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Growth rate and total nonstructural saccharides content in *Alopecurus pratensis* L.

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Abstract

Total nonstructural saccharides (TNS) content in young plant of *Alopecurus pratensis* was always above 4 % of dry matter even at several types of stress treatment (nitrogen deficiency, low irradiance). TNS content was in negative correlation with concentration of total nitrogen in all cases. Positive correlation was found between the TNS content in plants and relative increase in their root growth rate.

Introduction

The water soluble and easily hydrolysable saccharides, denoted as total nonstructural saccharides (TNS) are permanently present in all plant organs. They are indispensable not only for continuous synthesis of structural constituents of plant cells, but also as an instantly available source of energy for metabolic processes.

The actual content of TNS in a plant organ reflects the dynamic balance of several physiological processes: the rate of photosynthesis and respiration, the rate of translocation, and the rate of TNS utilization in synthesis of permanent structures. The dependence of these processes on external variables is specific in each case, which makes any prediction of TNC content in plants growing in field conditions very difficult. On the other hand, there is an increasing demand for some, at least empirical data on TNS content in plants growing under different environmental conditions. The information is needed not only for some practical reasons, such as, *e.g.* silage making, but also for description of the dependence between TNS content and growth processes (for review see Mc Ilroy 1967, Smith 1973).

Material and methods

Newly germinated seedlings of *Alopecurus pratensis* L. were grown in small pots (60 mm in diameter) with expanded Perlite as substrate in a glasshouse (natural daylight, temperature 15 to 25 °C.

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The pots were abundantly supplied with Hoagland nutrient solution. After one month selected uniform plants were transplanted into bigger plastic containers with Perlite. The day of transplantation was considered as the starting point of experiment (= day 0). At that moment, the plants had a total dry mass of about 45 mg.

The experimental plants were grown either freely exposed to daylight (= variant with high irradiance), or under a frame with white polyethylene foil, which transmitted only about 50 % of the incident photosynthetically active radiation (shaded variant). Each of the two variants were divided into two subvariants. One of them was watered daily with full Hoagland nutrient solution. The second subvariant was watered with a balanced modification of the Hoagland nutrient solution in which the nitrogen was reduced to 0.1 of the original concentration.

At time intervals of about one week eight plants from the four treatments were randomly sampled 1 h after the sunrise. The plants were washed free of Perlite and the roots were cut off. The shoots were divided into leaf laminae and "stems" (mainly leaf sheaths and shoot bases). All the plant fractions were dried at 70 °C and weighed. The dried plant material was ground and used for chemical analysis of TNS and total nitrogen concentrations. The content of TNS was estimated by colorimetric method (Nelson 1944) after extraction and hydrolysis in 0.5 M H_2SO_4 for 90 minutes at boiling point temperature. The total nitrogen concentration was determined using a *Model 1106 C. Erba Elemental Analyzer.*

Results

Total dry mass of experimental plants and its partitioning into shoots and roots were strongly influenced by nitrogen supply (Table 1). Substantial differences were found both in relative and absolute growth rates (RGR and AGR, respectively), which were derived from smoothened growth curves.

Table 1. Basic characteristics of cultivated plants of *Alopecurus pratensis* (day 34 of the experiment): dry mass (mean ±SE), root/shoot dry mass ratio (R/S), relative growth rate (RGR), and absolute growth rate (AGR).

Variant		Dry mass [mg]	R/S	RGR [d^{-1}]	AGR [mg d^{-1}]
Control	shoots	1362 ± 24	0.39	0.111	83.2
	roots	530 ± 17		0.101	34.2
N-deficient	shoots	469 ± 14	0.69	0.076	17.4
	roots	325 ± 17		0.085	16.3
Shaded	shoots	1020 ± 43	0.28	0.104	63.6
	roots	287 ± 19		0.083	18.1
N-deficient + shaded	shoots	362 ± 11	0.63	0.075	15.4
	roots	230 ± 13		0.076	12.2

The growth of roots was evidently prefered at nitrogen deficiency in substrate, as indicated by root/shoot ratios and RGR values. It should be noted, that the growth rate of roots in N-deficient variants was in no case higher than in plants fully supplied with nitrogen.

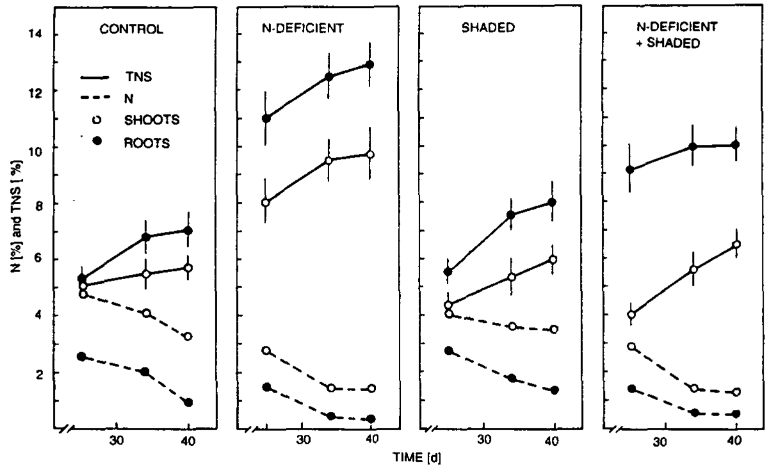

Fig. 1. Changes in concentration of total nitrogen (N) and total nonstructural saccharides (TNS) in young plants of *Alopecurus pratensis* during cultivation in pots. Mean values from three samples ±SE.

The effect of diminished irradiance was principially opposite to the effect of nitrogen deficiency - the growth of shoots in the shaded plants was prefered at the expenses of root growth. It was possible to observe some compensatory effects of simultaneous shading and nitrogen deficiency on biomass partitioning into shoots and roots. In any case, the two limiting factors exhibited cumulative adverse effect on absolute values of biomass production.

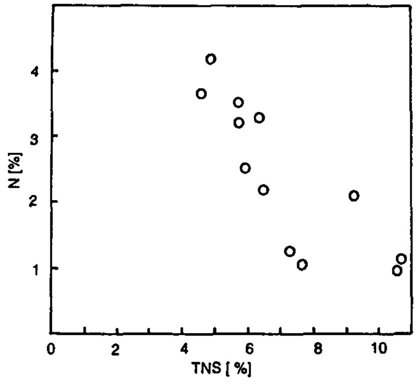

Fig. 2. The relationship between total nitrogen concentration (N) and total nonstructural saccharides (TNS) in whole plants of *Alopecurus pratensis* ($y = 10.73 - 1.47\ x$, $r = -0.82$). Based on mean values of concentrations in total biomass (shoot + root) of plants in each of the four variants and three sampling dates (the same as in Fig. 1).

The highest accumulation of TNS was found in all N-deficient plants, especially in their roots (up to 12.9 %, Fig. 1). The concentration of total nitrogen decreased with age of all experimental plants (both in roots and shoots), and the changes in TNS content had an opposite character. The negative linear correlation between the total N and TNS is rather strong (Fig. 2)

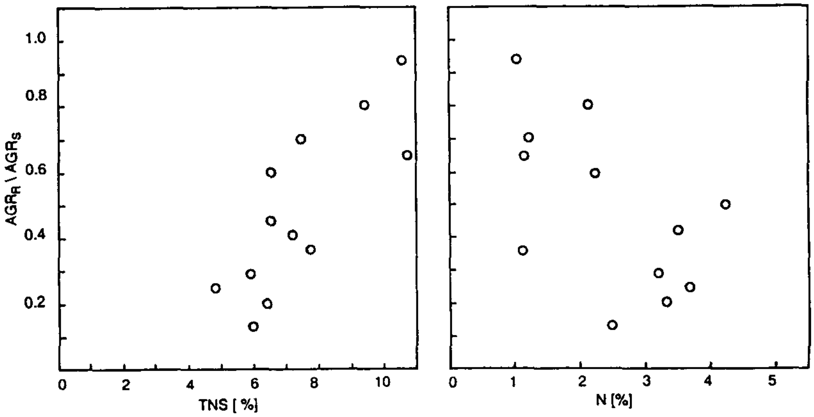

Fig. 3. The dependence of dry matter allocation (AGR_R / AGR_S) on the concentration of total nonstructural saccharides (TNS; $y = -0.11 + 0.094\ x$, $r = 0.75$), and on the concentration of total nitrogen (N; $y = 0.80 - 0.135\ x$, $r = 0.61$). Based on mean values found in plants in each of the four variants and three sampling dates (the same as in Fig. 1).

The ratio AGR_R/AGS_S (absolute growth rate of roots to absolute growth rate of shoots) was calculated as the most convenient measure of the pattern of biomass partitioning. Its dependence on the TNS content in the whole plant is shown in Fig. 3.

Discussion

Alopecurus pratensis belongs to the most important grasses in wet alluvial meadows rich in nutrients. In spite of this, the information about its carbon metabolism is scarse. Some ecological responses of photosynthesis and respiration were reported by Gloser (1976), seasonal dynamics of the TNS content in samples of a plant stand dominated by *A. pratensis* was assessed by Rychnovská (1972).

The range of variation in TNS content which was found in our experiments with young plants of *A. pratensis* under the influence of two stress factors (low nitrogen, low irradiance) was not as broad as one would expect. It should be noted that in our case the plants were harvested early in the morning, when the TNS content is usually very low (at least in shoots, *cf.* Plhák 1981). It is difficult to compare our data with results of other authors studying TNS content in *Alopecurus* or in similar meadow grasses (Rychnovská 1972, Smith 1973), because in these reports the daytime of sampling is not given. The highest concentration of the TNS in roots of N-deficient plants may be not only as a consequence of extremely low nitrogen content, but also due to different diurnal variation in TNS content in roots (with an increase in the morning, *cf.* Plhák 1981).

Although the content of TNS in plants fully saturated with nitrogen was distinctly lower than in N-deficient plants, it never dropped below 4 % of total dry matter. Such a level of TNS was maintained even in shaded plants where the supply of photosynthates was undoubtedly limited. From comparison of our results with published data on the relationship between growth rate of leaves and saccharide concentration (Kemp and Blacklow 1980) we may conclude that the concentration of TNS in our plants was probably always above the growth limiting value.

We have not observed any direct effect of the TNS content on the relative growth rate of shoots, roots, or the whole plants of *A. pratensis*. An indirect effect based on differences in biomass partitioning can be expected. As indicated by Chapin and Slack (1979), and Chapin *et al.* (1986), the idea of a plant with an optimization "programme" for partitioning of reserve saccharides and mineral nutrients (in order to maintain their constant levels in individual organs exposed to changing environment) is not far from reality.

The changes in allocation of biomass into roots and shoots can generally be predicted by nitrogen content or C/N ratio. A decreased N-supply leads to increased growth rate of roots (as compared with shoots), resulting in an increased root/shoot ratio (for review see Wilson 1988). Although this effect is well documented in many observations, it is difficult to explain it by an appropriate physiological mechanism. It seems as highly probable that the sink metabolism of a plant is directly and very effectively controlled by concentration of soluble saccharides (Farrar 1989), which is, of course, frequently in strong negative correlation with N content. In our experiments, the relative amount of dry matter allocated into roots (as expressed by AGR_R/AGR_S ratio), was much better correlated with TNS content than (negatively) with concentration of nitrogen, which supports the hypothesis of the primary role of free saccharides in control of dry matter allocation.

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