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Effects of cattle dung and urine on nitrogen uptake and yield of perennial ryegrass

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Abstract

Effects of artificially placed patches of cattle dung and artificial urine on nitrogen (N) uptake and herbage dry matter (DM) accumulation were studied in perennial ryegrass swards on a sandy soil at fertilizer inputs of 250 and 400 kg N $ha^{-1}yr^{-1}$ over a period of ten months after application in mid-summer. Positive effects were only observed in the 250 N sward and were confined to 15 cm from the edge of the dung and urine patches. Apparent N recovery (ANR) of dung was 8.3 % in the 250 N sward and nil in the 400 N sward. The N effect of dung was 3 g DM per g dung N applied in the 250 N sward and nil in the 400 N sward. The effects lasted until the end of the experiment (i.e. 10 months after application). ANR of urine was about 16 % in the 250 N sward and insignificant in the 400 N sward. In the 250 N sward the N effect of urine was low and lasted two months (on average 1.7 g DM per g urine N applied). In the 400 N sward the N effect was even negative due to scorching (on average –2.5 g DM per g urine N applied). The scorching effects were still evident at the end of the experiment.

Keywords: cattle dung, artificial urine, nitrogen response, nitrogen recovery, herbage accumulation, *Lolium perenne*, perennial ryegrass.

Introduction

Most of the nutrients ingested by grazing cattle are returned to the pasture via dung and urine. Depending on animal type, animal production level and nitrogen (N) concentration of the herbage about 80 to 95% of the ingested N is excreted, and the major proportion (65 to 80%) is contained in the urine. However, as pointed out by Petersen et al. (1956), the application of excreta by the grazing animal results in a time-space distribution of nutrients over the pasture quite unlike that obtained by the uniform application of fertilizers. Each urine and dung patch contains nutrients collected from a large area but deposited on a small area. It therefore contains a considerable concentration of nutrients. In intensively managed pastures the areas where urine is deposited contain biologically labile N in the order of 500 kg N ha^{-1}, whereas the areas of dung deposition receive inputs equivalent to about 2000 kg N ha^{-1} (Lantinga et al., 1987).

The area influenced by urine is often more than twice the area actually wetted directly following urination owing to diffusion of N in the soil and the lateral spread of the roots (Whitehead, 1986). With dairy cows it has been found that the area on which growth was influenced averaged 0.68 m^2 per urine patch (Lantinga et al., 1987). The quantities of urine deposited on pastures and the composition of the urine are extremely variable. Individual urinations from dairy cows may be from 1.5 to 3.5 l, volumes voided range from 14 to 30 l day^{-1} and total N content of urine may vary from about 6 to 15 g N l^{-1} (Holmes, 1989).

On average, the number of defaecations made by an adult cow in a day is about 11 to 12. A typical figure for the amount of dung voided daily by a milking cow is 4.0 kg dry matter (DM) or 28.6 kg faeces if the DM content is 14 % (Marsh & Campling, 1970). In different studies the mean size of cattle dung patches varied from 0.02 to 0.13 m^2 (MacLusky, 1960; MacDiarmid & Watkin, 1972; Bastiman & Van Dijk, 1975). In faeces approximately 0.8 g N per 100 g feed eaten is excreted, regardless of the N content of the feed (Barrow & Lambourne, 1962); hence the concentration in the faeces increases as digestibility increases. The influence is most evident in the first 15 cm from the edge of the patch (MacLusky, 1960; MacDiarmid & Watkin, 1971). Assuming a mean area of a dung patch of 0.05 m^2, this is equivalent to an affected area of 0.25 m^2.

Responses to urine can be attributed mostly to its N component and normally last for 2 to 3 months (Ledgard et al., 1982) Reclycling of N via dung is generally much slower than via urine, though the speed of decomposition is very variable (Dickinson et al., 1981). Since the breakdown of dung is relatively slow the availability of the N is low (about 25% in the first year). Therefore, yield responses from dung are observed over a longer period than those from urine (Norman & Green, 1958), though they may be observable under favourable conditions after as little as 15 days (MacDiarmid & Watkin, 1971). The visible effect of dung N may last for up to 2 years (Richards & Wolton, 1976). Although, in total at a whole paddock scale there is only a small beneficial effect on herbage growth (Wolton, 1979). Responses to dung and urine are variable, nonetheless, many studies have shown that the return of excreta to pastures can markedly stimulate local herbage growth and change botanical composition and can have a marked effect on element concentration.

However, experimental data on the effect of excretal N on herbage growth of pure grass swards receiving relatively high rates of fertilizer N (250-400 kg N $ha^{-1}yr^{-1}$), as prevail in the Netherlands, are scarce. Therefore, an experiment was conducted to study the effects of cattle dung and artificial urine on N uptake and herbage accumulation in swards receiving fertilizer N equivalent to 250 and 400 kg N $ha^{-1}yr^{-1}$.

Materials and Methods

The experiment was conducted in a formerly cut sward of predominantly perennial ryegrass (*Lolium perenne* L.), on a sandy soil (pH-KCl 4.6; organic matter content 6.5 %) near Wageneningen. The effect of applied dung and artificial urine on N uptake and local herbage growth was studied at two levels of fertilizer N application (250 and 400 kg N $ha^{-1}yr^{-1}$) during the second part of the growing season of 1987 and the following spring.

Table 1. Effect of fertilizer N on DM content and chemical composition of herbage on offer and dung collected from steers. Fertilizer application 250 (250 N) or 400 (400 N) kg N $ha^{-1}yr^{-1}$.

	Herbage		Dung	
	250 N	400 N	250 N	400 N
DM(%)	16.0	13.6	13.5	12.0
N (g/100 g DM)	2.4	2.7	3.0	3.4
K (g/100 g DM	4.1	4.3	2.2	1.8
P (g/100 g DM)	0.4	0.5	1.4	1.2

On 22 July, freshly-voided dung was collected indoors from two groups of steers fed fresh grass from swards receiving 250 and 400 kg N $ha^{-1}yr^{-1}$, respectively. The collected dung per group was thoroughly mixed and used the same day to produce discrete patches (0.07 m^2) on the sward cut the day before. Contents of DM, N, phosphorus (P) and potassium (K) of the offered herbage and the collected dung are presented in Table 1. Each patch comprised 2.5 kg fresh dung, which was poured into a 5 cm deep × 30 cm diameter polythene collar positioned in the centre of the allotted plot. After application the collar was removed. Per dung patch about 10.2 g N was applied, which is equivalent to 145 g N m^{-2} for both treatments.

Nutrient concentrations in urine vary considerably (Lantinga et al., 1987). Therefore artificial urine with a N concentration of 12.8 g l^{-1} was prepared (Table 2) according to Doak (1952). By means of dilution, three concentrations were obtained (6.4, 9.6 and 12.8 g Nl^{-1}), and as a consequence all other components were diluted. Urine (2 l) was sprayed onto areas of radius 30 cm (0.28 m^2). Urine applications corresponded with 46, 69 and 91 g N m^{-2}.

For sampling purposes, rings were centered round the patches, 15 cm in radius (R1), 15-30 cm (R2), 30-45 cm (R3), 45-60 cm (R4) and 60-75 cm (R5); the herbage from each concentric 15 cm ring was harvested separately. For the urine treatments the concentric sampling rings R1 and R2 were combined, since on this area the urine was applied. Herbage mass above a stubble height of 4 cm was determined by cutting with sheep shears at monthly intervals from August 1987 until October 1987

Table 2. Chemical composition of artificial urine (prepared according to Doak, 1952).

Constituents	Constituent concentrations ($g\ l^{-1}$)	Total N (g/100 g)
urea	24.0	89.1
hippuric acid	10.0	6.2
creatinine	0.2	0.6
allantoin	0.5	1.4
urine acid	0.1	0.2
ammonium chloride	1.2	2.5
potassium chloride	19.2	–
potassium bicarbonate	14.3	–

Table 3. Scheme of fertilizer N application (kg N ha^{-1}) for fertilizer treatments 250 (250 N) and 400 (400 N) kg N $ha^{-1}yr^{-1}$.

Fertilizer treatments	Harvests 1987						Harvest 1988
	1	2	3	4	5	6	1
250 N	50	50	50	40	40	20	50
400 N	50	110	80	60	60	40	80

and again in May 1988. Herbage harvested was oven-dried, weighed and analyzed for ash and total N.

The experimental layout was a split-plot design with two N treatments replicated six times, the sub-treatments included two controls, dung and urine with three N concentrations. The fertilizer treatments were started in spring 1987 after the first cut on a sward which had received 250 kg N $ha^{-1}yr^{-1}$ in the preceding years. The fertilization schedule is shown in Table 3. Dung and urine treatments were introduced after the third cut in July. In the analysis of variance the main plot analysis was that of randomized blocks with two N treatments replicated six times. The sub-plot analysis was performed separately for each ring and separately for the dung and urine treatments since the area on which urine and dung were applied differed in size.

Results

Control plots

In August 1987, DM yields in the control plots were 221 and 203 g DM m^{-2} in the 250 N and 400 N sward, respectively (Fig. 1). This negative DM response to fertilizer N applied was due to the pre-treatment of the experimental area. Fertilizer N treatments were introduced in spring 1987 after the first cut. In both swards herbage was cut at fixed dates at approximately monthly intervals. In the 400 N sward the higher DM yields of the pre-experimental harvests affected DM yield in August negatively. In September 1987 and May 1988, the N effect on DM accumulation in the control plots was positive and resulted in significant ($P<0.05$) differences between the N treatments. In September 1987, DM yields in the control plots were 205 and 229 g DM m^{-2} in the 250 N and 400 N sward, respectively. In October DM yields were about 60 g m^{-2} in both treatments (Fig. 1). In May 1988, DM yields in the control plots were 188 and 206 g DM m^{-2} in the 250 N and 400 N sward, respectively.

Dung

The dung-affected area was confined to 15 cm from the edge of the dung patch and equivalent to 0.28 m^2 (R1+R2) (Fig. 1). The effect of dung on herbage DM accumulation lasted for up to the end of the experiment (i.e. ten months). Up to and including the second harvest in September (two months after application) DM accumu-

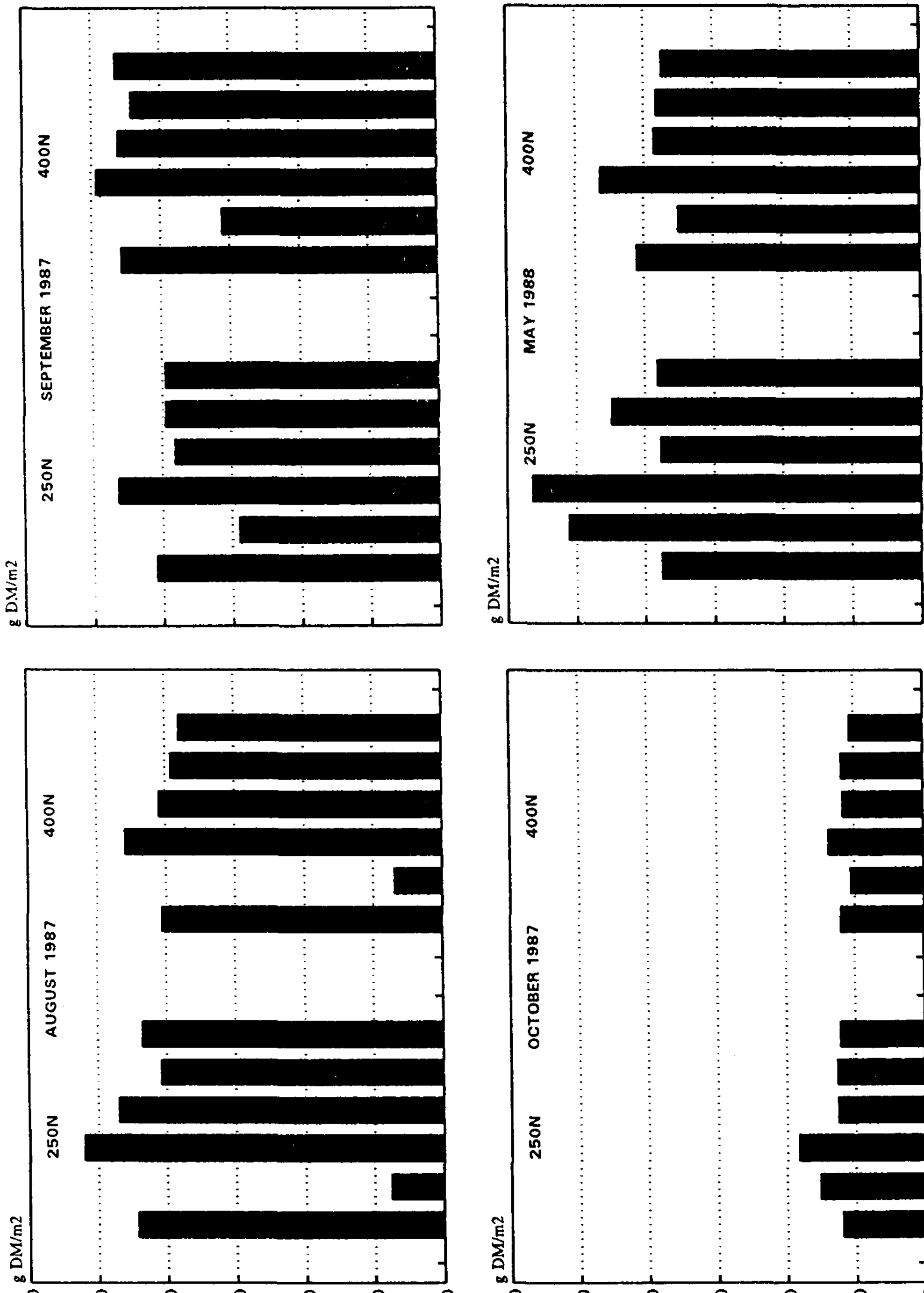

Fig. 1. Dry matter yield (g DM m^{-2}) of the control plots (O) and effect of dung on dry matter yield in each of the five concentric sampling rings: R1, R2, R3, R4 and R5. Nitrogen fertilization 250 (250 N) and 400 (400 N) kg N $ha^{-1}yr^{-1}$.

lation was significantly ($P<0.01$) depressed at the place of dung deposition (R1) in both swards. However, distinct differences occurred between the two N treatments since then. These differences were clearly reflected in significant ($P<0.05$) treatment × N interactions in October and May. Until September, DM accumulation in R1 was mainly reduced by the presence of the dung patch. In this experiment the dung patches took 60 to 90 days to disappear completely. Thereafter, sward quality (i.e. tiller density and cover of perennial ryegrass) became an important factor affecting herbage DM accumulation in R1. In the 250 N sward, herbage growth at the place of dung deposition (R1) was stimulated and yielded more than the control in October and May, in contrast to the 400 N sward where herbage growth was depressed until the end of the experiment. In the 400 N sward, lower herbage growth could be associated with stronger damage inflicted upon plants under the dung patches (R1) as well as plants immediately adjacent to the patch (R2). The observed damage showed resemblance with urine scorch. In both swards herbage DM accumulation around the dung patch (R2) was higher than in the controls. Response to dung was greatest in the 250 N treatment in May ($P<0.001$) (Fig. 1). DM yield was even greater than in the 400 N control due to a larger amount of available inorganic N (fertilizer N and mineralized organic dung N). In May colonization by *Lolium perenne* and *Poa annua* of the sward under the former dung patches was almost complete.

At the end of the experiment, total herbage accumulation on the dung-affected area was 14 % higher in the 250 N sward in comparison with the control plot (Fig. 2). This higher yield was mainly accomplished in the final harvest in May. Until

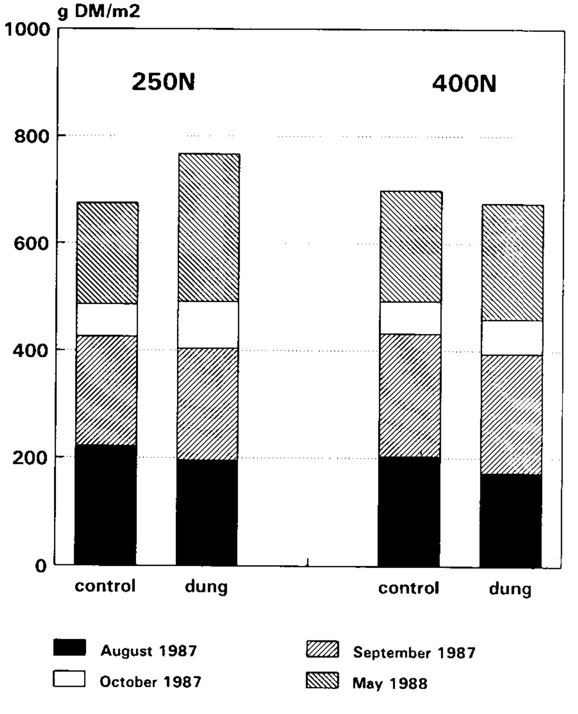

Fig. 2. Total herbage accumulation (g DM m^{-2}) on dung affected area (R1+R2; 0.28 m^2) and contribution of each consecutive harvest in control and fertilized plots. Nitrogen fertilization 250 (250 N) and 400 (400 N) kg N $ha^{-1}yr^{-1}$.

Table 4. Herbage N uptake (g N m^{-2}) in the control plots and the dung-affected area (R1+R2; 0.28 m^2) and apparent recovery of dung N (ANR). Swards receiving 250 (250 N) or 400 (400 N) kg N $ha^{-1}yr^{-1}$.

	250 N			400 N		
	control	dung	ANR (%)	control	dung	ANR (%)
August	7.1	7.1	0.0	7.3	7.3	0.0
September	7.0	6.8	–0.5	8.9	9.0	0.2
October	1.9	2.8	2.4	2.0	2.2	0.7
May	5.9	8.3	6.4	6.9	6.6	–0.9
Total	21.9	25.0	8.3	25.1	25.1	0.0

October, cumulative yields of the dung-affected area and the control were similar; yield depression in R1 was just compensated for by the stimulated growth in R2. In the 400 N sward, dung had no significant effect on herbage DM accumulation.

The efficiency of use of N from dung or urine is expressed in two ways: (i) as the apparent recovery of N (ANR) which is the difference in N uptake between the treated and untreated plots expressed as a percentage of the N applied in dung or urine, and (ii) as the apparent N effect (ANE) which is the increase of harvested DM per g N applied in dung or urine. The ANR of dung N was low (Table 4). In the 250 N sward ANR was nil or insignificant in the first two harvests, 2.4% in the third harvest in October and 6.4 % in the final harvest in May. Overall ANR at the end of the experimnent was 8.3 %. In the 400 N sward ANR was insignificant. As a consequence, the overall ANE of dung over the first ten months after application was low (viz. 3 g DM per g dung N applied in the 250 N sward and nil in the 400 N sward).

Urine

In July 1987, the average temperature was approximately 20 °C and the soil was permanently moist due to regular rainfall. These conditions were optimal for plant growth but unfortunately also for urine scorch to occur (Schechtner et al., 1980). Already some days after urine application considerable scorching damage could be observed. Although the degree of scorching varied strongly, scorching was most severe in the 400 N sward and increased with increasing urine N concentrations. In none of the scorched areas perennial ryegrass had disappeared completely. However, tiller density was low and the remaining tillers were irregularly distributed. The open patches were rapidly filled in, mainly by *Poa annua.*

The area affected by urine was confined to 15 cm from the edge of the urine patch: totally 0.64 m^2 (R1, R2 and R3). For the consecutive harvests herbage DM accumulation in the urine-treated area (R1 + R2; 0.28 m^2) and the surrounding concentric sampling rings (R3, R4 and R5) is presented in Fig. 3. The extent to which urine affected herbage growth was dependent on the level of fertilizer N input and the N content in the applied urine. In the first harvest (August) DM accumulation in the urine-treated area was significantly depressed in all treatments. Despite a deteriorat-

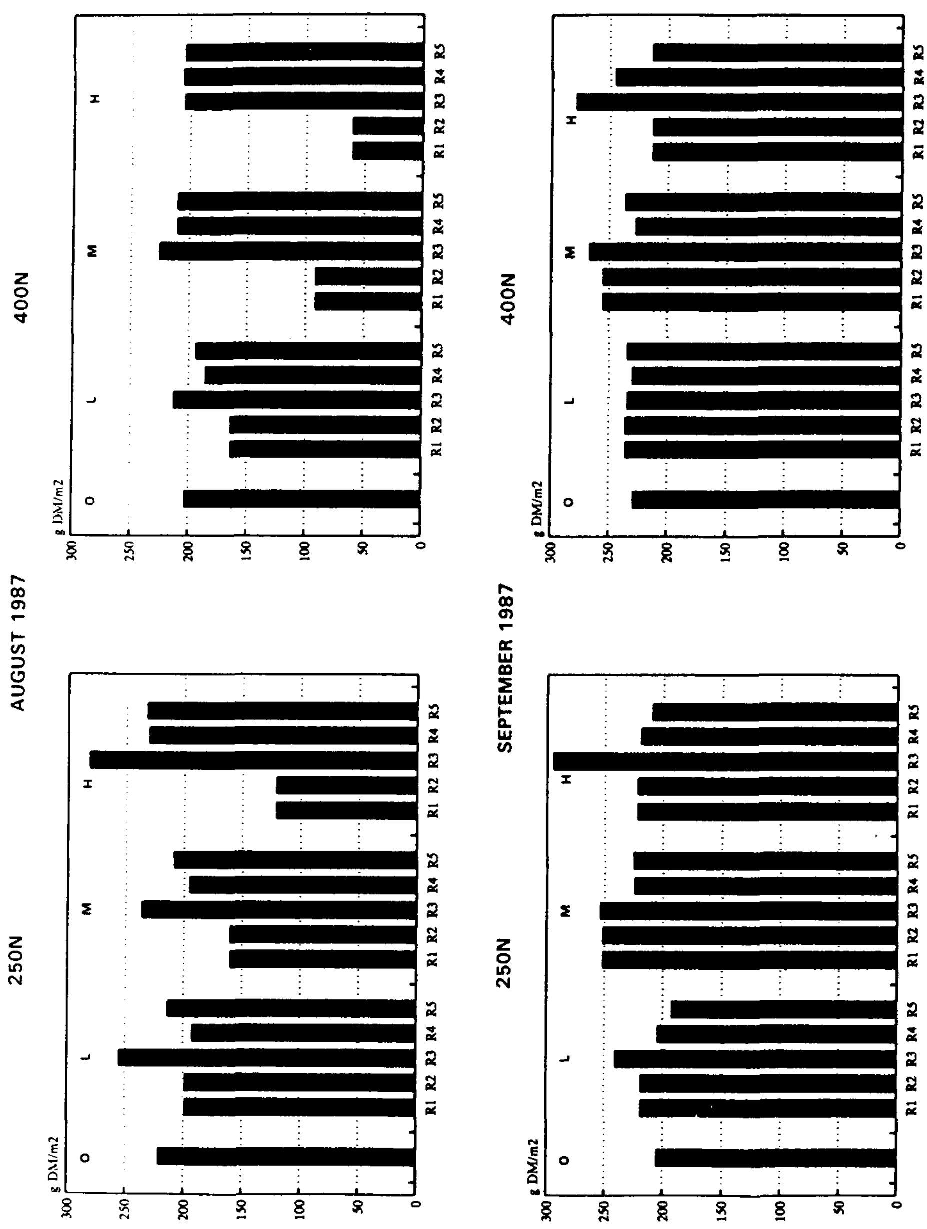

Fig. 3. Dry matter yield (g DM m^{-2}) of the control plots (O) and effect of urine N concentration (6.4 (L), 9.6 (M) and 12.8 (H) g N l^{-1}) on dry matter yield in each of the five concentric sampling rings R1, R2, R3, R4 and R5. Nitrogen fertilization 250 (250 N) and 400 (400 N) kg N ha^{-1}yr^{-1}.

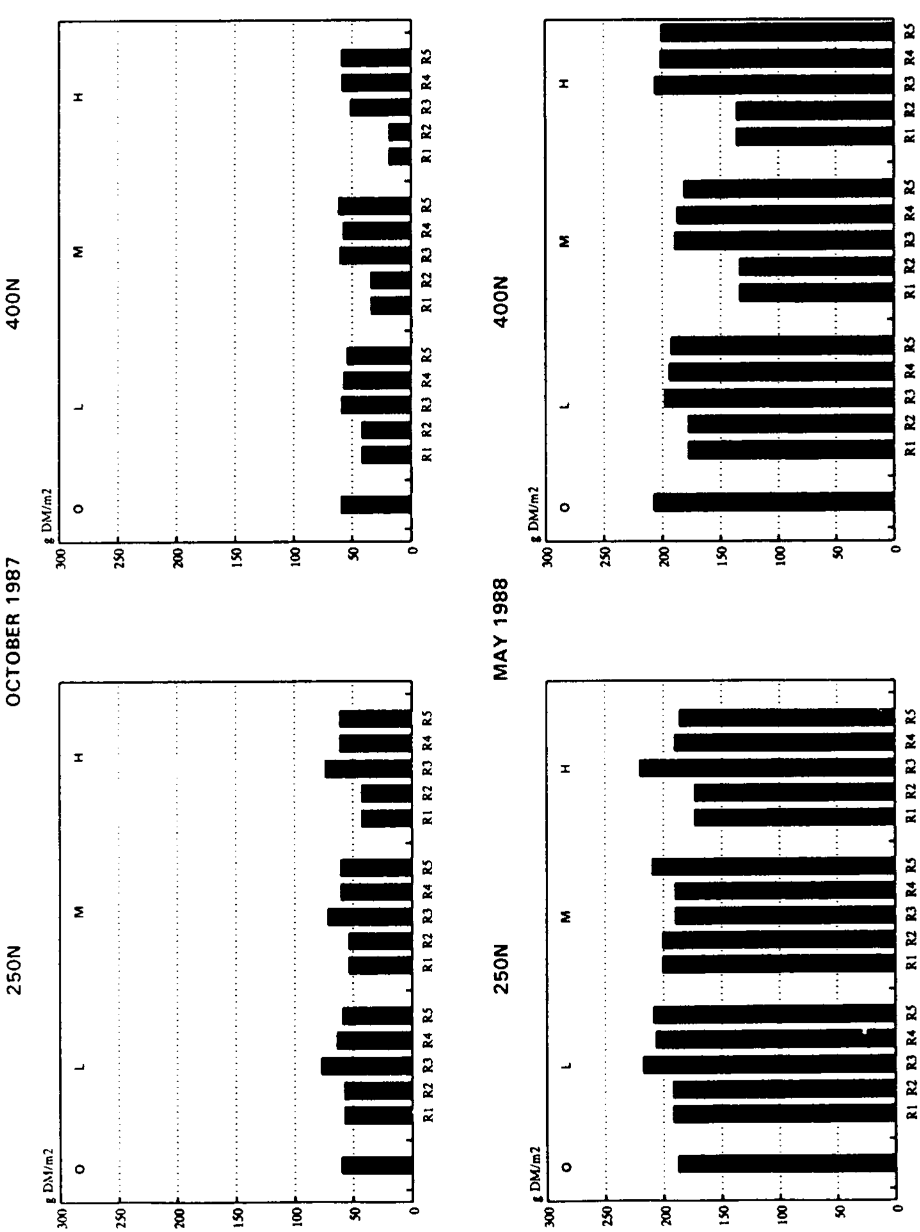

Fig. 3. *Continued.*

ed botanical composition in the 400 N sward, herbage DM accumulation recovered during the second regrowth period, probably due to a positive urine N effect (Fig. 3). In the second harvest (September), N uptake increased with increasing urine N concentrations (Table 5). The effect was greatest until two months after application. As a consequence, a significant stimulation of herbage growth due to a positive urine N effect lasted for two months only. In the 400 N sward the effects of urine on N uptake were less evident. In the first harvest, N uptake tended to decrease with increasing urine N concentrations due to sward deterioration; only in the low urine N treatment N uptake was higher than in the control. In the second harvest N uptake was higher in all urine treated areas, however, the effect on DM accumulation was insignificant (Fig. 3). In the 400 N sward, the negative effect of sward deterioration on N uptake and DM accumulation was still evident in the third and fourth harvest.

In May the total herbage DM accumulation in the urine-affected area (R1, R2 and R3: 0.64 m^2) was 5%, 3%, and 8% higher than the control in the 250 N sward, whereas total herbage DM accumulation in the 400 N sward was reduced by 0 %,

Table 5. Effect of urine N concentration on herbage N uptake (g N m^{-2}) in the urine-affected area (0.64 m^2). Between parentheses apparent recovery of urine N (ANR). Swards receiving 250 (250 N) or 400 (400 N) kg N $ha^{-1}yr^{-1}$. Urine N concentrations: 0 (O), 6.4 (L), 9.6 (M) and 12.8 (H) g N l^{-1}.

	250 N				400 N			
	O	L	M	H	O	L	M	H
August	6.8	8.4	8.1	8.7	6.8	7.7	6.8	6.2
		(7.8)	(4.4)	(4.8)		(4.3)	(–0.3)	(–1.7)
September	6.5	7.8	9.4	10.8	8.6	9.2	10.9	11.0
		(6.3)	(9.7)	(10.7)		(2.7)	(7.4)	(5.9)
October	1.8	2.0	2.0	2.0	1.9	1.6	1.5	1.1
		(0.9)	(0.8)	(0.6)		(–1.3)	(–1.2)	(–1.8)
May	5.7	5.8	5.7	6.1	6.5	5.7	5.0	5.6
		(0.9)	(0.2)	(1.1)		(–3.8)	(–4.9)	(–2.1)
Total	20.8	24.0	25.2	27.7	23.8	24.2	24.2	23.9
		(15.9)	(15.1)	(17.2)		(1.9)	(1.0)	(0.3)

Table 6. Effect of urine N concentration on herbage DM accumulation (g DM per g urine N applied) in the urine affected area (0.64 m^2) at two levels of fertilizer N. Swards receiving 250 (250 N) or 400 (400 N) kg N $ha^{-1}yr^{-1}$. Urine N concentrations: 6.4 (L), 9.6 (M) and 12.8 (H) g N l^{-1}.

	250 N			400 N		
	L	M	H	L	M	H
August	0.2	–0.9	–0.5	–0.6	–1.4	–1.7
September	1.4	1.8	1.6	–0.1	0.9	0.3
October	0.4	0.1	0.0	–0.5	–0.5	–0.7
May	0.7	0.1	0.2	–0.9	–1.5	–0.8
Total	2.7	1.1	1.3	–2.1	–2.5	–2.9

7 % and 12 % for urine concentrations of 6.4, 9.6 and 12.8 g N l^{-1}, respectively, in comparison with the control treatment.

Overall ANR of urine N was about 16 %, 15 % and 17 % for fertilizer treatment 250 N and 1.9 %, 1.0 % and 0.3 % for fertilizer treatment 400 N for urine concentrations 6.4, 9.6 and 12.8 g N l^{-1}, respectively (Table 5). The effects of urine N on herbage DM accumulation were low and even negative in the 400 N sward (Table 6).

Discussion

As the grazing animal returns a considerable quantity of N and other plant nutrients to the sward, it might be expected that the productivity of the sward would be increased owing to recycling. The results from the present experiment showed that N recycled via dung and urine was not very effective. However, it should be noted that the results were derived from a single experiment carried out at one location where dung and urine were applied in July.

After 10 months only 8% of the dung N was taken up by the herbage in the 250 N sward and nil in the 400 N sward. The area affected by dung was confined to 15 cm from the edge of the dung patch. This agrees well with MacDiarmid & Watkin (1971) and Weeda (1977). In the dung-affected area in the 250 N treatment DM accumulation was increased by only 13% whereas Weeda found an increase in total DM accumulation of about 50 %. Both Weeda and MacDiarmid & Watkin found a larger effect since their experiments were performed in unfertilized grass-clover swards. Grass growth in the surrounding area was enhanced by dung N and the enhancement was not the result of a border effect as was indicated by MacDiarmid & Watkin (1971). In the present study the effect of dung was still apparent after 10 months, at the end of the experiment. The observed effects might have been greater if the experiment had been continued longer or had been started earlier in the season.

The duration of approximately two months of the positive effect of applied urine N and its recovery of 15 tot 17 % were comparable to the findings reported by Ledgard et al. (1982). Recent experiments in the Netherlands (Van der Meer & Whitehead, 1990) with artificial urine, and where no further fertilizer N was applied after urine application, indicated that recovery of urine N in the harvested herbage was at a maximum of 60 % after urine applications made in April, May or early June and decreased to less than 20% after applications in August. A simultaneous similar increase of residual inorganic N in the soil was observed, which was subject to leaching and denitrification during the winter.

In the present experiment the low recovery of excretal N could be attributed to the high amount of N deposited on a small area and the relatively slow breakdown of the dung pats and the slow mineralization of the organic dung N. N deposition (fertilizer N plus excretal N) ranged from 71 to 185 g m^{-2}. Supply of N was far beyond the demand of the herbage and marginal recovery of excretal N will be relatively low at higher fertilizer N input rates. Besides, N recovery might have been negatively affected by sub-optimal sward conditions due to scorching. It is the urine-affected areas that afford the greatest potential for N loss. Since approximately 80 % of N excreted is contained in urine, most of which is present as urea. Dung N is present in organic compounds less readily hydrolyzable than urea and mainly of bacterial origin, much of which is expected to be incorporated into the soil organic matter by the action of the soil fauna. The relative heavy pre-experimental harvest resulted in a retarded regrowth in the 400 N sward, the first experimental yield in August was lower than in the 250 N sward. The effect was confined to the first experimental yield. A more proper pre-experimental sward management might have resulted in somewhat better results in August in the 400 N sward. Inorganic N originating from urine and not lost through ammonia volatilization may be nitrified, resulting in nitrate N concentrations under the patches equivalent to 200-1710 kg ha^{-1} (Ball & Ryden, 1984). Leaching losses from urine-affected areas can occur, as soil N levels are well in excess of plant requirements. Dutch experiments conducted at the same site as the present experiment indicated that grazing cattle increases N leaching losses by a factor 2 (Macduff et al., 1990). Leaching losses from the cut sward were 25 and 30 kg N $ha^{-1}yr^{-1}$ and from the grazed sward 48 and 61 kg N $ha^{-1}yr^{-1}$, respectively, at fertilizer input rates of 250 and 400 kg N $ha^{-1}yr^{-1}$.

Tentative estimates can be made of effects of urine and dung at a whole-paddock scale, assuming: (i) ten defaecations and ten urinations per day made by a cow; (ii) 700 and 750 cow-grazing days $ha^{-1}yr^{-1}$ at 250 N and 400 N, respectively; and (iii) an application of 10.2 g N per defaecation and 19.2 g N per urination irrespective fertilizer N level. From the results of this experiment it follows that in the 250 N sward the average N effect of urine was 1.7 g DM per g urine N applied and 3 g DM per g dung N applied. In the 400 N sward the effects were –2.5 g DM per g urine N applied and nil for dung. Ignoring overlapping of dung and urine patches, it can be calculated that herbage accumulation will increase by 443 kg DM $ha^{-1}yr^{-1}$ in the 250 N sward and decrease by 360 kg DM $ha^{-1}yr^{-1}$ in the 400 N sward. It will be evident that an increase or a decrease in herbage accumulation in the order of 350 to 450 kg DM is not of significance. However, when evaluating pasture growth at 250 N and 400 N there is a difference of about 800 kg DM in herbage DM accumulation due to effects of urine and dung which decreases the response to fertilizer N. Since excretal effects on herbage growth were positive at a low fertilizer N (250 N) input and negative at a high fertilizer N (400 N) input, DM yield response to fertilizer N under grazing will be lower than under cutting. From N response experiments at the same site Deenen (1990) reported under cutting a positive DM response up to 550 kg N $ha^{-1}yr^{-1}$; whereas, under grazing an N application of more than 250 kg N $ha^{-1}yr^{-1}$ had no effect.

The conclusion from this study is that in these moderately fertilized swards benefits from the recycling of ingested nutrients by grazing animals are low.

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