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DRY MASS AND PHOSPHORUS TRANSLOCATION IN BARLEY IN DEPENDENCE OF SOURCE-SINK RATIO

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Abstract

The changes in reutilization of vegetative dry mass of barley were studied in dependence of source-sink ratio as a result of the reduction of spike by half. A malting barley variety Krami was investigated in conditions of long-term fertilizer trial at the experimental field of Department of Agrochemistry and Soil Science of Agricultural University – Plovdiv on soil type Molic fluvisol. It was found that in anthesis the vegetative dry mass was higher than the dry mass of the growing spike, and its share of biomass was 31.0% for the first year of study and 31.9%, respectively for the second. The amount of phosphorus in the developing spike was 40.4% and 44.6%, respectively in 2013 and 2014. The reduction of the spike had a low influence on the accumulated straw dry mass but significantly reduced that of the grain, and therefrom the yield harvest index. As a result of the reduction of spike, the amount of phosphorus in grain was highly increased in both experimental years. As opposed to grain, the changes in the content of straw phosphorus in plants with and without reduced spikes, were less developed. Barley accumulated significant amounts of net dry mass after anthesis, and a gain of dry mass and phosphorus was established after that phase during the two years of study with high values in 2014-up to 67.3% for barley without reduced spikes. A higher efficiency of phosphorus reutilization was established in 2013-61.9%. The barley productivity decreased as a result of the spike reduction with a significant lowering of yield in 2014. A lower productivity was reported in the second year of study as a result of unfavourable weather conditions during the year.

Key words: *barley – sourse-sink ratio.*

INTRODUCTION

During the growth cycle yield is mainly limited by the source strength, the sink capacity or colimited by both (Borrás et al., 2004; Dordas, 2009). Many factors can affect the source–sink relations during the different growth phases including genotype, temperature, rainfall and fertilization (Mohammadi and Amri, 2008; Miralles and Slafer, 2007). Nitrogen and phosphorus are the main nutrients that affect the assimilate production and distribution and affecting directly or indirectly the source–sink relation (Arduini et al., 2006; Muchow, 1988). The most active acceptor for assimilates in anthesis and after this phase is grain. Improving the productivity of grain is a major scientific and application priority). The changed acceptor in wheat showed that the grain size is limited only by the acceptor under favorable growing conditions (Cartelle et al., 2006; Borrás et al., 2004; Slafer & Savin, 1994; Jenner et al., 1991). Under no irrigation the grain mass often increased as a result of reduction of the acceptor (Blum et al., 1988), which can be interpreted as a result of a (donor) source limitation of the grain growth. In Bulgaria barley is grown under non-irrigated fields where stressful conditions during grain filling can limit productivity and increase the dependence of the yield of spare assimilates. A better understanding of the relationship between vegetative and grain reserves in this culture is important for establishing physiological and agrochemical characteristics suitable for adaptation to adverse external effects, mainly related to climate changes such as frequent droughts and other external factors that lead to the modification of grain yield (Borras et al., 2004). The aim of present study was to examine the effect of changed sourse-sink ratio on accumulation and reutilization of dry mass and phosphorus in barley plants.

MATERIALS AND METHODS

The experiment was carried out in conditions of long-term fertilizer trial in rotation with maize. The barley variety Krami was investigated. The soil type was Molic fluvisoil.

The area of experimental plots was 20 m^2 and each variant were examined in four replications. A moderate mineral fertilization was applied in rate 80 kg $N.ha^{-1}$. In heading/anthesis of barley the aboveground plant parts were analyzed. The samples were divided into leaves, stems and growing spikes. They were dried, weighed, ground and later analyzed for primary nutrients nitrogen, phosphorus and potassium. At the same time in anthesis the spikes of barley from four plots were reduced by 50% (removing the top one-half) and they were marked. At maturity the plants from area of plots (subplots) with halved spikes and plots with no reduced spikes were taken for analysis. The samples were separated into grains and leaves, stems and chaffs. They were weighed and dried to constant weight at 60°C. An aliquot part of dry plant samples was mineralized with concentrated H_2SO_4 catalyzed by H_2O_2 and the content of phosphorus was defined (method of Egner-Rheem).

The parameters referring to dry mass and phosphorus accumulation, translocation and remobilization within the wheat and barley plants were calculated as follows according to different authors (Dordas, 2009; Abeledo et al., 2008; Przulj and Momcilovic, 2001a,b; Papakosta and Gagianas, 1991; Cox et al., 1986, 1985a,b):

1. Dry mass translocation ($kg.ha^{-1}$) = dry mass at anthesis –dry massof straw at maturity. Straw included leaves, culm and chaff.
2. Dry mass translocation efficiency (%) = (dry mass translocation/dry mass at anthesis) x 100.
3. Contribution of pre-anthesis assimilates to the grain (%) CAVG = (dry mass translocation/grain yield) x 100.
4. Harvest index (HI) = grain yield/total aboveground biomass at maturity.
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

Dry mass of vegetative plant parts (leaves and stems) in anthesis was higher, than dry mass of the growing spikes in anthesis (Table 1). The total accumulated aboveground dry mass of barley was 3854 $kg.ha^{-1}$ and 5120 $kg.ha^{-1}$, respectively for 2013 and 2014. The part of aboveground dry biomass in anthesis was 31.0% for the first year of study and 31.9%-for the second one. The content of phosphorus (Table 2) in aboveground plant parts was higher in 2013-31.4 kg $P_2O_5.ha^{-1}$ compared with 2014-20.4 kg $P_2O_5.ha^{-1}$. The amount of phosphorus distributed to the growing spikes was 40.4% for the first experimental year 44.6 kg $P_2O_5.ha^{-1}$, respectively for the second.

Table 1. Aboveground dry mass ($kg.ha^{-1}$) and spike/dry mass ratio in anthesis

Crop	Growing spikes	Leaves and stems	Dry mass in anthesis	Spikes/Dry mass
2013	1589	3531	5120	0.310
2014	1228	2626	3854	0.319

Table 2. Phosphorus content of aboveground plant parts (kg $P_2O_5.ha^{-1}$) in anthesis and ratio of P_2O_5 spike to aboveground dry mass P_2O_5

Crop	P_2O_5 of growing spikes	P_2O_5 of leaves and stems	P_2O_5 in anthesis	P_2O_5 of spikes/P_2O_5 in anthesis
2013	12.7	18.7	31.4	0.404
2014	9.1	11.3	20.4	0.446

The accumulation of dry mass and its distribution between the different plant parts in maturity is presented in Table 3. In anthesis dry mass of vegetative plant parts was higher than dry mass of the growing spikes. At maturity dry mass of grain in plants with reduced spikes was lower in both years of the study - 25.6% in 2013 and 41% - in 2014. The amount of straw yield formed was hardly affected by the reduction of the spike. Therefore, the reduction of the sink (grain acceptor) did not influence the dry weight of straw (leaves, culm and chaff). As expected the spikes halving decreased the grain yield and hence the yield harvest index, which was lower in plants with reduced spikes and was 16% for both experimental years.

Table 3. Productivity of barley ($kg.ha^{-1}$)

Parameters	2013 Barley	2013 Barley with reduced spike	2014 Barley	2014 Barley with reduced spike
Grain	4502	3350	3357	1982
Straw	3738	3970	3628	2944
Grain+Straw	8240	7320	6985	4926
HI	0.546	0.458	0.481	0.402

Spikes reduction resulted in most significant diminishing of the amount of grain phosphorus- with 55.6% for 2013 and 64.9% for 2014 (Table 4). Unlike grain phosphorus, changes in the phosphorus content of straw in plants with and without halved spikes were less demonstrated. The distribution of the total accumulated phosphorus of plants in maturity, expressed by phosphorus harvest index, indicated that the proportion of phosphorus in the grain was diminished due to the spikes reduction. This was expected as the total phosphorus content in the grain was lower in halved spikes plants. The phosphorus harvest index for 2013 was 0.716 and 0.551 in barley with or without changes in acceptor, while in 2014 values were respectively 0.660 and 0.490.

Table 4. Phosphorus content of barley at maturity (kg $P_2O_5.ha^{-1}$)

Parameters	2013 Barley	2013 Barley with reduced spike	2014 Barley	2014 Barley with reduced spike
Grain phosphorus	30.2	13.4	22.5	7.9
Straw phosphorus	12.0	10.9	11.6	8.2
Phosphorus of grain+straw	42.2	24.3	34.1	16.1
PHI	0.716	0.551	0.660	0.490
PHI/HI	1.311	1.203	1.372	1.218

Distribution of biomass is determined by the number and activity of the acceptor and the number of grains is closely related to the presence of assimilates in anthesis (Wardlaw, 1990). Under non-irrigated conditions, it is important to increase to maximum extent translocation (reutilization) of dry mass as it can provide a higher yield. Proper selection of varieties in addition to the cultivation of crops could increase the efficiency of reutilization of dry mass (Cox et al., 1985). The results of the trial showed that barley accumulated significant amounts of net mass after anthesis, as in both experimental years was established a gain of dry mass (Table 5). The translocated pre-anthesis biomass changed in range from 1150 to 1382 $kg.ha^{-1}$ in 2013 and from 1910 to 2260 $kg.ha^{-1}$ in 2014, as the efficiency of reutilization was higher in the first year of study. Barley plants with reduced spikes reutilized least pre-anthesis dry biomass in the grain.

The accumulated phosphorus, its reutilization and its part of pre-anthesis phosphorus were presented in Table 6. The results demonstrated that the barley accumulated a large amount of phosphorus after anthesis in plants without reduction of the sink - 10.7 kg $P_2O_5.ha^{-1}$ in 2013 and 13.7 kg $P_2O_5.ha^{-1}$ and 13.7 kg $P_2O_5.ha^{-1}$ in 2014, as in both years of study was observed a loss of phosphorus in the variants with reduced spikes, which was significantly expressed in 2013. It was established a gain of phosphorus after anthesis and more significant values were demonstrated in the second year of study - 67.3%, related to the first one - 34.2%. The translocated phosphorus was in range from 8.8 to 19.0 kg $P_2O_5.ha^{-1}$, respectively for 2013 and 2014. The highest efficiency of translocation-61.9% was reported in the first year of study. As a result of spike halving, it was established a loss of phosphorus after anthesis, therefore values of reutilization and efficiency of translocation were not reported.

Table 5. Dry mass accumulation after anthesis, dry mass translocation and contribution of pre-anthesis assimilates to the grain of barley

Parameters	2013 Barley	2013 Barley with reduced spike	2014 Barley	2014 Barley with reduced spike
Net dry mass after anthesis, $kg.ha^{-1}$	3120**	2201	3130	1070
Dry mass translocation, $kg.ha^{-1}$	1382**	1150	2260	1910
Dry mass translocation efficiency,%	27.0	22.5	5.9	23.6
CAVG, %	30.7	34.3		

Table 6. Phosphorus accumulation after anthesis, phosphorus translocation and contribution of pre-anthesis assimilates to the grain of barley

Parameters	2013 Barley	2013 Barley with reduced spike	2014 Barley	2014 Barley with reduced spike
Phosphorus after anthesis, kg $P_2O_5.ha^{-1}$	10.7	-7.1	13.7	-4.2
Phosphorus translocation, kg $P_2O_5.ha^{-1}$	19.0	-	8.8	-
Phosphorus translocation efficiency,%	61.9	-	43.0	-
CPG, %	64.4	-	39.0	-

CONCLUSIONS

Dry mass of vegetative plant parts in anthesis was higher, than dry mass of the growing spikes. The share of growing spike of biomass was 31.0% for the first year of study and 31.9% - for the second. After anthesis barley continues to accumulate dry biomass. The participation of pre-anthesis stem reserves in grain slightly amended due to the change of the acceptor. Sink reduction strongly reduced grain yield and harvest index and weakly affect the straw. The efficiency of reutilization of dry mass is higher in the first year of study. It was established a gain of phosphorus after anthesis and more significant values were demonstrated in the second year of study - 67.3%. The translocated phosphorus was in range from 8.8 to 19.0 kg $P_2O_5.ha^{-1}$, respectively for 2013 and 2014. The highest efficiency of translocation - 61.9% was reported in the first year of study. As a result of spike halving, it was established a loss of phosphorus after anthesis. The grain yields from plants with reduced spikes are lower-with 25.6% for 2013 and 41.0% for 2014.

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MISCELLANEOUS