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EFFECT OF NITROGEN ON THE ACCUMULATION AND REUTILIZATION OF DRY MASS IN GRAIN SORGHUM

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ABSTRACT

Accumulation and reutilization of dry mass until anthesis and during a grain filling period of sorghum in response to nitrogen fertilization in rates 0, 60, 120, 180, 240 and 300 kg N.ha^{-1} was studied in a field experiment. Grain sorghum hybrid EC Alize was grown under not- irrigated conditions in the experimental field of Agricultural University of Plovdiv, Bulgaria. The experimental design was a randomized, complete block design with four replications with a size of experimental plots of 20 m^2 after wheat as predecessor. Standard farming practices for the region of Southern Bulgaria were applied. It was established that nitrogen fertilization significantly increased the amount of accumulated dry mass at anthesis and total above ground dry mass at maturity compared to N_0. Not significant effect of higher rates (180, 240 and 300 kg N.ha^{-1}) on the dry mass accumulation of sorghum was found. Average post anthesis net dry mass accumulation was 3291 kg.ha^{-1} and its amount increased in parallel with the nitrogen rate up to N_{180}. The highest dry mass translocation, translocation efficiency, and contribution of pre-anthesis assimilations of the grain was established at nitrogen rate N_{120} with values 2073 kg.ha^{-1}, 25.0 % and 41,8 %, respectively. Growth of sorghum at higher nitrogen rates N_{180}, N_{240}, N_{300} significantly decreased efficiency of dry mass translocation and contribution of pre-anthesis assimilations of the grain. Nitrogen fertilization had very strong negative correlation with dry mass translocation efficiency (-0.860*) and contribution of pre-anthesis assimilations of the grain (-0.863*). Very strong positive correlation (0.988**) was found between dry mass translocation efficiency and contribution of pre-anthesis assimilations of the grain.

Keywords: *Grain sorghum, Nitrogen, Dry mass, Reutilization.*

INTRODUCTION

Yield of cereals crops is mainly determined by the source of assimilations, the irrigation capacity or collimated by both (Borras *et al.*, 2004; Dordas, 2009). The supply of assimilation of the grain 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). Many factors can affect the source–sink relations during the different growth phases including genotype, temperature, rainfall and fertilization (Miralles and Slafer, 2007; Mohammadi and Amri, 2008).Nitrogen is the main nutrient that affects the assimilation production and distribution and influence directly or indirectly the source–sink relation (Arduini *et al*., 2006; Muchow, 1988). The most active acceptor for assimilations in anthesis and after this phase is grain. Sorghum has better ability to tolerate drought stress compared with other crops and is known as an index for drought resistance of agronomic crops (Beheshti, 1997). Sorghum is mainly grown under non-irrigated fields where stressful conditions during grain filling can limit productivity and increase the dependence of the yield of spare assimilations. In Bulgaria studies were focused on studying wheat (Kostadinova and Panayotova, 2014) and barley (Kostadinova and Ganusheva, 2013; Kostadinova, 2014) and there is not enough information about grain sorghum, especially about the contribution of pre- and post-anthesis assimilation for grain production. 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; Beheshti and Behboodi, 2010). The aim of this study was to study the effect of nitrogen fertilization rates on the parameters of dry mass accumulation and reutilization in grain sorghum plants.

MATERIAL AND METHODS

The investigation was carried out on the experimental field of Agricultural University of Plovdiv, Bulgaria in 2017 under non-irrigated conditions. Accumulation, translocation and reutilization of dry mass until anthesis and during a grain filling period of grain sorghum hybrid EC Alize in response to nitrogen fertilization in rates 0, 60, 120, 180, 240 and 300 kg $N.ha^{-1}$ was studied. The experimental design was a randomized, complete block design with four replications with a size of experimental plots of 20 m^2 after wheat as predecessor. Total nitrogen as NH_4NO_3 was applied as pre-sowing fertilization on the background $P_{50}K_{50}$ fertilization as triple superphosphate and potassium chloride, respectively. Standard farming practices for the region of Southern Bulgaria were applied. The soil type of the experimental field is alluvial-meadow *Mollic Fluvisols* (FAO, 2006) with slightly alkaline reaction pH_{H2O}=7.80. The content of available nutrients in the soil before sowing of the sorghum was mineral N - 27.6 mg $Nmin.kg^{-1}$; available phosphorus (Egner-Ream) 158 mg $P_2O_5.kg^{-1}$ and exchangeable potassium 210 mg $K_2O.kg^{-1}$. Meteorological conditions during vegetation period of sorghum were recorded daily in the experimental area and are given in Table 1, together with the long-term average of temperature and precipitations. The values of temperature and precipitations during the vegetation of sorghum characterized hydro-thermal conditions of the period as warm and dry.

Table 1. Hydro-thermal conditions during sorghum vegetation period.

	Temperature (°C)					Precipitation (L.m^{-1})				
	April	May	June	July	August	April	May	June	July	August
2017	12.7	17.6	23.7	25.1	25.4	26.1	52.7	15.4	29.8	9.2
Long-term norm	12.2	17.2	20.9	23.2	22.7	45	65	63	49	31

At about mid-anthesis and at maturity the above ground dry mass of sorghum plants of each plot was analyzed by representative sampled areas of 1 m^2. Whole plants (leaves + stems + flowered panicles) were analyzed at anthesis. At maturity the plant samples were separated in two components - grain and straw (leaves + stems + chaffs). After cutting and separation at anthesis and maturity the samples were oven-dried at 70 °C for 48 h. Accumulation and reutilization of dry mass within the sorghum plants were studied on the base of parameters referring to dry matter translocation. The parameters were calculated as follows according to different authors for cereals (Cox *et al*., 1985ab; Abeledo *et al*., 2008; Dordas, 2009):

- Pre-anthesis and post-anthesis dry mass accumulation (DM, kg.ha^{-1});
- Dry mass translocation (DMT, kg.ha^{-1}) = dry mass at anthesis - dry mass of straw at maturity;
- Dry mass translocation efficiency (DMTE, %) = (dry mass translocation / dry mass at anthesis) × 100
- Contribution of pre-anthesis assimilates to the grain (CAVG, %) = (dry mass translocation / grain yield) × 100 (Papakosta and Gagianas, 1991)
- Post anthesis net dry mass accumulation, or the increased biomass during the period of grain filling, were estimated as the difference between total DM at maturity and the total DM at anthesis (Przulj and Momcilovic, 2001).

An overall analysis of variance (ANOVA) was performed to evaluate the effect of the experimental treatments on the referred variables. In order to establish the difference among the means Duncan's multiple range test at level of significance $p \leq 0.05$ was used. Pearson correlation coefficient was calculated for assessment of the dry mass translocation efficiency and contribution of pre-anthesis assimilates to the grain with some parameters of dry mass reutilization. Analyses were performed with a personal computer using the SPSS™ (SPSS Inc., IL, USA) statistical program.

RESULTS AND DISCUSSION

Nitrogen fertilization in rates N_{60} – N_{300} significantly increased the accumulated dry biomass of sorghum at anthesis compared to the control N_0 (Table 2). The highest amount of dry mass was obtained at N_{300}, which was by 1871 kg.ha^{-1} more than N_0. Growing of hybrid EC Alize at higher levels of nitrogen rates N_{180}, N_{240} and N_{300} did not significantly change dry mass at anthesis, vegetative plant parts (leaves+stems+chaff) and total DM at maturity. The nitrogen rates 60, 120, 180, 240 and 300 kg N.ha^{-1} demonstrated higher grain yield by 7.1, 17.6, 25.8, 19.3 and

17.1 %, in respect to control plants without nitrogen fertilization. Harvest index slightly depended on nitrogen fertilization, but its value proven decreased at N_{300}.

Table 2. Dry mass at anthesis and maturity in dependence of nitrogen fertilization rate.

N rate	DM at anthesis, kg.ha^{-1}	DM grain, kg.ha^{-1}	DM of straw, kg.ha^{-1}	Total DM at maturity, kg.ha^{-1}	HI, %
N_0	7630 d*	4572 d	5826 c	10398 d	44.0 ab
N_{60}	8390 c	4897 c	6407 bc	11304 c	43.4 ab
N_{120}	9000 b	5378 b	6751 b	12129 b	44.4 a
N_{180}	9492 a	5750 a	7419 a	13168 a	43.7 ab
N_{240}	9380 ab	5455 b	7535 a	12989 a	42.0 bc
N_{300}	9501 a	5355 b	7795 a	13150 a	40.7 c
Average	***8899***	***5234***	***6955***	***12190***	***43.0***

*Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

Table 3. Post anthesis net dry mass accumulation, kg.ha^{-1} and ratio of pre- to post anthesis accumulated dry mass of sorghum in dependence of nitrogen fertilization.

N rate	Post anthesis net dry mass, kg.ha^{-1}	Ratio of pre- to post anthesis accumulated dry mass
N_0	2768 c*	2.76
N_{60}	2914 bc	2.88
N_{120}	3129 b	2.88
N_{180}	3676 a	2.58
N_{240}	3609 a	2.60
N_{300}	3649 a	2.60
Average	***3291***	***2.72***

*Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

The difference between total dry mass at maturity and the total dry mass at anthesis was positive value in all nitrogen treatments (Table 3). Consequently, the plants increased biomass during the period of grain filling. Average post anthesis net dry mass accumulation was 3291 kg.ha^{-1}. kg.ha^{-1}. It was changed from 2768 kg.ha^{-1} (N_0) to 3676 kg.ha^{-1} (N_{180}). Post anthesis net dry mass accumulation of sorghum increased in parallel with the nitrogen rate up to N_{180}. The results showed that higher than 180 kg N.ha^{-1} rates did not increase the quantity of post anthesis net dry mass accumulation. The ratio of pre- to post anthesis accumulated dry mass was higher than one of all studied nitrogen rates. This indicated that plants accumulated more dry mass in the pre-anthesis period than after anthesis. The ratio of pre- to post anthesis accumulated dry mass varied in a range 2.58 – 2.88. A similar effect of increased biomass during the period of grain filling was found for grain sorghum (Ramazanzadeh *et al*., 2012; Beheshti and Behboodi, 2010) and sunflower (Koutroubas *et al*., 2004).

Table 4. Dry mass translocation, dry mass translocation efficiency and contribution of pre-anthesis assimilations of the grain in dependence of nitrogen fertilization.

N rate	Dry mass translocation, kg.ha^{-1}	Dry mass translocation efficiency, %	Contribution of pre-anthesis assimilates to the grain, %
N_0	1804 c	23.6 ab	39.5 a
N_{60}	1983 b	23.6 ab	40.5 a
N_{120}	2249 a	25.0 a	41.8 a
N_{180}	2073 ab	21.8 b	36.1 b
N_{240}	1845 c	19.7 bc	33.8 bc
N_{300}	1706 d	18.0 c	31.9 c
Average	***1943***	***22.0***	***37.3***

*Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

The contribution of pre-anthesis assimilations of the grain may be crucial for maintaining grain yield when adverse climatic conditions reduce photosynthesis, water and mineral uptake (Arduini *et al*., 2006). The highest dry mass translocation, translocation efficiency, and contribution of pre-anthesis assimilations of the grain was established at nitrogen rate N_{120} with values 2073 kg.ha^{-1}, 25.0 % and 41,8 %, respectively. Growth of sorghum at higher nitrogen rates N_{180}, N_{240}, N_{300} significantly decreased efficiency of dry mass translocation and contribution of pre-anthesis assimilations of the grain.

Table 5. Correlation of dry mass translocation efficiency and contribution of pre-anthesis assimilations of the grain with parameters of dry mass reutilization

Parameters	Dry mass translocation efficiency, r	Contribution of pre-anthesis assimilates to the grain, r
Nitrogen fertilization	-0.860*	-0.863*
Grain DM	-0.389	-0.461
Straw DM	-0.796	-0.817*
Maturity (Grain+Straw) DM	-0.673	-0.714
Anthesis DM	-0.609	-0.643
Post anthesis net DM accumulation	-0.768*	-0.821*
Dry mass translocation	0.724	0.679
Dry mass translocation efficiency	1	0.988**

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

The correlation analysis was represented in Table 5. It was shown that nitrogen fertilization very strong and negatively correlated with dry mass translocation efficiency (r = -0.860*) and contribution of pre-anthesis assimilations of the grain

(r = -0.863*). Very strong positive relationship (r = 0.988**) was found between dry mass translocation efficiency and contribution of pre-anthesis assimilations of the grain.

CONCLUSIONS

Nitrogen fertilization significantly increased the amount of accumulated dry mass at anthesis and total above ground dry mass at maturity compared to N_0. Not significant effect of higher rates (180, 240 and 300 kg $N.ha^{-1}$) on the dry mass accumulation of sorghum was found. Average post anthesis net dry mass accumulation was 3291 $kg.ha^{-1}$ and its amount increased in parallel with the nitrogen rate up to N_{180}. The highest dry mass translocation, translocation efficiency, and contribution of pre-anthesis assimilations of the grain was established at nitrogen rate N_{120} with values 2073 $kg.ha^{-1}$, 25.0 % and 41,8 %, respectively. Growth of sorghum at higher nitrogen rates N_{180}, N_{240}, N_{300} significantly decreased efficiency of dry mass translocation and contribution of pre-anthesis assimilations of the grain. Nitrogen fertilization very strong negatively correlated with dry mass translocation efficiency (-0.860*) and contribution of pre-anthesis assimilations of the grain (-0.863*). Very strong positive correlation (0.988**) was found between dry mass translocation efficiency and contribution of pre-anthesis assimilations of the grain.

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