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EFFECT OF NITROGEN ON THE TRANSLOCATION OF DRY MASS AND NITROGEN IN BARLEY

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Abstract

A pot experiment was carried out to determine dry mass and nitrogen accumulation until anthesis and at grain filling period, and dry mass translocation and utilization in grain filling of Bulgarian barley genotype Krami. The plants were grown on four levels of nitrogen nutrition – 0, 100, 200 and 300 mg N/kg soil. It was established that plants were synthesized 3-61% more dry biomass at pre-anthesis than at post-anthesis. Nitrogen fertilizing was diminished the relative amount of dry mass accumulated at pre- and post-anthesis and pre- to post-anthesis nitrogen uptake. The highest NHI/HI ratio was established at unfertilized plants – 1.67 and its values were slightly depended on the nitrogen levels. Pre- to post-anthesis N uptake was decreased with increasing N levels from 6.1 (at unfertilized plants) to 3.4 (at N_{300}). Nitrogen fertilizing was decreased the relative part of nitrogen in the grain. Dry mass translocation efficiency ranged from 18.8% in unfertilised plants to 22.4% at applying N_{100}. The mean nitrogen translocation efficiency was 60% and significant differences were obtained between unfertilized plants and those grown at N_{200}.

Key words: *dry mass; nitrogen; translocation efficiency; spring barley.*

INTRODUCTION

The supply of assimilate to the grain of barley may originate from current assimilation and matter assimilated before anthesis and is stored temporarily in the leaves, culms, chaff, and other vegetative plant parts (Van Sanford and MacKown, 1987). Accumulation of reserves before anthesis and their storage in the vegetative parts depend on the growing conditions and genotype (Przulj and Momcilovic, 2001; Blum, 1998). Pre-anthesis reserves contributed up to 74% to the grain yield of barley (Gallagher et al., 1975). According to Austin et al. (1980) the total dry mass of the aboveground vegetative parts of barley usually decreased after anthesis. The contribution of pre-anthesis assimilates to grain filling and grain weight depend on the amount of mass that is mobilized between anthesis and maturity and the efficiency of conversion of the mobilized mass in the grain (Gebbing et al., 1999). The N requirement of the growing grain can be supplied by the mobilization and utilization of N assimilated prior to anthesis (pre-anthesis N) and by the utilization of N assimilated during grain filling (post-anthesis N). Pre-anthesis accumulated nitrogen seems to be the predominant source of nitrogen during grain growth and development (Van Sanford and MacKown, 1987). The amount of nitrogen at anthesis in the aboveground wheat parts can be as high as 90-100% of total plant nitrogen at maturity (Clarke et al., 1990; Heitholt et al., 1990). For barley plants these values were established from 55 % up to 91 % (Przulj and Momcilovic, 2001). The precise amount of pre-anthesis N that is used for grain filling is difficult to estimate because it is necessary to know N losses and the role of the root in N balance (Rroco and Mengel, 2000). In cereals, research on N accumulation and utilization has been carried out mainly on wheat (Dachev, 1999; Papakosta and Gagianas, 1991; Cox et al., 1984; Austin, 1977). Studies have shown that grain N in wheat mainly represents N accumulated in the vegetative parts until anthesis and translocated to the grain during the reproductive phase. N distribution showed that 60-92% of the N accumulating in the wheat grain originates from the translocation from vegetative tissue after anthesis. In barley, 10-100% of grain N is taken up during vegetative growth and translocated during grain filling period (Carreck and Christian, 1990). After anthesis, plants continue the assimilation of N, and significant quantities of N can be assimilated during grain filling. The importance of both N sources has been emphasized by Van Sanford and MacKown (1987), who have found that variation in final spike N can be associated with variation in total N uptake. Environmental conditions during the pre- and post-anthesis periods are likely to have different effects on N accumulation. N uptake is influenced by available water, degree of association between the roots and the soil, the supply of nitrate, genotype requirements and efficiency of N use, and other properties of the genotype and conditions of growing (Clarke et al., 1990). Bulman and Smith (1994) found genotypic variation in N accumulation and translocation to the grain during the process of filling. The aim of this study was to assess contribution of pre- and post-anthesis assimilation for grain production at barley in dependence of nitrogen fertilization.

MATERIALS AND METHODS

The pot experiment with Bulgarian barley variety Krami (15 plants/pot) was conducted under greenhouse conditions. The plants were grown in plastic pots (5L volume) on four levels of nitrogen – 0, 100, 200 and 300 mg N/kg soil. Applying of NH4NO3 as water solutions created the different nitrogen levels. The soil reaction in water solution was 6.7 and content of Nmin – 43.2 mg N/kg. The content of available phosphorus and potassium per 100 grams of soil were 24 and 48 mg, respectively. Four pots of each variant at about mid-anthesis and the rest four pots of each variant at maturity were collected for analyses. These samples were separated in two components at anthesis (leaves+stems and chaff-flowered spikes) and at maturity [grain and straw (leaves+stems+chaff)]. The samples were weighed, oven-dried at 70 °C for 48 h and then weighed again. The nitrogen content was determined according to the Kjeldahl method (Walinga et al., 1995).

The following parameters related to dry mass and nitrogen accumulation and translocation within the barley plant are discussed in this paper:

1. Pre-anthesis and post-anthesis dry mass (DM) and nitrogen accumulation (g/pot);
2. Dry mass translocation (DMT) (g/pot) = dry mass at anthesis-dry mass (straw) at maturity;
3. Dry mass translocation efficiency (DMTE) (%) = dry mass translocation / dry mass at anthesis × 100
4. Contribution of pre-anthesis assimilates to the grain (CAVG) (%) = dry mass translocation / grain yield × 100 (Papakosta and Gagianas, 1991).
5. N translocation from vegetative tissues at anthesis to the grain was calculated as:

N translocation (NT) (mg N/pot) = N uptake at anthesis – N uptake at maturity (straw) (Cox et al., 1986).

6. Proportion of pre-anthesis N that was translocated to the grain:

N translocation efficiency (NTE) (%) = (N translocation / N content at anthesis) x 100

7. Proportion of N in grain in relation to the total above-ground N at maturity:

Nitrogen harvest index (NHI) (%) = (Grain N / total N in above-ground parts at maturity) x 100

Biomass and nitrogen increase during the grain filling period were estimated as the difference between total DM and nitrogen at maturity and the total DM and nitrogen at anthesis. For the estimation parameters of N translocation, it was assumed that all N from the vegetative parts was translocated to the grain during their filling. N losses due to dead leaves falling off before the harvest and root contribution were assumed to have been zero. This approach was used of other researchers (Przulj and Momcilovic, 2001).

An overall analysis of variance (ANOVA) was performed to evaluate the effect of the experimental treatments on the referred variables, and Duncan (1955) multiple range test (□ = 0.95) was used in order to establish the difference among the means.

5. Phosphorus translocation (kg $N.ha^{-1}$) = P_2O_5 content at anthesis− P_2O_5 content of straw at maturity.

6. Phosphorus translocation efficiency (%) = (P_2O_5 translocation/ P_2O_5 content at anthesis) x 100

7. Phosphorus harvest index (PHI) = grain P_2O_5 at maturity/total P_2O_5 content of aboveground biomass at maturity.

RESULTS AND DISCUSSIONS

The obtained results showed significant effect of the N fertilizing (ranged from 0 to 300 mg N/kg soil) on the above ground dry mass at anthesis and maturity (Table 1). Dry mass of leaves+stems, spikes and their sum was increased up to a level 200 mg N/pot. Growing of barley plants at higher level of nitrogen fertilizing (300 mg N/pot) let to decreasing of dry mass at anthesis. The similar result was obtained for grain production at maturity. Vegetative plant parts (leaves+stems+chaff) and total DM at maturity were no significantly decreased with increasing N fertilizing to 300 mg N/pot. Unfertilized plants had the lowest grain harvest index. This parameter was slightly depended on nitrogen fertilizing from 100 up to 300 mg N/pot.

Table 1. Above-ground dry mass at anthesis and maturity, (g/pot) and harvest index, (%)

Variants	Anthesis			Maturity			
	Leaves+stems	Spikes	Total	Grain	Straw	Total	HI
N_0	19.0 d	4.4 c	23.5 c	13.3 d	24.7 c	38.0 c	35.0 b
N_{100}	24.1 c	7,0 b	31.1 b	23.0 c	31.9 b	54.9 b	42.1 a
N_{200}	35.0 a	8.3 a	43.4 a	36.2 a	44.3 a	80.5 a	44.1 a
N_{300}	29.6 b	6.8 b	36.4 b	31.7 b	41.9 a	73.6 a	43.2 a

Table 2. Nitrogen concentration at anthesis and at maturity, (mg N/g DM)

Variants	Anthesis		Maturity	
	Leaves+stems	Spikes	Grain	Straw
N_0	15.2	10.2	17.4	6.4
N_{100}	18.6	15.4	19.0	7.1
N_{200}	20.9	17.7	20.7	7.5
N_{300}	22.1	19.8	21.8	7.9

Under field experiment with twenty barley genotypes Przulj and Momcilovic (2001) were established the mean N concentrations of leaves+stems and flowred spikes 19.2 and 16.4 mg N/g DM, respectively. Our results (Table 2) at anthesis showed that N concentrations of unfertilized plants were 15.2 mg N/g DM (leaves+stems) and 10.2 mg N/g DM (spikes). These values were increased to 22.1 and 19.8 mg N/g DM, respectively at applying N300. Nitrogen fertilization showed the positive effect on the N concentrations of all plant parts at anthesis and at maturity. Nitrogen fertilizing (N200) increased total N uptake of barley at anthesis by 2.6 times, in comparison to unfertilized plants (Table 3). The highest nitrogen level (N300) decreased total N uptake, because it was negatively affected dry mass accumulation. At maturity it was not established significant difference of N uptake between plants grown at N200 and N300.

Table 3. Nitrogen uptake at anthesis and at maturity, (mg N/pot) and NHI, (%)

Variants	Anthesis			Maturity			
	Leaves+stems	Spikes	Total	Grain	Straw	Total	NHI
N_0	289.4 d	45.1 c	334.5 d	231.8 c	157.8 c	389.6 c	59.5 b
N_{100}	449.0 c	107.3 b	556.3 c	437.8 b	226.2 b	664.0 b	65.9 ab
N_{200}	731.9 a	147.4 a	879.4 a	748.9 a	332.1 a	1081.0 a	69.3 a
N_{300}	653.7 b	134.6 a	788.4 b	690.6 a	331.3 a	1022.0 a	67.6 a

Nitrogen harvest index represents the ability of the plant to mobilize and translocate nitrogenous compounds from the leaves, culm, and chaff into the grain. The values of NHI were varied from 59.5 % (unfertilized barley plants) up to 69.3 % at applying N200 (Table 3). The NHI/HI ratio gives approximately estimation of relative parts of the nitrogen and carbohydrates in the grain (Hay, 1995). The highest NHI/HI ratio was established at unfertilized plants – 1.67 and its values were slightly depended on the N levels (Table 1 and 2). These data were corresponded with a viewpoint of Gooding and Davies (1997) for existing of strong genetical control of the NHI/HI ratio.

Table 4. Post-anthesis dry mass (PADM) and nitrogen (PANU) accumulated by barley plants and ratio of pre- to post-anthesis DM accumulation (ADM/PADM), and pre- to post-anthesis N uptake (AN/PANU)

Variants	PADM g/pot	PANU mg N/pot	ADM/PADM	AN/PANU
N_0	14.5 c	55.1 d	1.61	6.1
N_{100}	23.8 b	107.6 c	1.31	5.2
N_{200}	37.2 a	201.7 b	1.17	4.4
N_{300}	37.2 a	233.6 a	1.03	3.4

Nitrogen fertilization was positively affected post-anthesis dry mass (PADM) and post-anthesis N uptake (PANU) (Table 3). PADM accumulation of barley plants grown at N200 and N300 was increased 2.55 times, compared to the control plants. Nitrogen taken up by plants after anthesis (PANU) was significantly increased up to fertilizing N300 (more five-folds, in comparison with unfertilized plants). The relative amount of DM accumulated at pre- and post-anthesis was presented as the ADM/PADM ratio, which was higher than 1 for all variants. Nitrogen fertilizing was diminished ADM/PADM ratio. In dependence of applied N plants were synthesized 3 - 61% more DM at pre-anthesis than at post-anthesis. The ratio of nitrogen taken up pre-anthesis to that taken up post-anthesis (AN/PANU) was strongly depended on the genotype and the year conditions and it was varied from 0.78 up to 16.87 (Przulj and Momcilovic, 2001). We were established that pre- to post-anthesis N uptake was decreased with increasing N levels from 6.1 (at unfertilized plants) to 3.4 (at N300).

Dry mass translocation (DMT) and efficiency (DMTE) of barley plants were increased with N levels up to N200 (Table 5). Dry mass translocation efficiency (DMTE), the parameter that shows the percentage of translocated dry mass, ranged from 18.8 % in unfertilised plants to 22.4 % at applying N100. Nitrogen translocation, estimated as the difference between total amount of nitrogen at anthesis and vegetative nitrogen at maturity, was the highest (547.3 mg N/pot) in plants grown at N200. NT was decreased at higher nitrogen level (N300). The increased accumulation of nitrogen from anthesis till maturity indicated a continued uptake of nitrogen from the soil and a possible translocation from the root. Acording Przulj and Momcilovic (2001) nitrogen translocation efficiency of field grown barley widely varies in dependence of genotype (from 27 to 66 %) than years (from 47 to 52 %). The authors suppose that the ratio of translocated N to grain N can be an indicator of growing conditions during vegetation, i.e. a higher ratio indicates good growing conditions throughout both vegetative and generative phases. In present investigation NTE was high (mean value 60 %) and significant differences were obtained between unfertilized plants and those grown at N200 - 55 % and 64 %, respectively.

Table 5. Dry mass and N translocation and translocation efficiency

Variants	DMT g/pot	DMTE (%)	NT (mg N/pot)	NTE (%)
N_0	4.42 c	18.8 b	176.7 d	52.8 b
N_{100}	6.97 b	22.4 a	330.1 c	59.3 ab
N_{200}	8.33 a	19.2 ab	547.3 a	62.2 a
N_{300}	6.80 b	18.7 b	457.0 b	58.0 ab

CONCLUSION

Bulgarian barley cultivar Krami was synthesized 3 – 61 % more dry biomass at pre-anthesis than at post-anthesis. Nitrogen fertilizing was diminished the relative amount of dry mass accumulated at pre- and post-anthesis and pre- to post-anthesis nitrogen uptake. The highest NHI/HI ratio was established at unfertilized plants – 1.67 and its values were slightly depended on the nitrogen levels. Pre- to post-anthesis N uptake was decreased with increasing N levels from 6.1 (at unfertilized plants) to 3.4 (at N300). Nitrogen fertilizing was decreased the relative part of nitrogen in the grain. Dry mass translocation efficiency ranged from 18.8 % in unfertilised plants to 22.4 % at applying N100. The mean nitrogen translocation efficiency was 60 % and significant differences were obtained between unfertilized plants and those grown at N200.

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