No trade-off between root biomass and aboveground production in *Lolium perenne*

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Abstract

Grasses have dense rooting systems, but nutrient uptake and drought resistance can be increased, and N-leaching reduced, if rooting is further improved. Improved rooting of grasses in agricultural systems should, however, not be a trade-off with aboveground biomass allocation and yield. In two field experiments on sandy soil in the Netherlands, we measured the variation in grass yield of sixteen varieties of *Lolium perenne* (Lp) during three years, and the root dry matter (RDM) at the end of the experiments. The Lp-varieties differed in aboveground and genetic characteristics such as productivity (classified according to the measured yields in the actual experiments), grass cover and ploidy. Results of the experiments show that RDM of perennial ryegrass differed significantly between varieties, and that these differences were not linked to grass yield. Our results indicate that it is possible to select perennial ryegrass varieties that combine high aboveground productivity with high RDM. Considering challenges in the areas of climate change, pollution and soil degradation, high yielding grass varieties with improved root systems could contribute to an efficient use of nutrients and water, and to erosion control, soil improvement and carbon sequestration.

Keywords: root mass, grass yield, *Lolium perenne* varieties

Introduction

Grasses have dense rooting systems, compared with other agricultural crops, but there are indications that further increased rooting can enable additional increased uptake of nutrients, improve drought resistance and reduce N-leaching (Van Loo *et al.*, 2003). Improved rooting of grasses in agricultural systems should, however, not be a trade-off with aboveground biomass allocation and yield. Therefore, it is important to explore which management practices promote deeper rooting of grassland plants, and also to investigate the relation with yield. One management practice is the use of genetic variation among different grass varieties (Crush *et al.*, 2007). In this paper, we describe the relation between root biomass and grass yield of sixteen *Lolium perenne* (Lp) varieties in two field experiments.

Material and methods

In Experiment I, eight Lp varieties were selected from a field experiment that is part of the VCU (value for cultivation and use) testing programme for the Dutch variety list. This trial was sown in 2005 with 50 Lp varieties on a sandy soil in four replicates. The Lp-varieties differed in characteristics of productivity class, earliness class, and ploidy (diploid versus tetraploid) in an orthogonal way. Grass dry matter (GDM) yield was measured in 2006-2008. In October 2010, root samples were taken in three soil layers: 0-8, 8-16 and 16-24 cm. Per plot and per layer, three soil cores (8.5 cm diameter, 8 cm depth) were taken and pooled to one sample. The fresh samples were washed through a sieve (mesh size 2 mm) and non-root particles were removed. The root dry matter (RDM) was determined after drying, first at 70 and then at 105 °C. During the VCU testing and the following years, the experiment was managed according to a cutting regime with five cuts per year.

In Experiment II, eight other Lp varieties were selected in a second experiment, also part of the VCU testing programme and also on a sandy soil. Here, 80 Lp varieties had been sown in 2009 in four replicates. The varieties differed in their characteristics of productivity class, soil cover class and ploidy, also in an orthogonal way. GDM was measured in 2010-2012. Root sampling was done in September 2013 following the method of Experiment I. This trial was managed as a cutting/grazing pasture (two cuttings/four grazings per year). More details on the experiments are given in Deru *et al.* (2014).

Variety effect on RDM was analysed for each experiment separately using the ANOVA procedure in Genstat 13.3. RDM effect on GDM was calculated with linear regression analysis. Regression was carried out on the whole dataset with and without discerning different groups (experiments, ploidy, production). RDM was expressed as the total over the three soil layers or separately, and GDM as average of the three measured years.

Results and discussion

The grand mean RDM in the 0-24 cm soil layer in Experiment II (2,663 kg ha^{-1}) was lower than in Experiment I (3,286 kg ha^{-1}). Total nitrogen applied, including slurry manure, artificial fertilizer and the estimated extra N input from dung and urine during grazing (Experiment II) was comparable in both experiments. Besides differences in abiotic conditions and sampling year between the experiments, the more intensive cutting/grazing regime in Experiment II may have contributed to reduced RDM. Ennik and Baan Hofman (1983) measured a lower RDM with higher harvesting frequencies.

RDM in the sampled soil layers for the sixteen varieties are shown in Figure 1. In Experiment I, there was a significant variety effect on $RDM_{0\text{-}24cm}$ (P=0.004). In Experiment II the variety effect was close to significant on $RDM_{0\text{-}24cm}$ (P=0.053) and significant on $RDM_{8\text{-}16cm}$ (P=0.008).

Regression analysis showed that no significant relation existed between GDM and RDM in any soil layer, either in the whole dataset or with separated groups (Experiment I and II; high or low production category; diploid or tetraploid). This lack of negative relation, as measured in our experiments, does not exclude the possibility that varieties with high RDM would be less vulnerable to stress conditions (e.g. drought) and give higher aboveground yield compared with varieties with low RDM. Further, this indicates that it is possible to select perennial ryegrass varieties that combine high aboveground productivity with high root mass. The potential for improvement is certainly there, considering that Crush *et al.* (2006) reported a narrow-sense heritability value of 0.35 for perennial ryegrass, and Bonos *et al.* (2004) increased root mass in the deeper soil layer of forage type perennial ryegrass in test tubes by 367% after only two breeding cycles.

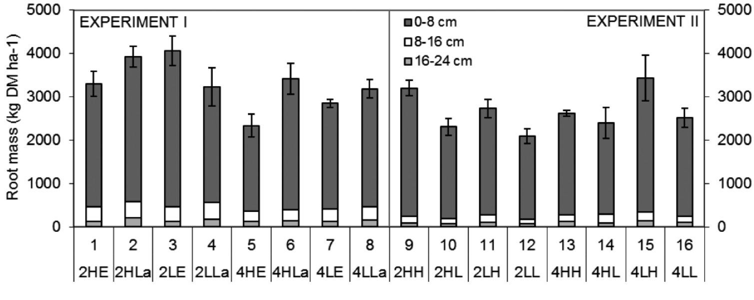

Figure 1. Cumulated root mass (kg dry matter (DM) ha^{-1}) of sixteen *Lolium perenne* varieties (Experiments I and II) with different genetic and aboveground characteristics. Abbreviations: 2 or 4: diploid or tetraploid; H or L: high or low productive; La or E: late or early; H or L (second character in experiment II): high or low soil cover). Error bars represent + and – the standard error of root DM across the 0-24 cm soil layer.

In this field experiment it is possible that differences in root morphology between genotypes (e.g. proportion of fine roots) influenced the results, as the washing method does not extract all roots from the soil. Another possible bias is that part of RDM can include dead roots, and that genotypes differ in their proportion of dead roots (or root decomposition rate). For breeding purposes other techniques could be used to quantify rooting characteristics of genetic material.

Conclusions

Based on the results of these two experiments, it can be concluded that root mass of *Lolium perenne* differs between varieties under field conditions and that there is no trade-off between root mass and grass yield.

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