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Nitrogen use efficiency and root dry matter partitioning in four perennial temperate forage grass species

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Introduction

In Chile, the livestock systems based on perennial swards (grasses/white clover) have intensified its production because of the indiscriminated increases in nitrogen fertilization (Vistoso *et al*., 2012). Currently, new agronomic practices are demanded to allow the increase of the Nitrogen Use Efficiency (NUE) of perennial swards. In livestock systems, NUE can be studied and improved at animal, soil and plant level. In Chile, the two first levels have been broadly studied (Vistoso *et al*., 2012) but the plant contribution has been ignored. Today, a lot of cultivars from temperate grass species originated from different part of the world are commercialized in Chile. The objective of this work was to evaluate the NUE of four perennial forage grasses species and to determinate the role of the root system.

Materials and Methods

The experiment was carried out under shade conditions at the Instituto de Investigaciones Agropecuairas in Chillán, Chile (36°34´S; 72°06´W). Five cultivars of four perennial forage grass species, *Lolium perenne* (Lp), *Bromus valdivianus* (Bv), *Festuca arundinacea* (Fa) and *Dactylis glomerata* (Dg), were established on mesocosms of PVC tubes of 11 cm of diameter and 100 cm depth, containing as substrate a mixture (v/v) of fine sand (50%), vermiculite (35%), soil (10%) and perlite (5%). Previous to the sowing, substrate was fertilized with 1L of a complete-(N excluded) nutrient solution. Then, the nitrogen was supplied as NH_4NO_3 at three times (sowing, first expanded leaf, tillering) during the experimental period. Plants were grown under two nitrogen treatments: high and low nitrogen availability, where substrate was fertilized with 5.4 and 13.0 mg N kg^{-1} of substrate, respectively. Trial was organized in a randomized complete block design with a factorial arranged and four replicates, each replicate consisting of 5 mesocosms per combination (species × N) and one plant per mesocosm. Irrigation water was delivered daily using 2.0 Lh^{-1} drippers with an irrigation time of 4 min day^{-1}. Environmental temperature and relative moisture were registered hourly with a sensor Hobo (H08-032-IS, Onset). The temperature and volumetric moisture content of the substrate were registered with capacitance sensors (5TE, Decagon). The shoot DM production was determined in two times (120 and 143 days after sowing, DAS) by harvesting at 5 cm above ground. After the second cut the mesocosms were disturbed and the roots were obtained through washing with water. Then, root tissues were divided in fine-roots (FnR; >2 mm diameter), structural-roots (StrR= first + second order roots) and crown. In both cuts the shoot DM nitrogen content was evaluated with the Kjeldahl method. The DM production of each part of the plant was measured at 65ºC until sample weight was constant. The nitrogen use efficiency (NUE= NupE × NutE) and its components, nitrogen uptake efficiency (NupE= ΔNupt/ΔNt) and nitrogen utilization efficiency (NutE= ΔW/ΔNupt), were calculated according to Lemaire and Gastal (2009). Where ΔNupt, is the difference between the N captured at high and low N treatments; ΔNt is the difference between the total substrate N available; ΔW is the difference between the Shoot DM at high and low N treatments. Results were analyzed by ANOVA and means were separated by LSD test (p=5%). All statistical analyses were performed by using R software (http://www.r-project.org/).

Results and Discussion

NUE and its components varied significantly between species ($P<0.05$). Bv, Fa and Dg showed the same NupE (97 mgN / g soil N in average). The Lp cv. Bealey obtained the highest NupE value (163 mgN / g soil N), almost a 50% higher than the remained species. The Lp diploid cultivar Nui showed a statically equal NupE to the tetraploid cultivar Bealey (Figure 1). On the other hand, the NutE did not show differences between species, excluding the Lp cv. Bealey, which reached a 40% higher NutE than the remained species and cultivars (Figure 1). The differences in NUE were attributed to modifications in root DM production and partitioning. The species with the highest NUE (Lp cv. Bealey) showed the higher total root DM and the higher DM partition toward fine-roots and structural-roots. In contrast, the lowest NUE species (Fa) showed the lowest total root DM (Table 1). Shoot DM production showed a highly significant N x species

interaction (P<0.001). Under high N conditions the tetraploid Lp cultivar Bealey surpassed to all other species and cultivars. However, under low N conditions the shoot DM production was equal to the diploid cultivar Nui (Table 1).

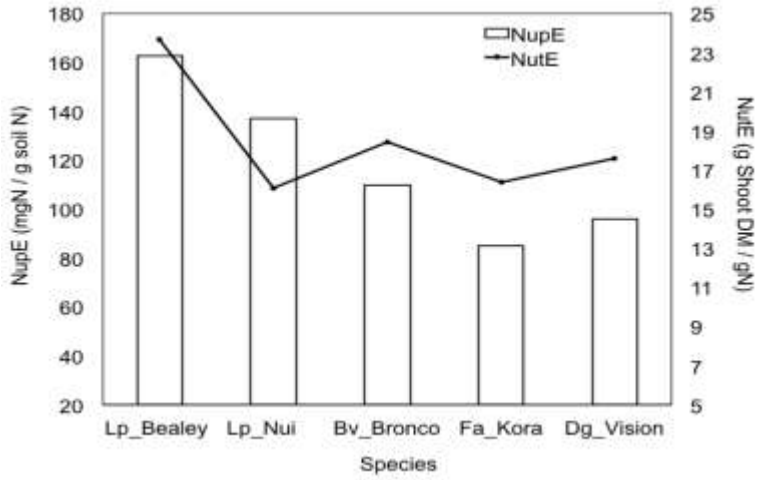

Fig 1. Nitrogen uptake efficiency (NupE, bar) and nitrogen utilization efficiency (NutE, line) of 4 perennial forage grasses species (*Lolium perenne* (Lp), *Bromus valdivianus* (Bv), *Festuca arundinacea* (Fa) and *Dactylis glomerata* (Dg)).

Table 1. Root dry mater partitioning and shoot dry mater production of 4 perennial forage grasses species (*Lolium perenne* (Lp), *Bromus valdivianus* (Bv), *Festuca arundinacea* (Fa) and *Dactylis glomerata* (Dg)).

	Root DM partitioning (g plant^{-1})					**Shoot DM (g plant^{-1})**	
Species	**Crown**	**FnR**	**StrR**	**Total**		**High N**	**Low N**
Lolium perenne cv. Bealey	0.96	0.98	1.69	3.2		9.0	3.2
Lolium perenne cv. Nui	0.83	0.89	1.54	2.9		7.2	3.2
Bromus valdivianus cv. Bronco	0.81	0.38	1.07	2.2		5.7	2.0
Festuca arundinacea cv. Kora	0.59	0.34	0.77	1.7		4.3	1.7
Dactylis glomerata cv. Vision	0.95	0.42	0.85	2.2		5.0	1.9
$LSD_{species}$	0.19***	0.18***	0.30***	0.52***		$LSD_{N*species}$	
Nitrogen level						1.05***	
High N	1.0	0.60	1.1	2.5			
Low N	0.6	0.56	1.2	2.2			
LSD_N	0.12***	0.11 ns	0.19 ns	0.33*			

*, **, ***, for P<0.05, P<0.01 and P<0.001, respectively; ns: no significant; LSD: least significant difference.

Conclusion

The four perennial forage grass species have different NUE, depending on the root DM accumulation and partitioning. The species with a higher root DM allocation toward fine roots showed the highest NUE and also were the most productive.

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