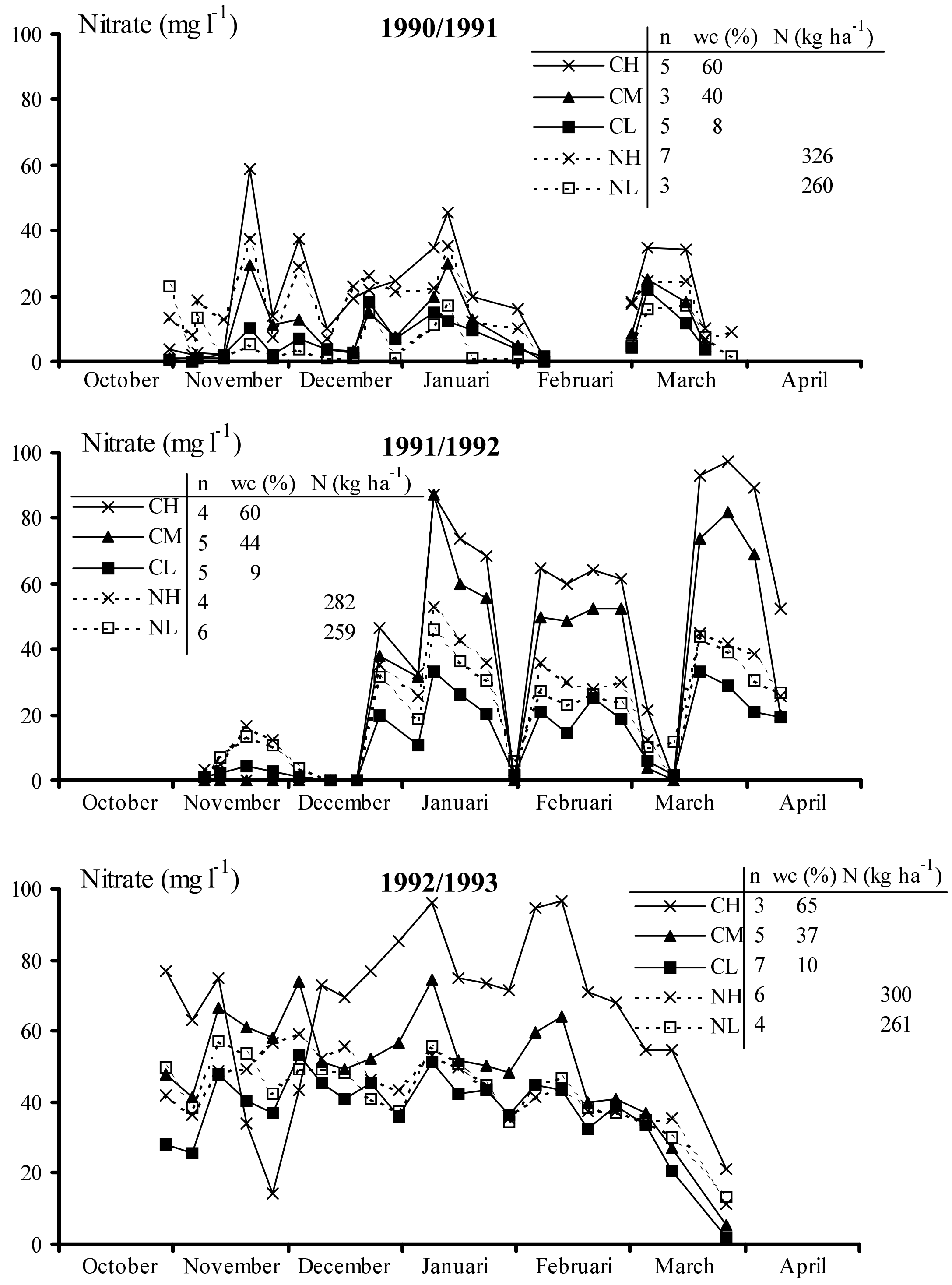

Figure 3. Average nitrate concentration in drain water (mg l^{-1}) in 1990/1991, 1991/1992 and 1992/1993, from grass/clover paddocks, in relation to white clover cover in the autumn, CL (< 20%), CM (20-50%) or CH (> 50%), and from grass/fertiliser-N paddocks, in relation to annual N application, NL (< 280 kg ha^{-1} $year^{-1}$) or NH (> 280 kg ha^{-1} $year^{-1}$). Number of paddocks (n), white clover content (wc) and N application (N) vary per year and are indicated in the legend.

Table 5. Average energy use of the grass/fertiliser-N and grass/clover system (GJ $year^{-1}$).

	Grass/fertiliser-N	Grass/clover
Diesel	124	122
Electricity	220	221
Direct energy	**344**	**343**
Concentrates	672	675
Fertiliser	286	37
Services	230	293
Buildings & Machinery	331	333
Other	100	16
Indirect energy	**1619**	**1354**
Total	**1963**	**1697**

Gross margin

Total revenues of the grass/clover farm were higher due to higher milk sales and the sale of the silage surplus (Table 6). The use of white clover reduced annual fertiliser costs to Euro 1,300 in the grass/clover system, compared to almost Euro 4,000 in the grass/fertiliser-N system. On the other hand, concentrate costs were higher, due to the use of Centralene® in 1990 and 1991. On the grass/fertiliser-N farm, silage had to be bought,

Table 6. Average financial results of the grass/fertiliser-N and grass/clover system (10^3 Euro $year^{-1}$).

	Grass/fertiliser-N	Grass/clover
Milk	157.6	161.0
Cattle	20.1	19.6
Silage	0.0	4.0
Revenues	**177.7**	**184.6**
Fertiliser	4.0	1.3
Concentrates, milk replacer	17.7	19.3
Silage	1.7	0.0
Inseminations	1.5	1.6
Health	6.1	6.1
Interest	5.1	5.1
Other	1.1	1.1
Direct costs	**37.3**	**34.6**
Gross Margin	140.4	150.0
Gross Margin per ha	**4.1**	**3.7**

at an average annual cost of nearly Euro 1,700.

The higher revenues and lower direct costs resulted in yearly advantage of Euro 9,600 in the whole farm gross margin for the grass/clover system. The gross margin per cow on grass/fertiliser-N and grass/clover was Euro 2,405 and Euro 2,496 respectively. Although the grass/clover system was competitive to the grass/fertiliser-N system on the basis of a "whole farm" or "per cow" comparison, the higher stocking rate on the grass/fertiliser-N system shifted this to a clear advantage in terms of gross margin per ha, i.e. Euro 4,129 for grass/fertiliser-N and Euro 3,676 for grass/clover.

Discussion

Animal performance

There was no confirmation of a higher milk production with grass/clover, as reported in earlier feeding experiments with either silage (Castle *et al*., 1983) or fresh herbage (Thomson *et al*., 1985; Wilkins *et al*., 1994; Remmelink, 2000). Considering that concentrate levels were similar in both systems and that a range of unintended and undetectable interactions may occur in system studies, the lack of a distinct response to clover is not surprising. Leach *et al*. (2000) and Weissbach & Ernst (1994) were also unable to demonstrate any milk production response to clover in their comparisons of grass/clover and grass/fertiliser-N based dairy systems.

Although the cows in the grass/clover system produced 1.1 kg FPCM day^{-1} more than the cows in the grass/fertiliser-N system, it is uncertain to what extent this difference can be attributed to white clover directly. It may be hypothesised that the higher stocking rate of the grass/fertiliser-N system is partly responsible for the silage shortage in that system. Along with the silage shortage, the area cut for silage, between July and the end of the growing season, was 40% lower in the grass/fertiliser-N system than in the grass/clover system. Consequently the mean proportion of grazing events on clean aftermath was 19% for grass/fertiliser-N and 37% for grass/clover.

There were no differences in milk production during the housing season, although the average silage intake was nearly 1 kg DM cow^{-1} day^{-1} higher for grass/clover. Possibly, the concentrate supplementation of 6 kg DM cow^{-1} day^{-1} has masked any effects of clover. Recent feeding experiments in the Netherlands (Remmelink, 2000) have confirmed that the milk production response to white clover is dependent on the concentrate level. Moreover, these experiments have revealed that the beneficial effect of white clover is higher in diets containing maize and grass(clover) silage together than in diets with only grass(clover).

The experiences in this experiment demonstrate that bloat is a potential hazard in rotational grazing systems with no supplementation of other roughages. The preventive measures used in this experiment, are either no longer allowed or unpractical for dairy farmers. Therefore it is advisable to prevent bloat by supplementation with small amounts of hay, grass silage or maize silage during periods with high risks. As experienced in a similar experiment in Scotland (Leach et.al., 2000), bloat risks might be lower in a set-stocking system, due to smaller and more gradual changes in the amounts of clover on offer.

Environmental performance

The achieved levels of N surplus and overall N utilisation do not suggest significant differences in the N utilisation between the two systems. Although the N surplus was 41 kg ha^{-1} $year^{-1}$ lower in the grass/clover system, this is mainly a direct consequence of the lower stocking rate. The N surplus per kg N produced was only 3% lower in the grass/clover system. Furthermore the difference in silage surpluses distorts the comparison as well. The sale of silage from the grass/clover system reduced the N surplus and improved the N utilisation, since the production of forage has a much higher N utilisation than the transformation of forage into milk. On the contrary, the purchase of silage in the grass/fertiliser-N system for the production of milk increased the N surplus and reduced the N utilisation. The calculation of the N surplus in the grass/clover system is also affected by the uncertainty of the exact amount of biological N fixation. If the amount of biologically fixed N would be estimated 10% lower, then the N utilisation would increase from 24.7 to 26.4%. Weissbach & Ernst (1994) also indicated that the use of grass/clover swards in itself, being the substitution of industrially fixed N by biologically fixed N, would not improve the N utilisation as such. It is the extensification, i.e. switching from high fertiliser N input systems to lower fertilised N input or low input clover systems, that increases the N utilisation.

The nitrate concentrations, measured in the drain water, are in line with the finding that the N utilisation was similar in both systems. But they also show the risk of grass/clover mixtures when clover contents in the swards become too high. In this respect, the upper limit of 50% white clover in the sward, suggested by Pflimlin (1993), seems justified. Especially in systems with no supplementation of low protein forages the relatively high protein concentration of autumn grass/clover is a disadvantage. Therefore it is recommended to compensate the high amounts of protein ingested on clover-rich swards with supplementation of maize silage, which is widely grown in the Netherlands, or whole-crop cereal silage.

As stated earlier, the amount of N fixed by clover is based on several assumptions and therefore the calculated N surplus of the grass/clover system has to be treated with caution. Biologically fixed N does not have to be accounted for in the Dutch mineral accounting system (MINAS), as is also the case with atmospheric deposition (MANMF, 1997). Using the MINAS methodology, the N surpluses would be 214 kg ha^{-1} for the grass/fertiliser-N system and −3 kg ha^{-1} for the grass/clover system. It is evident from this study that the calculated N surplus in MINAS is not a good indicator for the environmental performance of clover based dairy systems. Farmers might for instance adopt so called two-sward systems, for example with 35% of the area in unfertilised grass/clover and 65% of the area with intensively fertilised grass-only swards. In this way they can comply with MINAS regulations, although the real N surplus might still be environmentally unacceptable.

An environmental benefit of the grass/clover system is the lower energy consumption and thus the lower claim on fossil energy reserves. The energy use per 100 kg milk in the grass/clover system, 374 MJ per 100 kg milk, is in the lower part of the range of 373 to 742 MJ per 100 kg milk, as found in studies by Hageman & Mandersloot (1995).

Financial performance

The gross margin per cow in the grass/clover system was about 6% higher than in the grass/fertiliser-N system. However, the gross margin per ha of the grass/clover system lagged some 10% behind that of the grass/fertiliser-N system. With current high land prices, farmers will try to maximise the milk production per ha within the environmental limits. The results of the present experiment showed that the white clover based swards were able to support a moderately intensive dairy system, producing approximately 12 t milk ha^{-1} year^{-1}.

Conclusions

A white clover based dairy system, receiving 69 kg inorganic N ha^{-1} year^{-1}, produced 85% of the milk yield per ha of a grass/fertiliser-N based system, receiving 275 kg inorganic N ha^{-1} year^{-1}. The N utilisation at farm level was nearly 25% in both systems, and there was no difference in the average nitrate concentrations in drain water. The total energy use of the clover based system was 15% lower than that of the fertiliser-N based system.

The agronomic and environmental performance show that white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t FPCM ha^{-1} year^{-1} or less.

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CHAPTER 8

General discussion

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General discussion

Objectives

The major objective of this thesis is to provide a scientifically sound basis for the potential use of white clover on dairy farms in the Netherlands. This main objective is elaborated into more specific objectives for the system experiment and the field experiments. The objectives of the system experiment were

- to develop and demonstrate an agronomically, environmentally and economically sound white clover-based dairy system,
- to identify potential problems in the utilisation of white clover in dairying.

The field experiments aimed to quantify the potential herbage yield and herbage quality of mixed swards, under a range of management practices. Attention was given to nitrogen and phosphate application, and cutting and grazing management. For the field experiments, the following specific aims were formulated:

- to evaluate the potential yield and quality of mixed swards under cutting conditions,
- to determine the yield and herbage quality of mixed swards in a conventional rotational grazing and cutting system,
- to establish the effect of spring application of N on the performance of mixed swards,
- to quantify the combined effect of fertiliser N and P on the herbage yield and quality of mixed swards, and on the changes in soil nutrients,
- to increase the understanding of P utilisation in mixed swards and to provide a basis for P recommendations on mixed swards.

In the following sections the results of the experiments are evaluated, considering the initial objectives. Results of the field experiments are viewed in relation to the findings of the system study. In the first section the DM yield of mixed swards of perennial ryegrass and white clover in this study are compared with results of other studies in the Netherlands, both for cutting and grazing. The next two sections summarise the effects of N and P application on mixed swards, and formulate practical fertiliser recommendations for farmers. The two final sections present a general view on the prospects for white clover based dairy farms in the Netherlands. Special attention is paid to the effect of the present MINAS system on the use of white clover in dairy farms.

Dry matter yield of mixed swards

The average annual DM yield of grass/clover plots, without N application, in the three cutting experiments on the Waiboerhoeve was 13.3 t ha^{-1} (Table 1). Although the three experiments were all carried out at the Waiboerhoeve, the average DM yield ranged from 10.0 to 17.2 t ha^{-1} due to differences in years, grass and clover varieties, cutting dates and previous use of paddocks. If the DM yields are expressed as relative yields within an experiment, there appeared to be a curvilinear relation between the relative DM yield and the temperature during the growing season (Figure 1). The lowest relative yields were observed in the coldest years. The growth of white clover is positively related to temperature, with an optimum around 24 ^{o}C (Hart, 1987), but higher temperatures increase the need for water. The precipitation surplus during spring and summer varied considerably, from –165 to + 163 mm. However, no relation could be observed between the relative DM yields of the cutting experiments and precipitation surplus.

The observed DM yields on the cutting experiments at the Waiboerhoeve are among the highest yields recorded, for mixed swards receiving no fertiliser or slurry N, within the Netherlands (Table 1). At Lelystad, the overall weighed mean DM yield was 13.4 t ha^{-1} $year^{-1}$, with an average clover proportion of approximately 40%. On a river clay soil

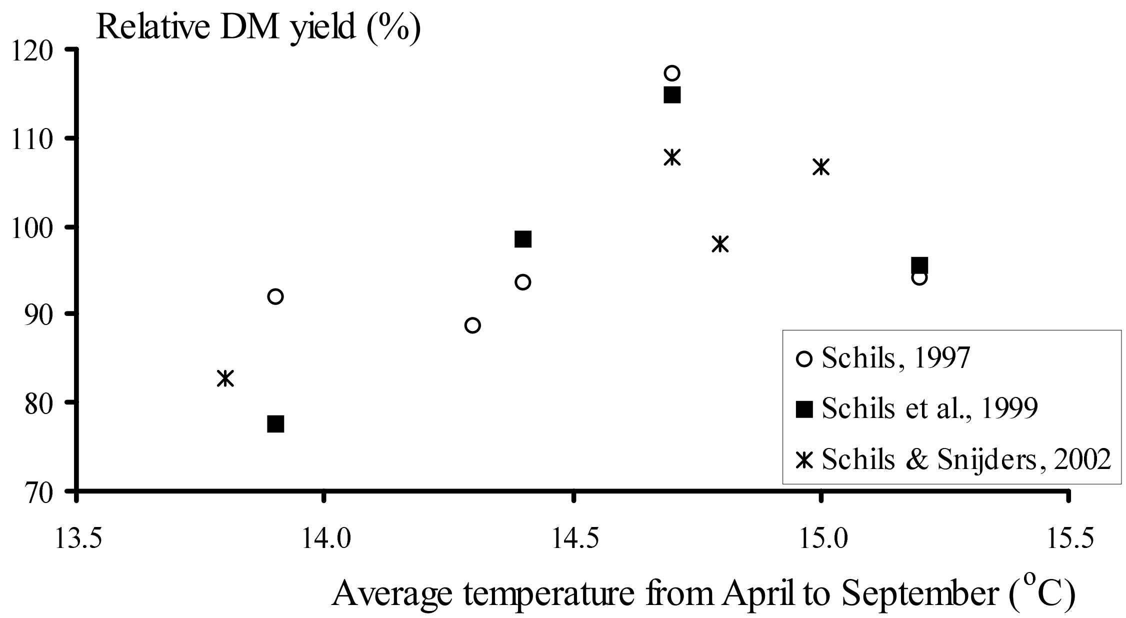

Figure 1. Relative DM yield (%) of unfertilised (N) cut grass/clover plots in relation to the average temperature during spring and summer. Within each of the three experiments, the DM yield is expressed relative to the average DM yield.

at Wageningen (Elgersma *et al*., 1998), the average DM yields were nearly 25% lower than at the marine clay soil in Lelystad. The relative DM yields of mixtures with Alice, Gwenda and Retor were 113, 100 and 87%, respectively. The overall weighed mean DM yield on clay was 12.0 t ha^{-1} $year^{-1}$.

The data of the sandy soils consist of a wider diversity of locations, soil types and clover varieties. Therefore, the annual DM yields show a much wider range, namely from 3.76 to 16.67 t ha^{-1}. On the sandy soils, the overall weighed mean DM yield was 10.0 t ha^{-1} $year^{-1}$, with an average clover proportion of approximately 43%. The lowest DM yields were observed on a dry sandy soil at Hengelo.

Table 2 presents an overview of DM yields recorded under practical farm management, i.e. rotational grazing and cutting and a moderate N application of up to 150 kg ha^{-1} $year^{-1}$. The overall weighed mean DM yields were 11.9 t ha^{-1} $year^{-1}$ on clay soils and 9.8 t ha^{-1} $year^{-1}$ on sandy soils, which is only slightly lower than the observed DM yields under permanent cutting. But it has to be taken into account that the data of Tables 1 and 2 cannot be compared directly, as they are partly based on different years and locations. A direct comparison is allowed for the data recorded at Lelystad and Heino. At Lelystad, the DM yields achieved under grazing were similar to the DM yields under cutting, despite the lower clover content. This also applies for the comparison of the organically managed at Heino. The average DM yield of the cut plots was 9.6 t ha^{-1} $year^{-1}$, compared to 9.3 t ha^{-1} $year^{-1}$ on the cut and grazed plots. Probably, the higher N input through fertiliser, slurry and return of excreta on the grazed plots offsets the lower N fixation.

In some cases, the DM yields obtained on organic farms were 20 to 30% lower than the DM yields on conventional farms. This may be caused by a sub-optimal application of other nutrients like P or K. Furthermore, the botanical composition of the organic swards will generally be more diverse, potentially with a higher proportion of lower yielding species.

In the system experiment (Schils *et al*., 2000a), the average calculated net DM yields of the grass/clover swards were 10.1 t ha^{-1} $year^{-1}$. Considering the three corresponding years of the experiment with rotational grazing and cutting (Schils *et al*., 1999), the DM yield of treatments, corresponding with the management of the grass/clover system, i.e. rotational grazing and cutting and 50 kg N ha^{-1}, was 13.64 t ha^{-1} $year^{-1}$. The gap between the 'gross' DM yield of the experiment and the 'net' DM yield of the system amounted to 26%. The net DM yield of 10.1 t ha^{-1} was made up of a 4.5 t ha^{-1} intake during grazing and 5.6 t ha^{-1} of cut grass for silage. Assuming the standard grazing losses of 20% for day-and-night rotational grazing (PR, 1997), the gross yield during grazing can be estimated at 5.6 t ha^{-1}. Experiments by Corporaal (1993) on the same site showed that the average DM field losses between cutting and ensiling were 9% for grass/clover swards.

Table 1. Annual DM yields (t ha^{-1}) and white clover proportion (%) of perennial ryegrass/white clover swards, receiving no fertiliser or slurry N, in recent cutting experiments in the Netherlands.

Soil type	Location	First year	Years	Clover variety	Clover Proportion	Method[1]	Annual DM yield Mean	Min	Max	System[2]	Reference
Clay	Lelystad	1989	5	Retor	50	dm	14.25	13.01	17.21	Conv	Schils, 1997
Clay	Lelystad	1994	1	Retor	34	dm	14.20			Conv	Schils, unpublished
Clay	Lelystad	1989	4	Retor	40	cv	12.41	9.97	14.74	Conv	Schils *et al*., 1999
Clay	Lelystad	1995	4	Alice/Retor	48	dm	12.94	10.83	14.11	Conv	Schils *et al*., 2002a
Clay	Lelystad	1993	1	Retor	30	dm	11.27			Conv	Schils, unpublished
Clay	Lelystad	1991	2	Retor	51	dm	15.12	15.01	15.23	Conv	Schils, 1993a
Clay	Wageningen	1992	5	Alice	65	dm	11.68	9.10	13.60	Conv	Elgersma & Schlepers, 1997; Elgersma *et al*., 1998
Clay	Wageningen	1992	5	Gwenda	54	dm	10.36	8.30	12.20	Conv	Elgersma & Schlepers, 1997; Elgersma *et al*., 1998
Clay	Wageningen	1992	5	Retor	52	dm	8.98	6.90	11.40	Conv	Elgersma & Schlepers, 1997; Elgersma *et al*., 1998
Clay/Peat	Mastenbroek	1999	3	Riesling	17	cv	12.97	12.43	13.87	Conv	Van Schooten & Sikkema, 2002
Sand	Heino	1992	3	Retor	42	dm	13.34	10.78	16.67	Conv	Schils, 1997
Sand	Heino	1995	3	Alice/Retor	51	dm	12.13	10.04	14.00	Conv	Schils & Sikkema, 1998
Sand	Heino	1993	4	Retor	24	dm	8.88	7.48	10.84	Organ	Baars, 2001
Sand	Heino	1993	6	Aberherald	37	dm	9.69	8.12	11.29	Organ	Baars, 2001
Sand	Heino	1993	6	Alice	36	dm	9.69	8.21	11.73	Organ	Baars, 2001
Sand	Heino	1996	3	Alice	51	dm	9.96	9.17	10.76	Organ	Baars, 2000
Sand	Heeten	1999	3	Riesling	59	cv	13.16	11.26	14.44	Conv	Van Schooten & Sikkema, 2002
Sand	De Lutte	2000	2	Alice	67	cv	12.84	11.77	13.90	Conv	Van Schooten & Sikkema, 2002
Sand	Hengelo	1990	1	Alice/Retor	50	dm	7.30	6.20	8.05	Conv	Baan Hofman, 1999
Sand	Hengelo	1992	3	Milka	33	dm	6.18	3.76	9.32	Conv	Baan Hofman, 1999
Sand	Wageningen	1993	3	Retor	49	dm	9.29	8.47	10.07	Conv	Van Der Meer & Baan Hofman, 1999
Sand	Wageningen	1996	2	Alice	54	dm	11.95	10.10	13.80	Conv	Elgersma *et al*., 2000
Sand	Wageningen	1996	2	Gwenda	41	dm	11.25	9.60	12.90	Conv	Elgersma *et al*., 2000
Sand	Wageningen	1996	1	Aberherald	21	dm	6.50			Conv	Elgersma & Schlepers, 2003
Sand	Wageningen	1996	1	Huia	27	dm	6.70			Conv	Elgersma & Schlepers, 2003

[1] Proportion of white clover was either determined in the dry matter (dm) or by a visual estimation of the plant cover (cv)
[2] conv = conventional system; organ = organic system

Table 2. Annual DM yields (t ha^{-1}) and white clover proportion (%) of perennial ryegrass/white clover swards, receiving up to a total of 150 kg N ha^{-1} year^{-1} from fertiliser and slurry, with rotational grazing and cutting management in the Netherlands.

Soil type	Location	First year	Years	Clover variety	Clover proportion	Method[1]	Annual DM yield Mean	Min	Max	System[2]	Reference
Clay	Lelystad	1989	4	Retor	23	cv	13.64	11.48	15.42	conv	Schils *et al.*, 1999
Clay	Lelystad	1990	2	Retor	14	dm	12.7	12.3	13.1	conv	Schils, 1993b
Clay	Werkendam	1987	3	Retor	51	dm	9.4	8.5	10.6	organ	Baars & Van Dongen, 1992
Clay	Linschoten	1991	3	Alice	38	dm	10.1	9.5	11.4	organ	T. Baars, pers. comm.
Clay	Wiewerd	1991	3	Alice	29	dm	11.1	10.9	11.5	organ	T. Baars, pers. comm.
Clay	Achlum	2001	1	Alice			14.5			organ	N. Van Eekeren, pers. com.
Clay	Sijbekarspel	2001	1	Alice	28	dm	15.4			organ	N. Van Eekeren, pers. com.
Loss	Walem	2001	1	Alice			10.6			organ	N. Van Eekeren, pers. com.
Loss	Reijmerstok	2001	1	Alice	16	dm	12.2			organ	N. Van Eekeren, pers. com.
Sand	Heino	1993	4	Retor	27	dm	8.82	7.18	9.96	organ	Baars, 2001
Sand	Heino	1993	5	Aberherald	34	dm	9.25	8.03	10.64	organ	Baars, 2001
Sand	Heino	1993	5	Alice	37	dm	9.41	8.50	9.99	organ	Baars, 2001
Sand	Venray	1994	3	8 varieties[3]	38	cv	9.91	8.86	10.48	conv	J. Visscher, pers. comm.
Sand	Venray	1997	2	8 varieties[3]	37	cv	12.55	11.88	13.21	conv	J. Visscher, pers. comm.
Sand	Venray	2000	2	8 varieties[3]	15	cv	10.39	9.80	10.99	conv	J. Visscher, pers. comm.
Sand	Heino	2001	1	8 varieties[3]	41	cv	10.99	10.99	10.99	organ	J. Visscher, pers. comm.
Sand	Orvelte	1991	3	Alice	21	dm	7.7	7.7	7.8	organ	T. Baars, pers. comm.
Sand	Haaren	2001	1	Alice	26	dm	11.4			organ	N. Van Eekeren, pers. com.
Sand	Doorn	2001	1	Riesling	51	dm	14.2			organ	N. Van Eekeren, pers. com.
Sand	Kallenkote	2001	1	Alice	25	dm	10.0			organ	N. Van Eekeren, pers. com.

[1] Proportion of white clover was either determined in the dry matter (dm) or by a visual estimation of the plant cover (cv)
[2] conv = conventional system; organ = organic system
[3] National List Trials; Pertina, Barbian, Retor, Rivendel, Aran, Riesling, Ramona and Alice

This leads to a gross DM yield of cut grass of 6.2 t ha^{-1}. The overall gross DM yield of the grass/clover swards in the system can therefore be estimated at 11.8 t ha^{-1} year^{-1}. Thus, taking into account the possible grazing and cutting losses narrows the observed difference between the calculated yields of grass/clover fields in the system and the measured yields in the corresponding experiment.

Nitrogen application

Nitrogen is the main nutrient determining the production of grassland. There is an abundance of experiments in which the effect of N application on the herbage production of grass/clover swards was measured (e.g. Frame & Newbould, 1987). The results of those experiments have led to the classic concept for the N response of grass/clover swards in relation to grass-only swards (Figure 2). It shows that the N response of grass/clover swards is considerably smaller than the N response of grass-only swards. Therefore, the year-round use of N on grass/clover swards is only considered to be beneficial up to low levels of 100 or 150 kg ha^{-1} year^{-1}. This is confirmed by the results of Schils *et al*. (2002a), in which an N application of 190 kg N ha^{-1} year^{-1} on grass/clover increased the DM yield with 4 kg per kg N. Exclusion of the establishment year reduces

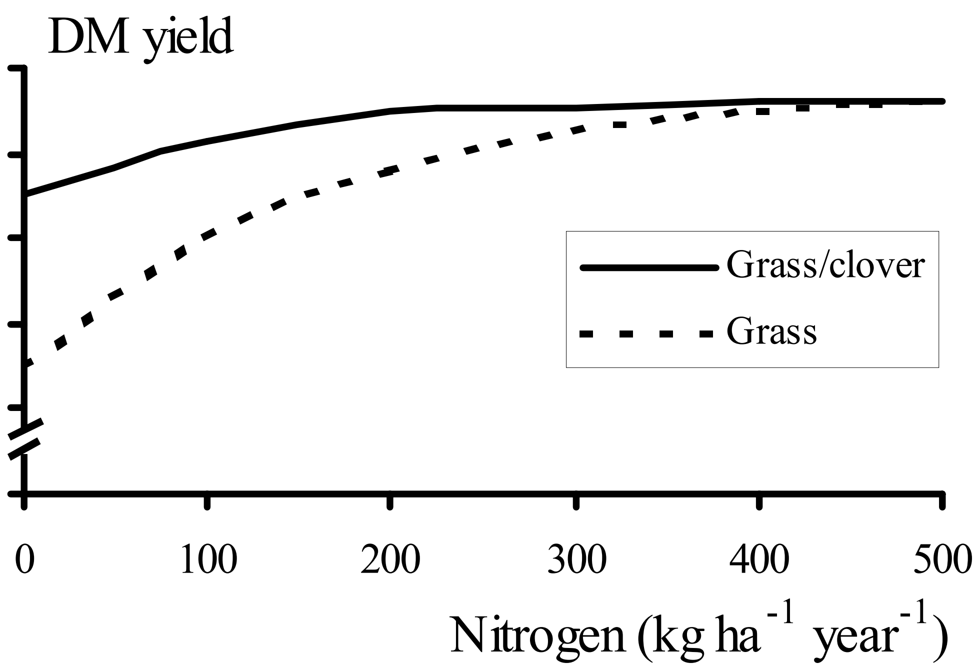

Figure 2. Dry matter yield of grass-only and grass/clover swards in relation to N application.

the N efficiency even further to 1.6 kg DM (kg N)$^{-1}$.

Considering the N yield of grass/clover mixture, N application has no positive effect or even a small negative effect. This means that the increased N yield of the grass component is completely offset by the reduced N fixation.

Although the year-round application of N is not considered to be economical, N can be used effectively on grass/clover swards, if its use is restricted to spring. The so-called 'strategic' application of N increases the DM yield in the first cut, only with a temporary reduction of white clover content. Of course, due to the lower clover content the dry matter yield in the following cuts is lower. But on an annual basis, strategic N application results in a higher DM yield. The results of cutting experiments on clay and sandy soil showed that a spring N application of 50 kg ha^{-1} increased the DM yield of the first cut with 11.2 and the annual DM yield with 10.4 kg DM per kg N (Schils, 1997). This N efficiency is above the economical optimal value of 7.5 kg DM per kg N (Unwin & Vellinga, 1994). The effect of an additional 50 kg N ha^{-1} was 6.3 kg DM per kg N in the first cut, and 4.4 kg DM per kg N for the annual yield.

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 temporary reduction of the white clover content. Moreover the results at Lelystad showed that, even after 5 years, repeated application of spring N had no detrimental effect on white clover. In a practical farming system, a strategic N application in spring does not necessarily has to be from artificial fertiliser but may just as well originate from slurry. For instance, shallow injection of 20 m^3 ha^{-1} of cattle slurry, which is approximately equivalent to 50 kg of fertiliser N per ha, is a common practice on most dairy farms.

Besides the relatively strict economical criteria, spring application of N can also be seen as a kind of safeguard for the herbage production in the first cut. On Dutch dairy farms, spring growth of grass is very important in order to secure a considerable proportion of the winter feed or 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. Especially in the first years after conversion to grass/clover swards, spring application of N might be useful for the farmer's confidence. This can be illustrated by the development of the fertiliser strategy on the white clover based dairy system at the Waiboerhoeve. In the first and second year of the experiment (Schils *et al.*, 2000a), the N application consisted of a basic slurry application of 20 m^3 ha^{-1}, and an additional fertiliser application of 20 kg N ha^{-1} for all paddocks. In the third year the additional fertiliser application was only applied on the paddocks, assigned to be cut for silage. In the follow-up of the system (Schils *et al.*, 2000c), fertiliser N was not used anymore.

Phosphorus application

The observed P response of the grass/clover swards was different from that of the grass-only swards (Schils & Snijders, 2002a). The grass component of the mixed swards showed a positive response of DM yield, P concentration and P yield to P application, similar to the responses observed in the grass-only swards. In contrast, the clover component of the mixed sward showed no response to P in DM yield and P yield. Consequently, there is a possible negative effect of P application on clover proportions in mixed swards. The negative effect of P application on white clover yield appeared to increase with N application. However, the data are not sufficient to quantify an optimal P strategy for grass/clover swards.

One of the objectives of the current P recommendations for grassland is to achieve an agronomically 'sufficient' soil P status (Agterberg & Henkens, 1995; PR, 1998). The recommended application is based on the current P-AL value of the soil and the P removal through silage cuts. If the present P-AL value is lower than the target P-AL value, the recommended P application exceeds the P removal through silage, and vice versa. The observed relationship between P surplus and change in P-AL value was similar for grass-only and grass/clover swards (Schils & Snijders, 2002b). Therefore, the procedure in the recommendations to change the P-AL value to a desired level does not have to be different for grass/clover swards.

Furthermore it is important to know whether the desired P-AL value for grass/clover should be dissimilar from the desired P-AL value for grass-only swards. The indication of a negative effect of P application on clover proportions in mixed swards would suggest that the target P-AL value for grass/clover swards should be lower than for grass-only swards. However, the present data are not sufficient to substantiate any new recommendation. For the moment, only a careful approach can be advised, i.e. at least not to exceed the P recommendations for grass-only swards.

Performance of white clover based dairy systems

The white clover based dairy system at the Waiboerhoeve produced 12 t Fat and Protein Corrected Milk (FPCM) per ha per year (Schils *et al.*, 2000b). As there was an annual silage surplus of 29 t DM, there was some scope for a higher milk production per ha. This was undertaken in the follow-up of the grass/clover system (Schils *et al.*, 2000c). After the completion of the system comparison between grass/fertiliser-N and grass/clover, the grass/clover system was continued as an independently run dairy farm. In this follow-up, the milk production per ha was increased to 13.5 t ha^{-1} $year^{-1}$.

However, the higher milk production per ha could only be achieved by more imports of concentrates and silage. Compared to the first phase, the silage surplus was turned into a silage shortage of 19 t year^{-1}, and the concentrate use increased from 2684 to 3099 kg ha^{-1} year^{-1}. Furthermore, 10% of the area was turned into forage maize. From July onwards, maize silage was supplemented to the dairy cows at a level of 2 to 4 kg DM cow^{-1} day^{-1}, in order to prevent bloat and to reduce the N content in the diet. Maize silage was also fed during the winter, along with grass/clover silage.

In the Netherlands, other data on milk productions per ha in white clover based dairy systems are scarce. There are no data on conventional white clover based dairy farms. In a similar experiment in the West of Scotland, 10.2 t milk per ha was produced (Leach *et al.*, 2000), with a similar concentrate use of 2608 kg ha^{-1} year^{-1}. In the experiment in Scotland, the annual milk production per cow was 5700 kg, which is substantially lower than the production of 8294 kg FPCM cow^{-1} year^{-1} in the experiment on the Waiboerhoeve.

In the Netherlands, the only farm data on hand are from organically managed dairy systems. In 1999, the average milk production per ha on organic dairy farms was 8.9 t milk per ha per year (LEI, 2002). In a current monitoring project of organic dairy farms (Bleumink & Van Eekeren, 2000), the milk production ranges from 5.2 to 11.3 t ha^{-1} year^{-1}. One of the most intensive organic farms in the Netherlands manages to produce 12.9 t milk ha^{-1} year^{-1} on sandy soil (Oenema *et al.*, 2001).

Taking into account the results of the dairy system on the Waiboerhoeve and organic farms, a milk production of approximately 12 t ha^{-1} year^{-1} could be considered as an upper limit for the use of grass/clover mixtures. Data from 1999 (LEI, 2002) show that, in the Netherlands, 50% of the dairy farms produce less than 12 t milk ha^{-1} year^{-1}. Assuming that white clover can be grown successfully on all clay and sandy soils in the Netherlands, there is a considerable scope for the use of grass/clover swards. Approximately 30% of the dairy farms are situated on clay soils, of which 53% produce less than 12 t ha^{-1} year^{-1}. Some 60% of the dairy farms are located on sandy soils, of which 47% produce less than 12 t ha^{-1} year^{-1}.

White clover in the MINAS era

In 1998, the Mineral Accounting System (MINAS) was introduced (Henkens & Van Keulen, 2001). The MINAS balance is a ‘farm-gate’ balance, taking into account the N imports such as fertilisers and feeds, and the N exports through milk and animals. Nitrogen input through biological fixation and deposition does not have to be accounted for. By the year 2003 the allowed, levy-free, MINAS N surpluses are 140 kg ha^{-1} year^{-1}

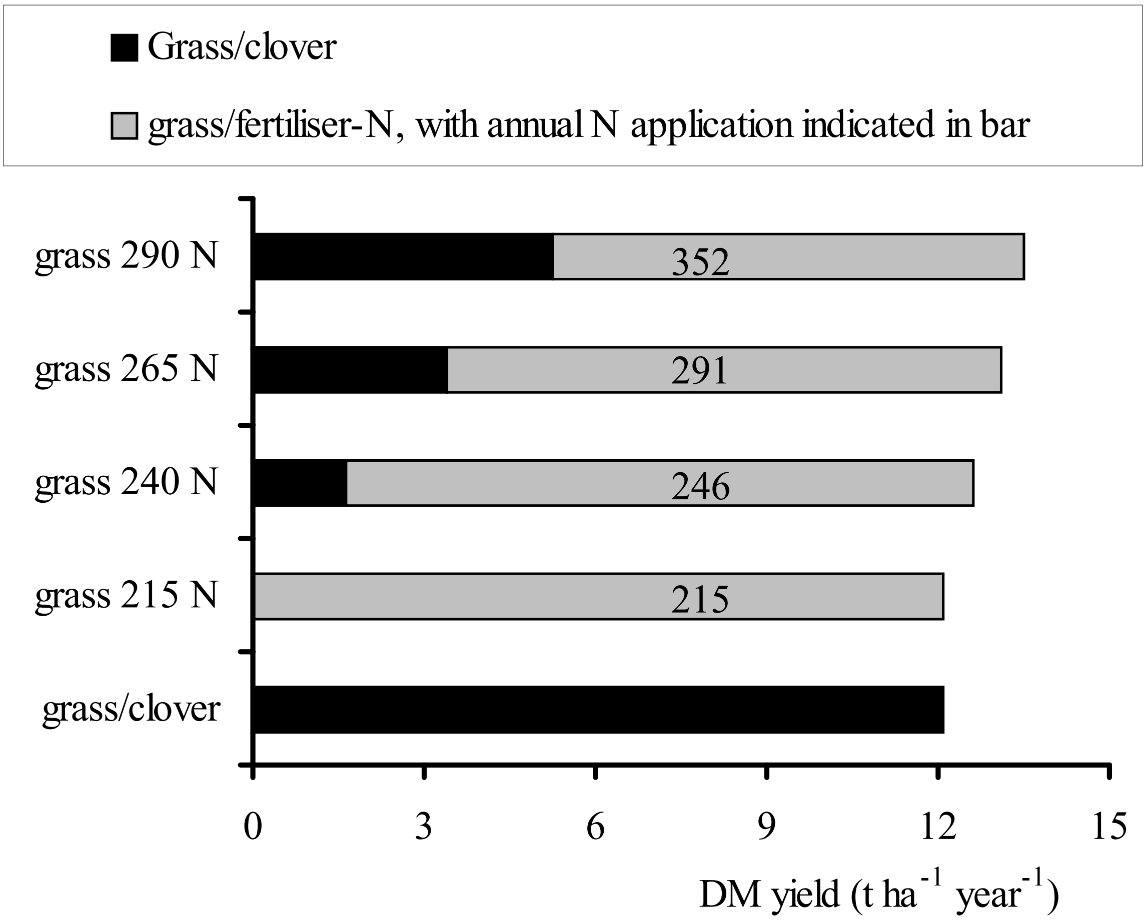

Figure 3. Strategies for two-sward systems, based on the data of Schils & Snijders (2002a). The DM yield of unfertilised grass/clover swards is similar to the DM yield of a grass-only sward that receives 215 kg N ha^{-1} year^{-1}. The DM yield of grass-only systems with an initial application of 240, 265 or 290 kg N ha^{-1} year^{-1} can alternatively be achieved with a combination of unfertilised grass/clover swards and more intensively fertilised grass-only swards. See text for further explanation.

for grassland on dry sandy soils and 180 kg ha^{-1} year^{-1} for grassland on the other soil types.

The white clover based dairy system at the Waiboerhoeve had a 'real' N surplus of 212 kg ha^{-1} year^{-1} and a MINAS surplus of –3 kg ha^{-1} year^{-1} (Schils *et al.*, 2000b). Clearly, these figures illustrate that the MINAS surplus of white clover based systems is not a proper indicator for the potential N losses. So, next to the first 'intensity-driven' category of potential users of mixed swards, there is second 'MINAS-driven' category.

The first group finds its motivation for the use of grass/clover swards in the relatively low intensity (< 12 t milk ha^{-1} $year^{-1}$). This first group benefits most by a complete conversion from grass/fertiliser-N to grass/clover. The second category produces more than 12 t milk ha^{-1} $year^{-1}$, and needs a high N input to achieve the necessary herbage production. That second group benefits most from a partial conversion to grass/clover, the so-called two-sward system. This implies that one area of the farm consists of unfertilised grass/clover swards, and another area consists of relative intensively fertilised grass-only swards. For instance, on a farm with grass-only swards that receive an annual N application of 290 kg ha^{-1}, the annual DM yield is 13.5 t ha^{-1} (Figure 3). To comply with MINAS, the N application has to be reduced to a level of 215 kg N ha^{-1} $year^{-1}$. If the N application on the grass swards would be reduced to 215 kg ha^{-1} $year^{-1}$, the DM yield would be reduced to 12.1 t ha^{-1} $year^{-1}$. By converting 40% of the area to unfertilised grass/clover swards, the N application on the remaining grass-only swards can be 352 kg ha^{-1} $year^{-1}$. The grass/clover swards produce 12.1 t ha^{-1} $year^{-1}$, while the grass-only swards now produce 14.3 t ha^{-1} $year^{-1}$. Averaged over the whole area, the production remains at the initial level of 13.5 t ha^{-1} $year^{-1}$, but with an average N application of only 215 kg ha^{-1} $year^{-1}$.

In a similar way, farms with an initial N application of 265 or 240 kg ha^{-1} $year^{-1}$, could convert 26 or 13% into grass/clover, respectively (Figure 3). Presently, this strategy is already put to practice by several dairy farms in the Netherlands (Oenema *et al.,* 2001). From the farmer's short-term point of view, the strategy with the two-sward system is understandable. But on the longer term it will become evident that this strategy does not serve the target of MINAS, that is reducing N losses.

Main conclusions

In a dairy farm system, mixed swards of perennial ryegrass and white clover had satisfactory but highly variable clover contents in the swards. The variation in clover was partly explained by season, clover variety and sward age x clover variety, but 72% of the variation remained unexplained. The mixed swards, fertilised with 69 kg inorganic N ha^{-1} $year^{-1}$, produced 90 to 95% of the DM yield on grass-only swards, fertilised with 275 kg inorganic N ha^{-1} $year^{-1}$.

The herd of the white clover based system produced 85% of the milk yield per ha of the grass/fertiliser-N based system. The N utilisation at farm level was nearly 25% in both systems, and there was no difference in the average nitrate concentrations in drain water. The total energy use of the clover-based system was 15% lower than that of the fertiliser-N based system.

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.

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. It reduced the mean annual white clover content from 45 to 34%.

The results of the present system experiment demonstrated the potential of mixed swards of perennial ryegrass and white clover in a rotational grazing and cutting system. In a controlled experiment, the average annual DM yields were 13.40 t ha^{-1} with rotational grazing and cutting, compared to 12.82 t ha^{-1} with cutting only. With rotational grazing and cutting, average values of *in vitro* Organic Matter Digestibility and Crude Protein were 801 g kg^{-1} OM and 193 g kg^{-1} DM, respectively.

Nitrogen was the main factor determining the yield and quality of the harvested herbage. Phosphorus application did not increase clover yield. The results indicated a possible negative effect of P application on clover proportions in mixed swards. Further research has to show whether this is valid under other conditions, e.g. other soil types and P statuses, as well. For the moment it can be advised at least not to exceed the P recommendations for grass-only swards.

There were no differences in accumulation of soil N and P under grass-only and grass/clover swards. Due to a lower C accumulation, the C/N-ratio was lower under grass/clover swards.

The agronomic and environmental performance show that white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t milk ha^{-1} $year^{-1}$ or less. However, within the MINAS system more intensive farms can benefit from a partial conversion to grass/clover. The prospect for white clover will certainly be affected by the developments in the nutrient policy.

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Summary

Introduction

In the Netherlands, the use of white clover (*Trifolium repens* L.) decreased during the 1960s and 1970s, along with the increased use of fertiliser nitrogen. However, the present efforts to reduce the nitrogen (N) losses on dairy farms have reduced the use of fertiliser N. Consequently, farmers show a renewed interest in white clover. However, for many dairy farmers it is unclear whether mixed swards of perennial ryegrass and white clover are able to produce enough herbage of good quality to be the backbone of their dairy system. Therefore, the general objective of this thesis was to provide a scientifically sound basis for the use of white clover on dairy farms in the Netherlands.

To facilitate the research on white clover, one of the dairy units at the Waiboerhoeve experimental farm was designated for the white clover project. A new dairy farm was built and grassland was re-arranged to be able to conduct a system comparison between a traditional grass/fertiliser-N system and a new grass/clover system. An integrated system research was chosen to study the whole cycle of events from the inputs of fertiliser, biologically fixed N and concentrates, through the processes such as feed production, grazing, feed intake and slurry application, to the outputs of milk and meat. The objectives of the system experiment were to design and demonstrate an agronomically, environmentally and economically sound white clover-based dairy system, and to identify potential problems in the utilisation of white clover in dairy farming.

Specific research questions on processes within the system were addressed in separate experiments with detailed measurements. The field experiments aimed to quantify the potential herbage yield and herbage quality of mixed swards, under a range of management practices. Attention was paid to nitrogen and phosphate application, and cutting and grazing management.

The results of the field experiments are presented in Chapters 2 to 5, and the findings of the system comparison are presented in Chapters 6 and 7. Chapter 8 synthesises all results and concludes with a general view on the perspective for white clover based dairy farms in the Netherlands.

Strategic nitrogen application

Strategic spring application of N was discussed in Chapter 2. 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.

Rotational grazing and cutting

Chapter 3 deals with the performance of a grass/clover sward under a rotational grazing and cutting management. The effects of intensity of cutting, grassland management system and N application in spring were evaluated in a four-year grazing experiment with dairy cows.

The experiment consisted of all combinations of two defoliation systems, i.e. one or two silage cuts per year (S1, S2), spring N application rate, i.e. 0 or 50 kg ha^{-1} year^{-1} (N0, N50) and management system, i.e. rotational grazing and cutting or cutting only (RGC, CO). The overall mean white clover cover was 30%. All treatments affected white clover cover, which was 8% higher with S2 than with S1, 6% higher with N0 than with N50 and 12% higher with CO than with RGC. The overall mean annual dry matter (DM) yield (13.1 t ha^{-1} year^{-1}) was significantly affected only by management system: in two relatively wetter years, the annual DM yield was 1.19 t ha^{-1} higher with RGC than with CO, while there was no difference in two relatively drier years. Nitrogen application increased the DM yield in the first cut by 7.0 kg per kg N applied, but had no significant effect on the annual DM yield. Herbage quality was not affected by the experimental treatments. The average *in vitro* organic matter digestibility was 801 g kg^{-1} organic matter and the average crude protein content was 193 g kg^{-1} DM.

Nitrogen and phosphorus application

Phosphorus (P) application on grass/clover swards, and its effect on herbage and soil parameters is discussed in Chapters 4 and 5. The combined effect of reduced N and P application on the production of grass-only and grass/clover swards was studied in a cutting experiment on a marine clay soil. The experiment was established on newly sown swards and lasted for five years. The treatments included specific combinations of four P levels (0, 35, 70 and 105 kg P ha^{-1} $year^{-1}$), three N levels (0, 190 and 380 N kg ha^{-1} $year^{-1}$) and two sward types (grass-only and grass/clover).

Nitrogen was the main factor determining the yield and quality of the harvested herbage. On the grass-only swards, N application increased the DM yield with 28 or 22 kg DM kg^{-1} N, after application of 190 or 380 kg N ha^{-1} $year^{-1}$, respectively. The average apparent N recovery of applied N was 0.78 kg kg^{-1}. On the grass/clover swards, N application increased grass production at the cost of white clover production. The average proportion of white clover decreased from 41 to 16% following an N application of 190 kg ha^{-1} $year^{-1}$.

The average apparent P efficiency after application of 34, 68 or 100 kg P ha^{-1} $year^{-1}$ was 13.0, 9.0, and 9.1 kg DM kg^{-1} P, respectively. Phosphorus application did not increase clover yield. The results suggested a negative effect of P application on clover proportions in mixed swards.

A positive interaction between N and P applications was observed. However, the consequences of this interaction for the optimal N application were only minor, and of little practical relevance.

In the same experiment, the effects of reduced nitrogen N and P application on the accumulation of soil N, P and carbon (C) were studied. Both the P-AL-value and total soil P showed a positive response to P application and a negative response to N application. Furthermore, the positive effect of P application decreased with increasing N application. The annual changes in P-AL-value and total soil P were closely related to the soil surface balance, which in turn was determined by the level of N and P application and their interaction. The observed effects were most evident in the top soil layer of 0-5 cm. Balanced P application did not lead to lower P-AL values.

The accumulation of soil N on the grass-only was positively affected by N application, but was unaffected by P application and sward type. The accumulation of organic C was unaffected by N or P application, but was lower under grass/clover than under grass-only.

White clover based dairy system

Chapters 6 and 7 presents the findings of a systems study, in which a grass/clover and a grass/fertiliser-N based dairy farm were compared during three years. Mixed swards of perennial ryegrass and white clover were established successfully through reseeding or sodseeding. Both systems had 59 dairy cows and a milk quotum of 450 tonnes per year. The allocated areas of 41 ha for the grass/clover system and 34 ha for the grass/fertiliser-N system were based on an expected yield difference of 15 to 20% in favour of the grass/fertiliser-N swards. The grassland management consisted of a rotational grazing system with one to three silage cuts per paddock, depending on herbage growth.

The average white clover ground cover was 31, 30 and 26% in the three subsequent years, but with a large variation between seasons and paddocks. Season, clover variety and sward age x clover variety accounted for 28% of the variance in clover cover, but 72% remained unaccounted for.

Grass/clover and grass/fertiliser-N swards received 69 and 275 kg N ha^{-1} $year^{-1}$, respectively, including the inorganic N from applied cattle slurry, but excluding animal excreta during grazing. The average annual net DM yield from grass/fertiliser-N swards was 10.8 t ha^{-1} and from grass/clover swards 10.1 t ha^{-1}. The yield difference occurred mainly in spring, but was smaller than expected, causing a relative silage surplus for the grass/clover system. The organic matter digestibility of grass/clover was slightly, but consistently, higher than that of grass-only, while the crude protein concentration of grass/clover was consistently higher from July onwards.

During the grazing season, the cows in both groups were supplemented with 3.5 kg concentrates day^{-1}. The daily Fat and Protein Corrected Milk (FPCM) production was 25.7 and 26.5 kg cow^{-1} for grass/fertiliser-N and grass/clover, respectively. The difference in milk production occurred from July onwards. Despite preventive measures in the grass/clover system, bloat occurred several times between August and October. During the housing season, cows received *ad libitum* grass or grass/clover silage with 6 kg concentrates cow^{-1} day^{-1}. Although the intake of grass/clover silage was consistently higher, there were no differences in milk production.

The grass/clover system had a lower N surplus, but this was related to the lower intensity of the system. The overall N utilisation was 25% in both systems. The average nitrate concentration in drain water, measured on a selection of fields, was 26 and 28 mg l^{-1} for grass/fertiliser-N and grass/clover, respectively. The nitrate concentrations in drain water from grass/clover fields were positively related with the clover content in the sward. The energy use of the grass/clover system was 15% lower than that of the grass/fertiliser-N system, with the fertiliser use as the main source of difference. Compared to the grass/fertiliser-N system, the gross margin per cow was slightly higher for grass/clover, but the gross margin per ha was 10% lower for grass/clover.

Considering agronomic and environmental aspects only, white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t milk ha^{-1} $year^{-1}$ or less.

Synthesis

In Chapter 8 the results of the experiments are evaluated, considering the initial objectives.

The observed DM yields on the cutting experiments at the Waiboerhoeve were among the highest yields recorded, for mixed swards receiving no fertiliser or slurry N, within the Netherlands. The mean DM yields, recorded on cutting experiments, not receiving any N from fertiliser or slurry, was 10.9 t ha^{-1} $year^{-1}$, and ranged from 3.8 to 17.2 t ha^{-1} $year^{-1}$. The average DM yields on clay and sandy soils were 12.0 and 10.0 t ha^{-1} $year^{-1}$, respectively.

The average DM yields recorded under a practical farm management, i.e. rotational grazing and cutting and a moderate N application of up to 150 kg ha^{-1} $year^{-1}$, were 10.6 t ha^{-1} $year^{-1}$, with a range of 7.2 to 15.4 t ha^{-1} $year^{-1}$. The results suggest that the achieved DM yields under grazing were almost similar to the DM yields under cutting, despite the lower clover content.

The year-round use of N on grass/clover swards is only considered to be beneficial up to low levels of 100 or 150 kg ha^{-1} $year^{-1}$. which was confirmed by the results in this study. Although the year-round application of N is not considered to be economical, N can be used effectively on grass/clover swards, if its use is restricted to spring. The so-called 'strategic' application of N increases the DM yield in the first cut, only temporarily reducing white clover content. 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.

The white clover based dairy system at the Waiboerhoeve produced 12 t FPCM per ha. In the Netherlands, other data on milk productions per ha in white clover based dairy systems are scarce. In the Netherlands, the only farm data on hand are from organically managed dairy systems. In 1999, the average milk production per ha on organic dairy farms was 8.9 t milk per ha. In a current monitoring project of organic dairy farms, the milk production per ha ranges from 5.2 to 11.3 t ha^{-1} $year^{-1}$. Taking into account the results of the dairy system on the Waiboerhoeve and organic farms, a milk production of approximately 12 t ha^{-1} could be considered as an upper limit for the use of grass/clover mixtures. Data from 1999 show that, in the Netherlands, 50% of the dairy farms produce less than 12 t milk ha^{-1}. Assuming that white clover can be grown successfully on all clay and sandy soils in the Netherlands, there is a considerable scope for the use of grass/clover swards.

The white clover based dairy system at the Waiboerhoeve had a "real" N surplus of 212 kg ha^{-1} $year^{-1}$ and a MINAS surplus of –3 kg ha^{-1} $year^{-1}$. Clearly, these figures illustrate that the MINAS surplus of white clover based systems is not a proper indicator for the potential N losses. So, next to the first "intensity-driven" category of potential users, there is a second "MINAS-driven" category. The first group finds its motivation for the use of grass/clover swards in the relatively low intensity (< 12 t milk ha^{-1} $year^{-1}$). This first group benefits most by a complete conversion from grass/fertiliser-N to grass/clover. The second category produces more than 12 t milk ha^{-1} $year^{-1}$, and needs a high N input to achieve the necessary herbage production. That second group benefits most from a partial conversion to grass/clover, the so-called two-sward system. Presently, this strategy is already put to practice on several dairy farms in the Netherlands. From the farmer's short-term point of view, the strategy with the two-sward system is understandable. But on the longer term it will become evident that this strategy does not serve the target of MINAS, that is reducing N losses.

The agronomic and environmental performance show that white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t milk ha^{-1} $year^{-1}$ or less. However, within the MINAS system more intensive farms can benefit from a partial conversion to grass/clover. The prospect for white clover will certainly be affected by the developments in the nutrient policy.

Samenvatting

Inleiding

Tussen 1950 en 1985 is het gebruik van stikstof (N) uit kunstmest in Nederland toegenomen van ongeveer 50 tot 300 kg ha^{-1} $jaar^{-1}$. De stijging in het gebruik van kunstmest ging gepaard met een daling in het gebruik van witte klaver (*Trifolium repens* L.). In de jaren vijftig en zestig bevatte zo'n 80% van de verkochte mengsels witte klaver. In de jaren tachtig was dat gedaald tot 3 à 4%. Echter, de huidige inspanningen van veehouders om de stikstofverliezen te beperken leiden tot een daling van het kunstmestgebruik, waardoor een hernieuwde interesse in witte klaver is ontstaan. Voor veel veehouders is het onduidelijk in hoeverre mengsels van Engels raaigras en witte klaver in staat zijn om als basis te dienen voor een goede ruwvoerproductie op het eigen bedrijf. Daarom is het algemene doel van dit proefschrift het vaststellen van een wetenschappelijke basis voor het gebruik van witte klaver op melkveebedrijven in Nederland.

Om het onderzoek naar witte klaver mogelijk te maken is één van de melkveebedrijven van het proefbedrijf Waiboerhoeve toegewezen aan het witte klaver project. De bedrijfsgebouwen werden vernieuwd en het grasland werd opnieuw ingedeeld zodat het mogelijk was om een systeemvergelijking uit te voeren tussen een gangbaar gras/kunstmest-N bedrijf en een nieuw gras/klaver bedrijf. De geïntegreerde systeembenadering is gekozen om de gehele kringloop te volgen, van de aanvoer van kunstmest, biologisch gebonden N and krachtvoer, via processen als ruwvoerproductie, beweiding, voeropname en mestproductie, tot aan de afvoer van melk en vlees. Het doel van het systeemexperiment was het ontwerpen en demonstreren van een landbouwkundig, milieukundig en bedrijfseconomisch duurzaam melkveebedrijf op basis van witte klaver. Tevens diende de systeemvergelijking voor het opsporen van knelpunten bij het gebruik van witte klaver.

Specifieke onderzoeksvragen, afgeleid van de systeemontwikkeling, werden aangepakt in afzonderlijke veldexperimenten met gedetailleerde waarnemingen. Het doel van de veldexperimenten was het vaststellen van de potentiële productie en kwaliteit van gras/klaver mengsels, bij toepassing van verschillende managementpraktijken. Daarbij is aandacht besteed aan stikstof- en fosfaatbemesting, en graslandgebruik.

De resultaten van de veldexperimenten worden gepresenteerd in de hoofdstukken 2 tot en met 5. De bevindingen van de systeemvergelijking worden beschreven in hoofdstuk 6 en 7. Hoofdstuk 8 sluit af met een synthese van de resultaten en een algemene visie over het gebruik van witte klaver op melkveebedrijven in Nederland.

Strategische stikstof bemesting

Strategische N bemesting in het voorjaar is besproken in hoofdstuk 2. In een vijfjarige veldproef op klei zijn vijf niveaus van stikstofbemesting in het voorjaar (0, 25, 50, 75 en 100 kg ha^{-1} $jaar^{-1}$) gecombineerd met twee maaifrequenties (4-5 sneden $jaar^{-1}$ en 6-7 sneden $jaar^{-1}$). In een driejarige veldproef op zand zijn alleen de effecten van een voorjaarsgift van N (0, 50, en 100 kg ha^{-1} $jaar^{-1}$) bestudeerd. De gemiddelde droge-stofopbrengsten waren 14.7 t ha^{-1} $jaar^{-1}$ op klei en 13.8 t ha^{-1} $jaar^{-1}$ op zand. Voorjaarstoediening van 100 kg ha^{-1} verhoogde de droge-stofopbrengst met 11.1 kg droge stof per kg N. Het aandeel witte klaver daalde met toenemende N bemesting, waardoor op de bemeste veldjes de droge-stofopbrengst van de overige sneden lager was. Op jaarbasis bleef er echter een positief effect over van 7.4 kg droge stof per kg N.

De jaarlijkse stikstofopbrengst was onafhankelijk van de N bemesting. Ten opzichte van de lage maaifrequentie (4-5 sneden $jaar^{-1}$), leidde de hoge maaifrequentie (6-7 sneden $jaar^{-1}$) tot een verhoging van het klaveraandeel van 36 naar 47% en een verhoging van de N opbrengst van 458 naar 528 kg ha^{-1}. De maaifrequentie had geen invloed op de droge-stofopbrengst.

Het onderzoek toonde aan dat een strategische voorjaarsgift met N een praktisch instrument is om de voorjaarsproductie veilig te stellen met slechts een tijdelijke daling van het klaveraandeel.

Graslandgebruik

In Hoofdstuk 3 komt de opbrengst en kwaliteit van gras/klaver in een systeem van omweiden aan bod. Het effect van maaipercentage, graslandgebruik en N bemesting zijn bestudeerd in een vierjarige beweidingsproef met melkvee.

De proef bestond uit alle combinaties van twee maaipercentages, te weten 100 en 200% (S1, S2), N in het voorjaar, te weten 0 of 50 kg ha^{-1} $year^{-1}$ (N0, N50) en graslandgebruik, te weten omweiden in combinatie met maaien of alleen maaien (RGC, CO). Gemiddeld over alle jaren en behandelingen was de gemiddelde klaverbedekking 30%. Alle behandelingen waren van invloed op de klaverbedekking. De klaverbedekking was bij S2 8% hoger dan bij S1, 6% hoger bij N0 dan bij N50, en 12% hoger bij CO dan bij RGC. De jaaropbrengst, gemiddeld 13.1 t ha^{-1} $jaar^{-1}$, werd alleen significant beïnvloed door het graslandgebruik. In twee relatief natte jaren was de droge-stofopbrengst 1.19 t ha^{-1} hoger bij RGC dan bij CO, terwijl er geen verschil was in de twee relatief drogere jaren. Stikstofbemesting verhoogde de droge-stofopbrengst in de eerste snede met 7.0 kg per kg N, maar had geen significant effect op de jaaropbrengst. De voederwaarde van gras/klaver was onafhankelijk vande behandelingen. De gemiddelde *in vitro* verteerbaarheid van de organische stof was 80.1%, en het gemiddelde ruw-eiwitgehalte was 193 g kg^{-1} droge stof.

Stikstof en fosfor bemesting

Het gecombineerde effect van stikstof en fosfor (P) op de gewasproductie en bodemkenmerken is besproken in de hoofdstukken 4 en 5. De maaiproef is in 1994 aangelegd op nieuw ingezaaid grasland op klei, en is gedurende 5 jaar uitgevoerd. De behandelingen bestonden uit specifieke combinaties van vier P niveaus (0, 35, 70 and 105 kg P ha^{-1} $jaar^{-1}$), drie N niveaus (0, 190 and 380 N kg ha^{-1} $jaar^{-1}$) en twee grasmengsels (gras en gras/klaver).

Stikstof had het grootste effect op de opbrengst en kwaliteit van het geoogste gewas. Op de grasveldjes leverde een N gift van 190 of 380 kg N ha^{-1} een opbrengstverhoging van respectievelijk 28 of 22 kg ds kg^{-1} N. De gemiddelde schijnbare N terugwinning was 0.78 kg kg^{-1}. Op de gras/klaver veldjes leidde N bemesting tot een verhoogde grasopbrengst, ten koste van de klaveropbrengst. Het gemiddelde aandeel witte klaver daalde van 41 naar 16% na een N bemesting van 190 kg ha^{-1} $jaar^{-1}$.

De gemiddelde schijnbare P efficiëntie was 13.0, 9.0 of 9.1 kg ds kg^{-1} P na toediening van respectievelijk 34, 68 of 100 kg P ha^{-1} $jaar^{-1}$. Fosforbemesting had geen effect op de klaveropbrengst. De resultaten wijzen in de richting van een negatief effect van P op het aandeel klaver.

Alhoewel er een positieve interactie is vastgesteld tussen N en P bemesting, zijn de gevolgen voor de optimale N bemesting slechts gering.

In hetzelfde experiment zijn de effecten van N en P bemesting op de bodemvoorraad aan N, P en koolstof (C) bestudeerd. Zowel het P-AL getal als het gehalte aan P-totaal reageerde positief op P bemesting en negatief op N bemesting. Tevens nam het positieve effect van P-bemesting af bij een toenemende N bemesting. De jaarlijkse veranderingen van het P-AL getal en het gehalte aan P-totaal waren afhankelijk van de bodembalans. Op haar beurt was de bodembalans afhankelijk van de N en P bemesting. De vastgestelde effecten waren het duidelijkst in de toplaag van 0-5 cm. Fosfaatevenwichtsbemesting leidde niet tot lagere P-AL getallen.

Op de grasveldjes had N bemesting een positief effect op de het gehalte aan N totaal in de bodem. De C accumulatie was onafhankelijk van N en P bemesting, maar was op de gras/klaver veldjes lager dan op de grasveldjes.

Systeemvergelijking

In de hoofdstukken 6 en 7 zijn de bevindingen weergegeven van de drie-jarige systeemvergelijking tussen een gras/klaver bedrijf en een gras/kunstmest-N bedrijf. Voor het gras/klaverbedrijf zijn percelen aangelegd door middel van herinzaai en doorzaai. Beide bedrijven hadden 59 melkkoeien en een melk quotum van 450000 kg. Het gras/klaverbedrijf had een oppervlakte 41 ha en het grasbedrijf van 34 ha. De grotere oppervlakte van het gras/klaver bedrijf was gebaseerd op een opbrengstverschil van 15 – 20% ten gunste van het grasbedrijf. Het graslandgebruik bestond uit een omweidesysteem met een tot drie maaisneden, afhankelijk van de groeiomstandigheden. De gemiddelde klaverbedekking was 31, 30 en 26% in de drie opeenvolgende jaren, maar met een grote variatie tussen seizoenen en percelen. Het seizoen, klaverras en de zodeleeftijd x klaverras interactie verklaarden samen 28% van de variatie in klaverbedekking. Echter 72% van de variatie bleef onverklaard.

De jaarlijkse N bemesting van de gras/klaver en gras/kunstmest-N percelen was respectievelijk 69 en 275 kg ha^{-1} $jaar^{-1}$, inclusief het werkzame deel van de dierlijke mest. De gemiddelde netto droge-stofopbrengst bedroeg 10.8 t ha^{-1} $jaar^{-1}$ op de gras/kunstmest-N percelen en 10.1 t ha^{-1} $jaar^{-1}$ op de gras/klaver percelen. Het opbrengstverschil kwam vooral in het voorjaar tot stand. Echter, het gerealiseerde opbrengstverschil was lager dan het verwachte verschil waardoor het gras/klaverbedrijf meer ruwvoer over hield. De verteerbaarheid van de organische stof was bij gras/klaver wat hoger dan bij gras. Het ruw-eiwitgehalte van gras/klaver was vanaf juli consistent hoger dan bij gras.

Gedurende het weideseizoen kregen de melkkoeien van beide bedrijven 3.5 kg krachtvoer per dag. De dagelijkse vet en eiwit gecorrigeerde melkproductie was 25.7 and 26.5 kg koe^{-1} voor respectievelijk gras/klaver en gras/kunstmest-N. Het verschil in melkproductie kwam tot stand in de periode van juli tot oktober. Ondanks preventieve maatregelen is tussen augustus en oktober diverse keren trommelzucht opgetreden.

Gedurende het stalseizoen kregen de melkkoeien *ad libitum* gras of gras/klaver kuilvoer, aangevuld met 6 kg krachtvoer per koe per dag. Alhoewel de opname van ruwvoer hoger was in de gras/klaver groep, was er geen verschil in melkproductie.

Het gras/klaverbedrijf had een lager stikstofoverschot, maar dat was vooral gerelateerd aan de lagere veebezetting. De stikstofbenutting was in beide systemen 25%. De gemiddelde nitraatgehalten in het drainwater waren 26 and 28 mg l^{-1} voor respectievelijk gras/kunstmest-N en gras/klaver. De nitraatgehalten in het drainwater van de gras/klaver percelen was positief gerelateerd aan het klaveraandeel. Het energieverbruik van het gras/klaverbedrijf was 15% lager dan van het gras/kunstmest-N bedrijf, hetgeen vooral veroorzaakt is door het indirecte energieverbruik via kunstmest. Het saldo per koe was enigszins hoger voor het gras/klaver bedrijf, maar vanwege de hogere veebezetting was het saldo per ha op het gras/kunstmest-N bedrijf zo'n 10% hoger.

De resultaten van de systeemvergelijking laten zien dat, vanuit landbouwkundig en milieukundig oogpunt, gras/klaver in de toekomst een levensvatbare optie is. Echter vanuit financieel oogpunt is het gebruik van gras/klaver slechts aantrekkelijk op bedrijven die niet meer dan 12 t melk per ha produceren.

Synthese

In hoofdstuk 8 zijn de resultaten geëvalueerd aan de hand van de geformuleerde doelen. De waargenomen droge-stofopbrengsten op de maaiproeven in Lelystad waren hoog in vergelijking met opbrengsten van andere proefvelden in Nederland. De gemiddelde droge-stofopbrengst op onbemeste veldjes van maaiproeven in Nederland was 10.9 t ha^{-1} jaar^{-1}, met een variatie van 3.8 tot 17.2 t ha^{-1} jaar^{-1}. De gemiddelde droge-stofopbrengst op klei en zand was respectievelijk 12.0 en 10.0 t ha^{-1} jaar^{-1}.

De gemiddelde opbrengst onder praktijkgebruik, dat wil zeggen omweiden en maaien, en een gematigde N bemesting van maximaal 150 kg ha^{-1} jaar^{-1}, was 10.6 t ds ha^{-1} jaar^{-1}, met een variatie van 7.2 tot 15.4 t ds ha^{-1} jaar^{-1}. De resultaten doen vermoeden dat de gerealiseerde opbrengsten onder beweiding vrijwel niet onder doen voor de opbrengsten onder maaien, ondanks de lagere klaveraandelen bij beweiding.

Het jaarrond gebruik van stikstof wordt slechts aantrekkelijk geacht tot niveaus van 100 of 150 kg ha^{-1} jaar^{-1}, hetgeen in deze studie wordt bevestigd. Stikstof kan echter efficiënter ingezet worden als de toepassing beperkt blijft tot een strategische gift in het voorjaar. Een dergelijke voorjaarsgift verhoogt de opbrengst van de eerste snede, met slechts een tijdelijke daling van het klaveraandeel. Een voorjaarsgift van 50 tot 100 kg ha^{-1} kan voor veehouders een praktisch instrument zijn om de gewasproductie in het voorjaar veilig te stellen.

Het gras/klaverbedrijf op de Waiboerhoeve produceerde 12 t melk per ha per jaar. In Nederland zijn weinig data voorhanden over de melkproductie van gras/klaverbedrijven. De enige beschikbare data zijn van biologische melkveebedrijven. In 1999 was de gemiddelde melkproductie op biologische melkveebedrijven 8.9 t melk per ha. In een monitoringsproject van biologische melkveebedrijven loopt de melkproductie uiteen van 5.2 tot 11.3 t ha^{-1} jaar^{-1}. Rekening houdend met de resultaten van de Waiboerhoeve en de biologische bedrijven, zou een melkproductie van ongeveer 12 t ha^{-1} als een bovengrens kunnen gelden voor gras/klaverbedrijven. In 1999 produceerde de helft van de Nederlandse melkveebedrijven minder dan 12 t melk ha^{-1}. Aannemende dat witte klaver succesvol kan worden geteeld op alle klei- en zandgronden in Nederland, betekent dat een aanzienlijke toename in het mogelijke gebruik van gras/klaver.

Het gras/klaver bedrijf op de Waiboerhoeve had een "werkelijk" stikstofoverschot van 212 kg ha^{-1} $jaar^{-1}$, terwijl het MINAS overschot slechts –3 kg ha^{-1} $jaar^{-1}$ bedroeg. Deze cijfers illustreren dat het MINAS overschot van een gras/klaver bedrijf weinig zegt over de potentiële N verliezen. Naast de eerste groep van "intensiteit-gedreven" gebruikers van gras/klaver er een tweede groep "MINAS-gedreven" gebruikers van gras/klaver is. De eerste groep vindt gras/klaver aantrekkelijk vanwege de relatief lage intensiteit (< 12 t melk ha^{-1} $jaar^{-1}$). De bedrijven in deze groep profiteren het meest van gras/klaver door een complete omschakeling van het gras/kunstmest-N naar gras/klaver. De tweede groep produceert meer dan 12 t melk ha^{-1} $jaar^{-1}$, en heeft een hoge N aanvoer nodig om de benodigde ruwvoerproductie te kunnen realiseren. De bedrijven in deze groep profiteren het meest van een gedeeltelijke omschakeling naar gras/klaver. Op dit moment wordt deze strategie al op verschillende melkveebedrijven in de praktijk toegepast. Vanuit het korte-termijn perspectief is deze strategie begrijpelijk, maar op de lange termijn dient dit niet het doel van MINAS, namelijk het verlagen van de N verliezen.

De landbouwkundige en milieukundige resultaten laten zien dat gras/klaver een levensvatbare optie is voor de toekomst. Vanuit bedrijfseconomisch perspectief is het gebruik van gras/klaver aantrekkelijk voor bedrijven die niet meer produceren dan 12 t melk ha^{-1} $jaar^{-1}$. Echter, vanwege het MINAS systeem kunnen ook intensievere bedrijven baat hebben bij een gedeeltelijke omschakeling naar gras/klaver. De toekomst van gras/klaver zal ongetwijfeld afhankelijk zijn van de ontwikkelingen in het mestbeleid.

Curriculum vitae

René Lodewijk Marie Schils werd geboren op 3 juli 1961 te Hollandia (Nieuw Guinea). In 1979 behaalde hij het Atheneum-B diploma aan de scholengemeenschap Groenewald te Stein. Vanaf 1982 studeerde hij aan de Hogere Landbouw School te 's-Hertogenbosch. In 1986 rondde hij zijn studie af in de richting Rundveehouderij, met onder andere de vakken ruwvoederwinning en weidebouw.

In 1986 kwam hij in dienst als onderzoeker bij het toenmalige Proefstation voor de Rundvee-, Schapen- en Paardenhouderij te Lelystad. Hij werkte bij de afdeling weidebouw en voederwinning onder andere aan de verbetering van de stikstofbenutting bij de toediening van dunne rundermest aan grasland. Vanaf 1987 raakte hij betrokken bij projecten op het gebied van witte klaver. Het onderzoek dat in het kader van die projecten is uitgevoerd, heeft geleid tot dit proefschrift. In 1991 begon hij aan de wetenschappelijke opleiding Toegepaste Natuurwetenschappen aan de Open universiteit. De studie werd in 1996 afgerond in de afstudeerrichting Milieukunde. In zijn huidige functie als projectmanager bij Praktijkonderzoek Veehouderij is hij verantwoordelijk voor onderzoek op het terrein van nutriëntenstromen in grasland.

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