Lolium perenne populations effects on nitrogen concentration, use and uptake efficiency when grown on peat

Pijlman J.[1], Hoekstra N.J.[1], Deru J.G.C.[1], Erisman J.W.[2] and van Eekeren N.[1]
[1]*Louis Bolk Institute, Kosterijland 3–5, 3981 AJ Bunnik, The Netherlands;* [2]*Institute of Environmental Sciences, Leiden University, Einsteinweg 2, 2333 CC Leiden, The Netherlands*

Abstract

Grass nitrogen (N) concentrations of dairy grasslands are higher on peat soil than on mineral soils. This can lead to increased N losses from dairy farming systems on peat soils. Our objective was to determine whether perennial ryegrass (*Lolium perenne* L.) populations with different shoot tissue N concentrations, recorded on a sandy soil, would show different shoot tissue N concentrations and N use efficiencies (NUE) or N uptake efficiencies (NUptE) when grown on a peat soil. A pot experiment lasting 62 days was carried out with nine diploid and seven tetraploid populations, followed by a field experiment with two diploid and two tetraploid populations and a control lasting 30 months. In the pot experiment, shoot tissue N concentrations differed among tetraploid populations, the NUE differed among diploid and tetraploid populations and the NUptE differed among diploid populations. In the field experiment, two populations had a 1.4 g kg^{-1} lower shoot tissue N concentration compared to a commercial control, after ten harvests and at a N fertilisation level of 25 g m^{-2} year^{-1}. We conclude that it is possible to alter shoot tissue N concentrations of perennial ryegrass grown on peat soil via the selection of low-N populations.

Keywords: crude protein, dairy farming, nitrogen use efficiency, perennial ryegrass, plant breeding

Introduction

On dairy grassland on peat soil, grass N concentrations often exceed 24–26 g (kg dry matter (DM))$^{-1}$, equal to about 150–169 g crude protein (CP) (kg DM)$^{-1}$, even under limited N fertilisation regimes. This is mainly due to the a high soil N supply (SNS), caused by a high organic matter mineralisation of drained peat soils (Vellinga and André, 1999). At dietary CP concentrations above 150 g CP (kg DM)$^{-1}$, milk and protein yields generally do not increase, while urine urea N losses do increase, which can lead to increased ammonia losses (Edouard *et al.*, 2019). The selection of perennial ryegrass with low shoot tissue N concentrations could therefore be a potential way to reduce environmental impacts of dairy farming on peat soils. A pot experiment and a field experiment were carried out consecutively to compare perennial ryegrass population shoot tissue N concentrations, N use efficiency (NUE) and N uptake efficiency (NUptE). It was hypothesised that, on a peat soil, perennial ryegrass populations selected for a different shoot tissue N concentration observed on a sandy soil, would have a different shoot tissue N concentration and NUE or NUptE, and that populations with a high NUE and populations with a low NUptE would have a lower shoot tissue N concentration.

Materials and methods

Nine diploid and seven tetraploid perennial ryegrass populations differing in N concentration recorded on sandy soil, were selected from a large database of populations from a commercial breeding programme (for details, see Pijlman *et al.*, 2023). In the pot experiment, the populations were grown at three N fertilisation levels with three replicates per treatment. 144 pots (size 15×15×15 cm) were allocated in a randomised complete block design. At day zero, the pots were filled with a peat-based substrate mix (pH 5.8). The pots were placed in a greenhouse without artificial lighting or heating, and received water through sub-irrigation on a daily basis. Per pot, 38 germinating seeds were sown. Prior to sowing, all pots received P, K and S at a rate of 35, 5 and 10 g m^{-2}, respectively. On day 42, N was applied at a rate of 0, 6 or 12 g m^{-2}. All fertilisation was done with inorganic fertilisers. On days 22 and 42, aboveground biomass was harvested in order to stimulate perennial ryegrass tillering, and discarded. On day 62, grass was harvested and collected for DM (70°C for 48 h) and total N analyses (Kjeldahl).

In the field experiment, two diploid and two tetraploid populations were used with either the lowest (2Nlow, 4Nlow) or the highest (2Nhigh, 4Nhigh) mean shoot tissue N concentration in the pot experiment. A commercially available diploid perennial ryegrass mixture was used as control. Four replicates per treatment were allocated according to a randomised block design. The experiment was established on a peat soil that had been in use as a permanent dairy grassland (KTC Zegveld, 52°08′ N, 4°50′ E) and included 10 harvests in three growing seasons. Each growing season, fields were fertilised with in total 25 g N m^{-2}, 10 g K m^{-2} and 1.7 g P m^{-2} using inorganic fertilisers. Every five to eight weeks herbage was harvested and weighed using a small plot harvester (J. Haldrup, Løgstør, Denmark). Representative herbage samples from each plot were analysed for DM (70°C for 48 h) and total N concentration (Kjeldahl).

The NUE of populations was calculated as the increment of aboveground dry biomass weight between two N fertilisation levels (ΔW) divided by the increment of shoot tissue N uptake between two N fertilisation levels (ΔNupt). The NUptE was calculated as ΔNupt divided by the fertiliser N increment between two N fertilisation levels (ΔN supply), assuming SNS remains constant at different N fertilisation levels (Gastal *et al*., 2015). Results were analysed taking the nutritional N status into account by using the N nutrition index as an assessment tool (Sandaña *et al*., 2021)200, 300, 400 and 500 kg of N ha−1. Analyses for differences were done with an ANOVA, in which population was used as factor and N nutrition index (for NUE and NUptE) or N fertilisation (for all other variables) was used as independent variable. In the field experiment, harvest number was used as a within-subject factor according to a repeated measures design.

Results and discussion

In the pot experiment, shoot tissue N concentrations differed among tetraploid populations (Table 1). The NUE differed among diploid and tetraploid populations and the NUptE differed only among diploid populations. Shoot tissue N concentrations of the tetraploid populations correlated negatively with NUE (r=−0.85 and P=0.014), in line with results of Sandaña *et al.* (2021)200, 300, 400 and 500 kg of N ha−1. Dry matter yields did not differ among populations.

In the field experiment, population 2Nlow and 2Nhigh had a 1.4 g kg^{-1} lower shoot tissue N concentration than the control (Table 2). Furthermore, population 2Nlow had a higher DM yield than population 4Nhigh.

Table 1. Pot experiment.

Parameter	Diploid			Tetraploid		
	Mean	SEM	*P*-value	Mean	SEM	*P*-value
Tissue N concentration (g (kg DM)$^{-1}$)	37.5	1.3	0.122	35.5	1.4	<0.001
NUE (g DM (g N)$^{-1}$)	17.4	1.1	0.008	17.1	0.9	0.005
NUptE (g Nupt (g Nsupply)$^{-1}$)	0.47	0.02	0.043	0.50	0.02	0.751
DM yield (g m^{-2})	135	5.2	0.505	139	5.3	0.785

Overall mean, standard error of the mean (SEM) and *P*-value of shoot tissue N concentration, N use efficiency (NUE), N uptake efficiency (NUptE) and dry matter (DM) yield for nine diploid and seven tetraploid perennial ryegrass populations grown at a N fertilisation level of 0–12 g m^{-2}.

Table 2. Field experiment.

Parameter	Control	2Nlow	4Nlow	2Nhigh	4Nhigh	SEM	*P*-value
Tissue N conc. (g (kg DM)$^{-1}$)	35.0^{a}	33.6^{b}	34.4^{ab}	33.6^{b}	34.7^{ab}	0.29	0.018
DM yield (g m^{-2})	252^{ab}	260^{a}	243^{ab}	243^{ab}	238^{b}	7.3	0.032

Means, standard error of the mean (SEM) and *P*-value of shoot tissue N concentrations and dry matter (DM) yield for five perennial ryegrass populations grown for ten harvests at a N fertilisation level of 25 g m^{-2} year^{-1}.

^{abc} Values with an unequal superscript differed significantly ($p<0.05$).

Differences in shoot tissue N concentration among populations were inconsistent between the pot and field experiment, and between harvests within the field experiment. These differences were possibly a result of a higher growth rate of grass in spring compared to later in the growing season, of a lower SNS in spring compared to summer and autumn, and of other environmental variations such as weather variations. Understanding these inconsistencies could be an important aspect of future research.

Conclusion

It is possible to select perennial ryegrass populations for low N concentrations for dairy grassland on peat soil. Further research is needed on the consistency of population effects on N concentrations, for the use of low-N populations as a reduction option for N losses on dairy farms on peat soil.

References

Edouard N., Charpiot A., Robin P., Lorinquer E., Dollé J.-B. and Faverdin P. (2019) Influence of diet and manure management on ammonia and greenhouse gas emissions from dairy barns. *Animal* 13, 2903–2912.

Gastal F., Lemaire G., Durand J.-L. and Louarn G. (2015) Quantifying crop responses to nitrogen and avenues to improve nitrogen-use efficiency. In Sadras V.O. and Calderini D.F. (eds.), *Crop Physiology* (Second Edition). Academic Press, San Diego, CA, pp. 161–206.

Pijlman J., Hoekstra N., Deru J., Erisman J.W. and van Eekeren, N. (2023) Effect of *Lolium perenne* population differences on shoot tissue nitrogen concentrations when grown on a peat soil. *The Journal of Agricultural Science* 161(4), 536–548.

Sandaña P., Lobos I.A., Pavez P.B. and Moscoso C.J. (2021) Nitrogen nutrition index and forage yield explain nitrogen utilization efficiency in hybrid ryegrasses under different nitrogen availabilities. *Field Crops Research* 265, 108101.

Vellinga T.V. and André G. (1999) Sixty years of Dutch nitrogen fertiliser experiments, an overview of the effects of soil type, fertiliser input, management and of developments in time. *Netherlands Journal of Agricultural Science* 47, 215–241.

The Netherlands 9-13 June

EGF 2024

Why grasslands?

Edited by

C.W. Klootwijk
M. Bruinenberg
M. Cougnon
N.J. Hoekstra
R. Ripoll-Bosch
S. Schelfhout
R.L.M. Schils
T. Vanden Nest
N. van Eekeren
W. Voskamp-Harkema
A. van den Pol-van Dasselaar

EGF

Volume 29
Grassland Science in Europe