THE EFFECT OF NITROGEN ON DRY MATTER
ALLOCATION IN YOUNG SPRING BARLEY PLANTS
(HORDEUM VULGARE L.)

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Spring barley plants (Hordeum vulgare L., cv. Koral) were cultivated in nu-
trient solutions Hoagland 2 and Hoagland 3 containing 5 mM and 15 mM
concentrations of nitrate, respectively. In the two to three day intervals, sam-
bles consisting of 4 replicates, each containing 4 plants, were taken. Dry mass
of the leaf blades, remaining parts of the shoot, and of the roots were measured.
Shoot and total plant dry matter was calculated. Values of the dry mass time
course were fitted to an exponential function (except for leaf blades). Although
the differences in the initial values and differences in the relative growth rate
were rather small, the time course of the dry mass shoot/root ratio differed
considerably between the two treatments. It can be concluded that the dry mass
shoot/root ratio is an efficient measure not only to determine individual nutri-
tent deficiency but also to detect differences in the nitrogen supply in the region
of its general sufficiency.

spring barley; nutrient solution; nitrogen; relative growth rate (RGR);
shoot/root ratio; nitrogen deficiency determination

INTRODUCTION

Nitrogen and dry matter allocation represent the most important factors
determining the rate of plant growth. Nitrogen is of both "theoretical" and
"practical" importance. The former may be seen in its quantitative superiority
among all the mineral elements contained in plant dry matter as well as in its
role as a constituent of proteins (Hikosaka, Terashima, 1996). The latter may be
expressed in the fact that a farmer is able to efficiently modulate the
time course of canopy productivity by timing various amounts of nitrogen
fertilizers (Bockman et al., 1990).

Dry matter allocation plays a dominant role in yield formation. It also
considerably regulates most of the processes connected with dry matter pro-

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duction and distribution. Brouwer (1962) in his classical paper emphasizes the role and the “responsibility” of both shoot and root in the acquisition of energy and nutrients from both the atmosphere and the soil. The shoot is responsible for providing enough carbohydrates while the roots look after supply of water and mineral nutrients. Both shortage and excess of any of these three substances negatively affect plant growth. Hence, a functional equilibrium between the availability of carbohydrates, water, and mineral nutrients is of prime importance. A plant has certain possibilities to modulate the absorption of radiant energy, water and nutrients. However, the main and long-lasting regulation of equilibrium may be achieved by preferential growth of those organs that are able to supply the deficient substrate. Carbohydrate deficiency therefore induces an increase in the allocation of dry matter into the shoot while nutrient or water deficiency promotes the translocation of assimilates into the roots. Differences in dry matter allocation are best seen in changes of the dry matter shoot/root ratio (Baker, Milburn, 1989).

Studying mineral nutrient deficiencies most often involves treatments with deficient and sufficient amounts of the appropriate substance (Rephael, 1990). In such a case, pronounced symptoms of nutrient deficiency are compared with those of complete sufficiency. In this paper, the results of a study on the effects of a good and increased nitrogen supply to young barley plants cultivated in nutrient solutions are reported. They are evaluated by growth analysis.

MATERIAL AND METHODS

Spring barley plants (Hordeum vulgare L., cv. Korád) were germinated for 3 days at 22 °C in darkness and then transferred to nutrient solutions Hoagland 2 (H2) or Hoagland 3 (H3) containing 5 mmol N per liter or 15 mmol N per liter, respectively (Laštůvka, Minár, 1967). Plants were cultivated at 16-hour photoperiod under irradiance of 320 μmol.m⁻².s⁻¹ (photosynthetically active radiation). The day/night temperature was 23/18 °C with fluctuations ±2 °C.

In the time interval of 2 to 3 days 4 replicates, each containing 4 plants, were sampled, oven dried and the dry mass of the leaf blades, roots and remaining parts of the plants was measured. The experiment terminated when the plants were 31 days old.

The statistical evaluation of the experimental data included the standard errors (SE) of the samples that are given in the figures. The time course of dry mass of the individual plant parts was fitted to the exponential function of the general form:

\[(\text{Dry Mass at day } D) = a \cdot e^{RD},\]

where \(R\) indicates the relative growth rate (RGR) in mg.mg⁻¹.day⁻¹. Only the time course of leaf blade dry mass was fitted to linear regression:

\[(\text{Dry mass at day } D) = a + b \cdot D.\]

RESULTS AND DISCUSSION

Nitrogen availability influences barley growth from the very beginning. In experiments with dark germinated and grown barley plants nitrogen deficiency affected the rate of respiration and the shoot/root ratio when plants were only 5 days old (Nátr, 1988, 1993). However, many experiments studying the effects of nutrient supply use the concentrations of ions that range from its absence from the solution to very high concentrations. In the experiments reported here, the differences between nitrogen availability were low and corresponded to sufficient N supply. The standard Hoagland 2 solution contains 5 mmol N per liter solution in the form of NO₃ while Hoagland 3 15 mmol N per liter in the same chemical form. Even the lower concentration corresponding to the solution of Hoagland 2 should supply the plants with sufficient amounts of nitrogen (Laštůvka, Minár, 1967). The obtained results prove this assumption because in total dry mass of plant (Fig. 1) a relatively very small difference was between the two treatments. Strange enough, the RGR values were identical for plants cultivated in Hoagland 2 and Hoagland 3, i.e. 0.075 mg.mg⁻¹.d⁻¹ indicating that the daily increase in dry mass corresponded to 7.5 per cent. The difference between the two treatments seems to start from the very beginning of growth. According to the fitted function, the calculated value for Day = 0 equals 28.8 mg and 34.9 mg per plant for the H2 and H3 treatment, respectively. The experimental values for the 1st sampling, i.e. Day = 4 equal 27.9 mg and 30.9 mg for the H2 and H3 treatment. It confirms our previous results, that even during the first days of grain germination, the coleoptile, leaf and root growth was modified by the presence or absence of nitrogen from the ambient solution (Nátr, 1988, 1993).

The data also confirm the assumption, that during this short-term experiment, the plant growth expressed as dry matter increase was exponential (Lamberts et al., 1990). It was therefore fully justified to calculate the average RGR by fitting the data to the exponential function (Hunt, 1982).

Similar conclusion may be drawn from the data on shoot dry mass per plant (Fig. 2) calculated as the sum of leaf blade dry mass (Fig. 3) and the remaining parts of the plant (Fig. 2). Again, the shoot dry mass differs from the values of the fitted function for the Day = 0 while the RGR values are
1. Experimental data (individual points) and fitted curves of exponential function of the time course of dry mass (mg) per
plant of young barley plants cultivated 31 days in Hoagland 2 (●) or Hoagland 3 (■) nutrient solutions containing 5 mM and 15 mM nitrate, respectively.

2. Experimental data (individual points) and fitted curves of exponential function of the time course of dry mass (mg) per
plant of young barley plants cultivated 31 days in Hoagland 2 (●) or Hoagland 3 (■) nutrient solutions containing 5 mM and 15 mM nitrate, respectively.

Below: Shoot dry mass consisting of leaf blades and leaf sheaths
Above: Shoot plant parts with leaf blade dry mass excluded. Vertical bars indicate the ± standard error.

The changes of the dry mass of the remaining parts of the plant consisting mainly of leaf sheaths yielded differences in RGR reaching some 10 per cent (relative value). The daily dry mass increase corresponds to 9.0 per cent and 9.7 per cent for the H2 and H3 treatments, respectively. The fitted curve (Fig. 2) indicates similar values at the beginning of the experiment with considerable divergence by its end.

The only values where the exponential fit yielded inadequate results were those for leaf blade mass per plant (Fig. 3). The linear regression seemed to produce the best fit indicating the constant dry mass increase of 3.36 mg and 3.95 mg per plant and day for the H2 and H3 treatment, respectively. Because of the relatively small values of standard errors of the leaf dry mass (see Fig. 3), the difference is statistically significant. The difference between the treatments reached some 15 per cent and clearly indicates the positive effect of higher nitrogen concentration in plants cultivated in the H3 treatment on leaf area development (S a c k i, 1961; N á t r, 1989).

On the other hand, the differences in root dry mass per plant between the two experimental treatments are not statistically significant for all the samplings in the course of the experiment. The RGR values were lower compared with those for the shoot or rest dry mass (Fig. 2) and reached only 0.066 mg.mg⁻¹.day⁻¹ and 0.060 mg.mg⁻¹.day⁻¹ for the H2 and H3 treatment, respectively. Although the experimental values were not statistically different when their standard errors were compared, their calculated RGR values differed by some 10 per cent. This indicates clearly that more dry matter was allocated into the roots of plants supplied with lower nitrogen content in the course of the experiment. The time course of the two curves illustrating the RGR values also shows that the difference between the two treatments increases with the age of the plants. There were no differences at the beginning of the sampling period either between measured or calculated values. The calculated values for the Day = 0 were 7.50 mg and 8.18 mg while the measured values on Day = 4 were 7.0 mg and 6.7 mg per root dry mass per plant for H2 and H3, respectively.

Small differences in the dry matter allocation into the individual plant parts summed up and finally yielded considerable differences in the shoot/root ratio of plant dry mass (Fig. 4). During the whole duration of the experiment, the shoot/root ratio was steadily increasing in the H3-treated plants while that of the H2-treated plants was slowly decreasing. Hence, small differences found in the dry mass of the individual plant parts yielded considerable difference in the time course of the shoot/root ratio. This is the very conclusion of the whole experiment.
3. Experimental data (individual points) and fitted lines of exponential function (curve) of the time course of the root dry mass (mg) per plant or linear regression of leaf dry mass of young barley plants cultivated 31 days in Hoagland 2 (●) or Hoagland 3 (■) nutrient solutions containing 5 mM and 15 mM nitrate, respectively. Vertical bars indicate the ± standard error.

BELOW: Root dry mass
ABOVE: Leaf blade dry mass

4. Values of the shoot/root dry mass ratio calculated from measured values (points) and fitted linear regression to these values (lines) of young barley plants cultivated 31 days in Hoagland 2 (●) or Hoagland 3 (■) nutrient solutions containing 5 mM and 15 mM nitrate, respectively.
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References


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Rostliny jarního ječmene (Hordeum vulgare L., cv. Korál) byly pěstovány v živném roztoku Hoagland 2 obsahujícím 5 mM koncentrací nitrátů a v roztoku Hoagland 3 obsahujícím 15 mM koncentrací nitrátů. Kultivace probíhala v 16hodinovém dni při ozáření 320 μmol·m⁻²·s⁻¹ a teplotě den/hn noc odpovídající 22 °C/18 °C s kolísáním ±2 °C. V pravidelných dvou až třímedenních intervalech byly odebrány 4krát 4 rostliny a stanovena hmotnost sušiny listových čepelí, kořenů a zbytku rostliny s tim, že byla dopolčta hmotnost sušiny celé nadzemní části a celé rostliny.

Casovým průběhem experimentálních hodnot byla proláhena exponenciální funkce, jejíž exponent vyjadřuje hodnotu relativní rychlosti růstu, RGR (mg·g⁻¹·den⁻¹). Pouze pro průběh hmotnosti sušiny listových čepelí se ukázala jako vhodnější lineární regrese.

RGR hmotnosti sušiny celé rostliny (obr. 1) byla identická a činila 0.075 mg·g⁻¹·den⁻¹, což odpovídá dennímu přírůstku hmotnosti sušiny 7,5 %. Významně byly zde lze pozorovat rozdíly v počáteční hodnotě vysázeni pro nutný den, a to 28,78 mg pro rostliny H2 a 34,92 pro rostliny H3. Experimentálně naměřené hodnoty při 1. odběru, který proběhl 4. den od počátku nákličování, činily 27,78 mg pro H2 a 30,96 mg pro H3. Obdobné závěry byly vyvozeny z časového průběhu hmotnosti sušiny nadzemní části (obr. 2). Naproti tomu hmotnost sušiny zbytků části rostlin výrazně převyšovala při stejnéch počátečních hodnotách téměř 10% rozdíl v RGR (obr. 2).

Lineární regrese hmotnosti sušiny listů na stáří rostlin poskytuje hodnotu denního přírůstku sušiny 3,56 mg na rostlinu pro H2 a 3,95 mg pro H3 (obr. 3). RGR hmotnosti sušiny kořenů se lišila mezi oběma variantami opět přibližně o 10 % a činila 6,55 mg·g⁻¹·den⁻¹ pro rostliny H2 a 5,98 mg·g⁻¹·den⁻¹ pro H3.

Při poměrům malé rozdíly v průběhu hmotnosti sušiny jednotlivých částí rostlin (obr. 1, 2 a 3) byly stanoveny podstatné rozdíly v hodnotách poměru hmotnosti sušiny nadzemní část/kořenů (obr. 4).

Pokusy prokázaly vysokou citlivost a vhodnost parametru hmotnost sušiny nadzemní část/kořenů pro detekce stavu zásobení rostlin minerálními živinami, především dusíkem. Tímto parametrem lze stanovit nejen výrazný deficit, ale i poměrně

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mалé rozdíly při celkově dobré zásobenosti rostlin dusíkem. Citlivost tohoto paramet-ru lze zvýšit stanovením dynamického průběhu jeho hodnot při několika časově následných odběrech.

jarní ječmen; živný roztok; dusík; relativní růstová rychlost (RGR); poměr nadzemní část/kořeny; detekce déficitu dusíku