SELECTION FOR NITROGEN USE EFFICIENCY IN PERENNIAL RYEGRASS USING HYDROPONICS

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ABSTRACT

A selection method was tested for improving nitrogen use efficiency of perennial ryegrass (*Lolium perenne* L.) using a hydroponics system that controls the plant nitrogen concentration. Divergent selection for plant production, leaf area increase and dry matter distribution in six segregating populations under limiting nitrogen supply resulted in differences between offspring of upward and downward selections larger than 20 % in most characteristics. Moderately high realized heritabilities were found for some characteristics (up to 0.88). It is concluded that early selection for nitrogen use efficiency is feasible using this hydroponics system.

KEYWORDS

Ryegrass, nitrogen use efficiency, hydroponics, selection response

INTRODUCTION

Environmental concerns have put pressure on dairy farmers in North West Europe to strongly reduce their high nitrogen surpluses. Van Loo and Vellinga (1994) have shown that breeding for a higher productivity of grasses at lower nitrogen input may contribute substantially to reduce nitrogen surpluses without decreasing farm income. Field trials are not very efficient for the evaluation of large numbers of plants for crop productivity under limiting nitrogen supply because of the long time required for both seed multiplication and the actual evaluation. Therefore, a fast 'early selection' method was developed using a hydroculture system in which grass plants can be individually evaluated - in a crop situation - grown at a constant, limited plant nitrogen concentration (Van Loo *et al*., 1992). The aim of the present study was to measure the response to selection for productivity under limited nitrogen supply in this hydroculture system.

MATERIALS AND METHODS

Hydroculture system. The hydroculture system used has been described before by Van Loo *et al.,* (1992). The nitrogen supply aimed at achieving a plant nitrogen concentration (in the dry matter of leaves) of 3.6%, which for perennial ryegrass leads to a reduction of 20% of the relative crop growth rate compared to non-limiting nitrogen supply. Four experiments were carried out.

Measurements. Each third or fourth week, all shoot and root material was harvested, leaving only 2 cm of stubble and 4 cm of root length. For each plant, dry weight of harvested shoots (DWS) and of harvested roots (DWR) was determined at each cut. In Expt. 1, 3 and 4, four cuts were harvested and in Expt. 2 six cuts. One week after defoliation, the number of tillers (T) of each plant was determined. At that time, also the leaf elongation rate (L, mm d^{-1}) and width (W, at half of the length of the leaf) was determined on the longest leaf. Multiplying T, L and W gives an estimate of the leaf area increase after defoliation (dLAI, m^2(leaf)/m^2(soil area) per day). Leaf weight ratio (LWR,%) was calculated as 100*DWS/(DWS+DWR).

Materials and selection. From each of three diploid and three tetraploid populations, about 100 plants were evaluated. The three tetraploid populations were evaluated from August to December 1994 (Expt. 1) and the three diploid populations from January to June, 1995 (Expt. 2). On the basis of standardized values of DWS, LWR, dLAI, T, L and W (each averaged over all cuts, but for T only the value after the last harvest), non-hierarchical clustering (CLUSTER in GENSTAT with unequal sizes of groups allowed) was applied to create twelve groups, for each segregating population. Between groups, differences were maximized. In each population, for each characteristic the groups with highest and lowest group mean (upward and downward selections) were selected and multiplied in separate polycrosses. This selection procedure resulted in four selections per population. For the downward selection of DWS and dLAI, the group with the one but lowest mean was chosen, because the group with the lowest mean mainly consisted of dead plants. The offspring of the selected groups from Expt. 1 and 2 were evaluated from September, 1995 to January, 1996 (Expt. 3, for tetraploids) and from February, 1996 to June, 1996 (Expt. 4, for diploids).

Selection response. The average selection differential S for a characteristic was calculated as the average difference between the performance of the upward selection and the downward selection for the diploid and tetraploid populations, respectively. The selection response R was calculated as the average difference between the offspring of these upward and downward selections. For one population, one downward selection did not produce seed. Instead of that selection, the original segregating population was used in the calculation of the selection response (that population was evaluated both in Expts. 2 and 4). The selection differential was expressed as a percentage of the average of the performance of the selections in Expts. 1 and 2 (for the tetraploid and diploid populations, respectively). The selection response was similarly expressed as a percentage of the performance of the offspring of selections in Expts. 3 and 4.

RESULTS AND DISCUSSION

The selection differential was about 1.5-3 times the phenotypic standard deviation in both diploid and tetraploid populations (Table 1). For all characteristics, the selection response was 0.5 to 1.3 times the phenotypic standard deviation. Figure 1 shows for dLAI that both for diploid and tetraploid populations, performance of offspring in Expt. 3 and 4 was fairly well correlated to the average performance of parents in Expts. 1 and 2. Realized heritabilities were variable, but fairly high for some characteristics ($0.19<h^2$-0.88) and always higher for the diploid than for the tetraploid populations.

Van Loo and Vellinga (1994) have calculated for Dutch conditions that an increase by 20 % in LWR and by 20 % in dLAI under limiting nitrogen supply will allow a reduction of the nitrogen surplus on the farm level by 30 % or 125 kg nitrogen per hectare per year with even an increase in farm income. These improvements of nutrient use and of farm economics lie within reach in view of the presented genetic variation and selection responses.

The selection response we measured was obtained after only one cycle of breeding that lasted only one year from seed to seed. Therefore, we conclude that selection for improved productivity under limiting nitrogen supply using our hydroponics system may greatly accelerate grass breeding for improved nitrogen use efficiency.

REFERENCES

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Table 1

Mean (μ) of original populations, phenotypic standard deviation (s_P), selection differential (S) and response (R) and realized heritability (h^2_R=R/S) of diploid (2X) and tetraploid (4X) populations.

		μ		s_P		S(%)		R(%)		h^2_R
			(% of μ)							
	S (%)		R (%)		h^2_R					
	2X	4X	2X	4X	2X	4X	2X	4X	2X	4X
DWS (g per plant)	1.07	1.01	41	32	86	81	47	30	0.55	0.37
DWR (g per plant)	0.29	0.35	50	40	98	87	37	21	0.38	0.24
LWR (%)	79.6	74.8	5.3	5.5	9.6	10.8	5.5	2.9	0.57	0.27
dLAI (m^2 m^{-2} d^{-1})	0.070	0.079	49	37	101	96	63	42	0.62	0.43
W (mm)	2.89	3.31	13	13	20	32	17	6.2	0.88	0.19
L (mm d^{-1})	13.2	14.5	14	13	25	32	18	12	0.71	0.37
T (number per plant)	10.6	7.6	40	36	111	81	63	34	0.57	0.41

Figure 1

Parent-offspring relationship among selections for leaf area increase after defoliation (dLAI, relative units) in tetraploid (A) and diploid (B) populations.