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DRY MATTER REMOBILIZATION, YIELD AND YIELD COMPONENTS OF DURUM (*TRITICUM DURUM* DESF.) AND BREAD (*TRITICUM AESTIVUM* L.) WHEAT GENOTYPES UNDER DROUGHT STRESS

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Abstract

Drought is a major limiting factor affecting wheat production in the world. We aimed to study the effect of soil water deficit on dry matter remobilization (DMR), grain yield (GY) and yield components of durum and bread wheat genotypes. Drought stress accelerated DMR. Lowest remobilization of dry matter into grains was detected in the tallest, late heading genotypes, which were also characterized by low harvest index (HI). Drought stress showed less affect on plant height (PH), peduncle length (PL), spike length (SL), spike width (SW), spikelet number per spike (SNS) but strongly affected the biological yield (BY), spike mass (SM), grain number per spike (GNS) and grain mass per spike (GMS), thousand kernels mass (TKM). GY positively and significantly correlated with spikes m^{-2} (SN), BY and HI under drought stress condition. We consider that wheat characteristics DMR, SN, BY, HI are good selection criteria under drought stress.

Key words: Bread wheat, Dry matter remobilization, Durum wheat, Grain yield, Yield components.

Introduction

With the population growing rapidly and the limited water resources becoming scarcer, maintenance of sustainable productivity of cereal crops is of great importance. Wheat (*Triticum* L.) is one of the main crops for human nutrition. Global wheat production in 2017 amounted to 754 million tons, which is 2.7 percent more than in 2016 (FAO 2017). Adverse biotic and abiotic stresses negatively affect the productivity of wheat, do not allow the realization of genetic potential. Drought is a major factor limiting the productivity of wheat throughout the world in addition to other environmental stresses, particularly high temperature, irradiance and salt stresses (Mekliche *et al*., 2015). Some estimates obviously indicate that approximately 50% of the 230 million hectares are being cultivated annually with wheat in the world is regularly affected by drought (Pfeiffer *et al*., 2005). In general, breeding for drought tolerance involves combining good yield potential in the absence of the stress and the selection of high heritable traits that provide drought stress tolerance (Jones 2007). The deficiency of water leads to severe decline in yield traits of crop plants probably by disrupting leaf gas exchange properties which not only limit the size of the source and sink tissues but the phloem loading, assimilate translocation and dry matter portioning are also impaired (Farooq *et al*., 2009). Water stress is known to reduce tillering ability, number of spikes per unit area, leaf area index, biomass accumulation, SNS, GNS, GMS and TKM, which ultimately cause noticeably low grain productivity (Vessar *et al*., 2007; Mirbahar *et al*., 2009; Akram 2011). During grain filling, most of assimilates translocated to grains are provided by current photosynthesis in flag, penultimate leaves and spike (Arduini *et al*., 2006). A substantial part of grain dry matter can originate from remobilization of assimilates accumulated until anthesis and deposited temporarily in different vegetative parts of plants (Santiveri *et al*., 2004; Dordas 2012). Contribution of pre-anthesis assimilates to grain varies in different wheat genotypes and it can range from 5 to 51% to total grain yield of durum and spelt wheat (Ercoli *et al*., 2008; Koutroubas *et al*., 2012). Postanthesis nitrogen and drought stress decrease grain yield of wheat through sink strength and source capacity (Yang *et al*., 2002; Schapendonk *et al*., 2007).

Wheat is one of the widely cultivated (about 804.000 hectares) cereal crops in Azerbaijan, where drought is the main limiting factor for its production (Aliyev 2001). The prolonged drought from anthesis growth stage to grain ripening causes serious reduction in GY. Different agronomical, morphological and physiological traits play a critical role in the stabilizing of GY under drought stress condition. Appropriate physiological traits (high stomatal conductance, photosynthesis and transpiration rates) are important in the formation of greater assimilation area, dry matter accumulation and grain yield but usually associated with drought susceptibility. Selecting cultivars with drought tolerance and exploring their mechanisms of drought tolerance are very important for the purpose of yield improvement under water limiting conditions (Shan *et al*., 2012).

The present study was carried out to study the effect of drought stress on DMR, GY and yield components of durum and bread wheat genotypes. We also aimed to identify traits related to drought tolerance of wheat genotypes.

Materials and Methods

Plant material and growth conditions: Field studies were carried out during the 2014-15 growing season at the experimental field of the Department of Plant Physiology and Biotechnology Research Institute of Crop Husbandry, located in Absheron peninsula, Baku,. Durum wheat genotypes (Garagylchyg 2, Vugar, Shiraslan 23, Barakatli 95, Alinja 84, Tartar, Sharg, Gyrmyzybugda) and bread wheat genotypes (Nurlu 99, Gobustan, Akinchi 84, Giymatli 2/17, Gyrmyzy gul1, Azamatli 95, Tale 38, Ruzi 84, Pirshahin1, 12ndFAWWON№97, 4thFEFWSN№50, Gunashli, Dagdash, Saratovskaya 29) were grown under two environments: drought (non-irrigation) and irrigated (three irrigations: at seedlings, stem elongation, and grain filling stages). The size of plot was 1.05 m×10 m, with 15.0 cm row spacing. Each plot had three replications under drought and irrigation. Soil had a weak alkaline property at 0-75 cm depth with pH 8,6-8,9 (Table 1). Fertilization was applied as N_{120},P_{60},K_{60} per hectare.

Table 1. Soil characteristics of experimental site.

	Soil profil		
Characteristics	**0-25 cm**	**25-50 cm**	**50-75 cm**
Texture	Sandy clay	Clay	Clay
Nitrogen, %	0.089	0.065	0.051
Available P, mg/kg soil	13.5	8.5	2.6
Exchangeable K, mg/kg soil	296	181	135
Organic matter, %	1.345	0.895	0.467
pH	8.6	8.7	8.9
$CaCO_3$, %	14.6	16.1	17.3

Dry mass measurement: Dry mass was measured after oven drying samples at 105°C for 24 h. DMR was calculated as the difference between total aboveground dry mass at anthesis and vegetative plant parts (leaves, stem plus sheaths and vegetative parts of spike) at maturity (Dordas 2012). Dry matter remobilization efficiency (DMRE) was calculated as the ratio of DMR to the dry matter at anthesis. Contribution of pre-anthesis assimilates to grain (DMRC) was calculated as the ratio of DMR to grain mass at maturity.

Agronimical and yield compoenents: PH, PL, SN were determined at physiological maturity. Days to heading (DH) calculated from 1st November. Before harvest 10 spikes from each genotype collected for the determination of SL, SW, SNS, SM, GNS and GMS. After harvest BY, TKM, GY and HI were determined. HI calculated as the ratio of GY/BY.

Statistical analysis

Mean values were calculated by Excel program. Correlation among traits was calculated by SPSS 16 software.

Results and Discussion

Drought stress accelerated the outflow of photoassimilates from vegetative parts of plant into grains (Table 2). The DMR varied across genotypes. DMRE was higher in stressed plants than in irrigated plants. DMRC amounted to 2.67-46.96% and 7.10-51.48% in durum wheat genotypes, 12.06-69.79% and 11.89-95.01% in bread wheat genotypes under irrigated and drought stress conditions, respectively. Ebadi *et al*., (2007) estimated that, in barley, DM remobilization from shoot to grain was increased by water stress from 36 to 82.5%. Yang *et al.,* (2001) reported that at maturity, 75 to 92% of pre-anthesis carbon stored in straw was reallocated to grain under postanthesis drought stress. Higher DMRC and higher HI were detected in genotypes Barakatli 95, Tartar, Nurlu 99, Giymatli 2/17, Azamatli 95, Tale 38, Ruzi 84, Pirshahin1, 12nd FAWWON№97 and Gunashli. Lowest DMR and DMRE were detected in the tallest, late heading genotypes Sharg, Gyrmyzybugda, Dagdash, Saratovskaya 29, which are also characterized by low values of HI. It is assumed that in tall genotypes there is a competition for photoassimilates between stem growth and grain filling (Austin et al. 1977). Generally, the HI was higher in bread wheat than in durum wheat. We found an increase of HI under water deficiency in genotypes Nurlu 99, Gobustan, with early heading time. In such genotypes, the outflow of photoassimilates into grains takes place in more favorable conditions.

Drought stress had no strong effect on the PH and PL (Fig. 1). Significant reduction of both traits was detected in genotypes Garagylchyg 2 (15 and 10%), Akinchi-84 (12 and 14%), Giymatli 2/17 (15 and 24%). Richards *et al*., (2001) reported that one of the major effects of water stress was to decrease PH, which also caused a reduction in dry matter accumulation and subsequently plant production. Mirbahar *et al*., (2009) reported about drastic effect of water stress on height of bread wheat genotypes. The differences in PH resulted from a reduction in PL of all cultivars when exposed to drought stress (Izanloo *et al*., 2008). Bogale *et al*., (2011) demonstrated positive correlation between PL and grain yield of durum wheat genotypes, suggesting this traits good criteria for durum wheat genotypes under drought. We consider that optimal PH is also desirable trait under rain-fed condition (Allahverdiyev, 2016).

Some yield components, such as SL and SW, SNS were not sensitive to drought stress (Table 3). However yield components, such as SM, GNS, GMS, BY and TKM were sensitive to drought stress. An average SN was higher in bread wheat than durum wheat. This is due to the relatively higher tillering capacity of bread wheat. The highest SN was detected in bread wheat genotypes Gyrmyzy gul 1 and 12ndFAWWON№97. Limitation in the SN under the influence of drought was most pronounced in genotypes Nurlu 99, Pirshahin 1 and Azamatli 95. Water limitation decreased SN by 30% when applied from one leaf to floral initiation stage (Moayedi *et al*., 2010). On average the SL was larger in bread wheat, while the SW in durum wheat. A smaller SN is compensated by an increase in the GNS and GMS.On average, durum wheat exceeds bread wheat by the SNS, SM, GNS, GMS, TKM. However, the decrease in these parameters of the yield under the influence of drought was more pronounced in durum wheat. More profound reduction in the SM during water deficiency was observed in genotypes Sharg, Gyrmyzybugda, Nurlu 99, Tale 38 and 12nd FAWWON№97. We detected a significant decrease in the GNS only in genotypes Tartar, Gyrmyzybugda, while strong decrease in the GMS was revealed in genotypes Shiraslan 23, Sharg, Gyrmyzybugda, Nurlu 99, Tale 38, Ruzi 84, 12ndFAWWON№97. We found an increase of GMS in genotype Gyrmyzy gul 1 and also an increase in TKM in genotypes Nurlu 99, Gobustan, Gyrmyzy gul 1. An increase in the GMS and TKM may be a compensation against spike reduction under water deficiency. This result is in agreement with the findings of Moayedi *et al.,* (2010). More profound decrease in the TKM was revealed in genotypes Vugar, Shiraslan 23, Sharg, Ruzi 84, Pirshahin 1, and 12ndFAWWON№97. Water deficit more influenced on the BY of genotypes Garagylchyg 2, Sharg, Gyrmyzybugda, Nurlu 99, Pirshahin1, 12ndFAWWON№97 and 4thFEFWSN№50, less affected on the BY of genotypes Barakatli 95, Alinja 84, Akinchi 84, Giymatli 2/17, Gyrmyzy gul1 and Saratovskaya 29. Limitations in increase of assimilation surface of vegetative organs, decreasing the tillering ability, as well as accelerating the senescence of leaves, increasing the loss of photoassimilates during photorespiration led to a reductions in the BY of wheat genotypes. Wingler *et al*., (2000) reported an increase in photorespiratory flux during drought stress in heterozygous barley mutant. Nagy *et al*., (2017) reported negative effect of applied stresses (drought stress, salt stress and combined drought+salt stress) on the PH and BY of differently originated bread wheat genotypes. There was decrase in agronomical performance of bread wheat lines under salinity stress (Khan *et al*., 2017).

Table 2. Post-anthesis dry matter remobilization (DMR), dry matter remobilization efficiency (DMRE), contribution of dry matter accumulated until anthesis to grain (DMRC), harvest index (HI) as affected by drought stress.

Genotype	Growth condition	DMR,g/ stem	DMRE (%)	DMRC (%)	HI (%)
		***Triticum durum* Desf.**			
Garagylchyg 2	Irrigated	0.879	21.54	29.95	0.31
	Drought	0.612	19.0	34.96	0.29
Vugar	Irrigated	0.693	21.05	29.06	0.36
	Drought	0.612	19.56	26.01	0.29
Shiraslan 23	Irrigated	0.438	14.72	16.77	0.37
	Drought	0.707	21.89	34.59	0.30
Barakatli 95	Irrigated	0.772	22.41	30.97	0.35
	Drought	1.127	33.51	54.92	0.31
Alinja 84	Irrigated	0.583	17.68	23.38	0.35
	Drought	0.910	30.46	51.48	0.31
Tartar	Irrigated	1.246	27.72	46.96	0.33
	Drought	1.029	25.61	43.54	0.31
Sharg	Irrigated	0.376	8.82	14.08	0.33
	Drought	0.187	5.57	7.65	0.29
Gyrmyzybugda	Irrigated	0.064	2.19	2.67	0.27
	Drought	0.156	4.67	7.10	0.26
		***Triticum aestivum* L.**			
Nurlu 99	Irrigated	0.672	22.87	30.86	0.34
	Drought	1.097	36.94	62.68	0.38
Gobustan	Irrigated	0.294	9.94	12.06	0.32
	Drought	1.026	30.95	46.03	0.36
Akinchi 84	Irrigated	0.751	23.54	35.51	0.31
	Drought	1.002	34.27	57.16	0.31
Giymatli 2/17	Irrigated	1.152	33.69	46.23	0.35
	Drought	1.637	49.33	92.89	0.34
Gyrmyzy gul 1	Irrigated	0.252	13.50	15.27	0.34
	Drought	0.787	36.76	48.14	0.28
Azamatli 95	Irrigated	0.737	26.96	43.18	0.36
	Drought	0.625	23.49	36.80	0.33
Tale 38	Irrigated	0.681	24.30	36.88	0.37
	Drought	1.062	42.15	81.17	0.32
Ruzi 84	Irrigated	0.583	21.87	31.87	0.40
	Drought	1.014	43.72	95.01	0.37
Pirshahin 1	Irrigated	1.374	37.99	69.79	0.39
	Drought	1.105	41.38	82.86	0.35
12ndFAWWON№97	Irrigated	0.479	24.23	35.94	0.37
	Drought	0.666	36.24	57.98	0.37
4thFEFWSN№50	Irrigated	0.708	22.88	34.81	0.37
	Drought	0.537	20.52	28.67	0.30
Gunashli	Irrigated	0.921	29.51	46.28	0.41
	Drought	1.019	37.77	62.14	0.34
Dagdash	Irrigated	0.266	8.64	14.02	0.33
	Drought	0.223	7.74	11.89	0.28
Saratovskaya 29	Irrigated	0.374	17.19	34.02	0.29
	Drought	0.584	27.71	56.68	0.29

Table 3. The effect of the drought on yield components and grain yield of wheat genotypes. Note: I-irrigated, D-drought.

Genotypes		SN	SL cm	SW cm	SNS	SM g	GNS	GMS g	TKM g	BY g/m²	GY, g/m²
Triticum durumDesf.											
Garagylchyg 2	I	450	9.4	1.4	22.7	3.17	59.4	2.3	34.2	1761	546
	D	404	8.9	1.3	20.8	2.88	52.8	2.1	30.9	1268	374
Vugar	I	392	8.4	1.5	21.1	2.88	53.8	2.2	40.6	1620	590
	D	390	8.2	1.4	20.0	2.83	47.7	2.1	29.7	1302	376
Shiraslan 23	I	405	8.0	1.5	19.8	3.19	52.0	2.5	43.4	1551	576
	D	367	7.7	1.5	19.0	2.53	47.9	1.9	33.7	1242	375
Barakatli 95	I	387	8.7	1.5	19.7	3.11	49.5	2.1	40.3	1484	519
	D	357	8.6	1.4	19.6	2.71	46.4	1.9	35.5	1315	412
Alinja 84	I	360	9.0	1.5	18.8	2.62	51.5	1.9	41.7	1396	486
	D	336	8.9	1.4	18.7	2.59	42.6	1.8	34.3	1239	378
Tartar	I	338	9.6	1.6	21.8	3.72	53.8	2.7	44.3	1673	549
	D	321	9.1	1.5	19.8	3.41	42.5	2.4	39.8	1434	450
Sharg	I	316	8.9	1.4	22.0	3.75	47.5	2.7	47.6	1543	511
	D	276	9.1	1.3	21.6	2.89	44.8	2.0	37.9	1123	327
Gyrmyzybugda	I	432	9.7	1.2	20.8	3.16	56.3	2.5	37.5	1991	537
	D	374	8.7	1.0	17.4	2.07	40.1	1.6	31.7	1405	371
Mean	I	385	9.0	1.5	20.8	3.20	53.0	2.4	41.2	1627	539
	D	353	8.6	1.4	19.6	2.74	45.6	2.0	34.2	1291	383
Reduction, %		8	4	8	6	14	14	16	17	21	29
***Triticum aestivum* L.**											
Nurlu 99	I	544	10.6	1.5	18.5	2.70	56.4	2.0	27.8	1595	542
	D	426	9.7	1.2	17.5	2.13	49.4	1.6	29.9	1250	478
Gobustan	I	520	10.9	1.3	17.5	3.05	54.1	2.2	30.3	1724	552
	D	443	10.6	1.1	17.3	2.63	53.6	1.9	34.9	1524	550
Akinchi 84	I	401	12.2	1.3	20.1	2.70	51.6	2.0	33.0	1477	459
	D	400	11.9	1.2	18.8	2.41	49.7	1.9	32.3	1374	430
Giymatli 2/17	I	393	9.5	1.5	20.6	3.04	56.2	2.4	41.4	1583	560
	D	368	9.3	1.4	19.6	2.52	46.4	1.9	35.4	1414	475
Gyrmyzygul 1	I	745	8.6	1.1	16.9	1.78	42.4	1.4	28.5	1806	609
	D	643	8.5	1.1	16.6	1.75	41.4	1.4	29.0	1656	466
Azamatli 95	I	540	11.4	1.4	17.5	2.59	51.7	2.0	37.8	1980	703
	D	454	11.1	1.3	17.1	2.45	50.8	1.8	33.7	1637	546
Tale 38	I	487	11.3	1.2	20.0	3.16	59.0	2.3	36.4	1695	627
	D	485	10.6	1.1	18.6	2.13	48.1	1.5	29.9	1464	474
Ruzi 84	I	439	11.2	1.4	18.0	2.91	52.3	2.2	41.8	1715	680
	D	433	10.9	1.2	17.8	2.34	50.0	1.6	32.1	1396	510
Pirshahin 1	I	425	11.4	1.5	17.9	2.92	50.3	2.1	39.4	1607	621
	D	353	11.8	1.3	18.6	2.78	52.5	1.9	30.9	1114	391
12ndFAWWON97	I	618	9.5	1.2	15.4	2.05	41.5	1.5	33.3	1495	553
	D	528	8.8	1.0	14.4	1.48	35.0	1.1	27.2	1112	406
4thFEFWSN№50	I	324	12.0	1.5	19.2	2.60	59.0	1.8	36.3	1240	454
	D	296	11.2	1.3	17.9	2.43	53.1	1.5	26.0	906	276
Gunashli	I	394	11.8	1.1	17.5	2.67	50.4	2.0	42.3	1449	590
	D	374	11.5	1.0	17.1	2.62	46.0	1.9	39.1	1224	422
Dagdash	I	403	10.7	1.3	17.8	2.63	41.2	1.9	38.5	1426	471
	D	400	10.4	1.3	17.4	2.38	39.8	1.7	31.9	1189	335
Saratovskaya 29	I	490	10.3	1.0	18.4	1.91	41.6	1.4	30.8	1361	396
	D	474	9.7	0.9	17.0	1.86	37.1	1.4	26.5	1211	346
Mean	I	480	10.8	1.3	18.2	2.62	50.6	1.9	35.6	1582	558
	D	434	10.4	1.2	17.6	2.28	46.6	1.6	31.4	1319	436
Reduction, %		10	4	9	3	13	8	15	12	17	22

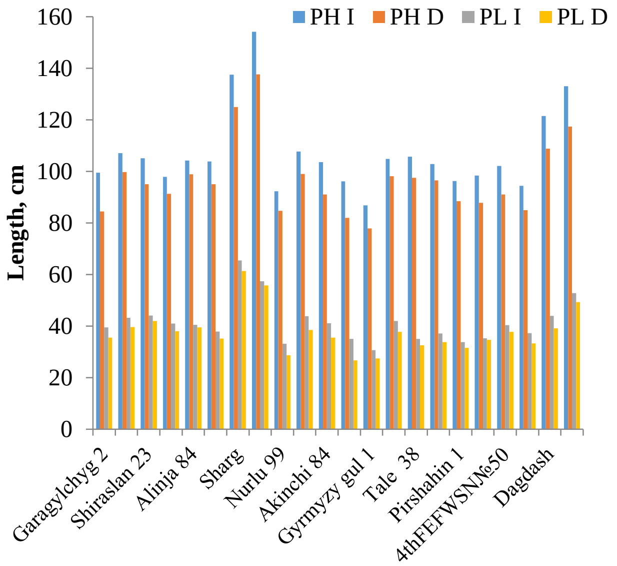

Fig. 1. The effect of the drought on plant height and peduncle length. PH I- plant height irrigated, PH D- plant height drought, PL I- Peduncle length irrigated, PL D- peduncle length drought. Each value represent mean of 30 replicates.

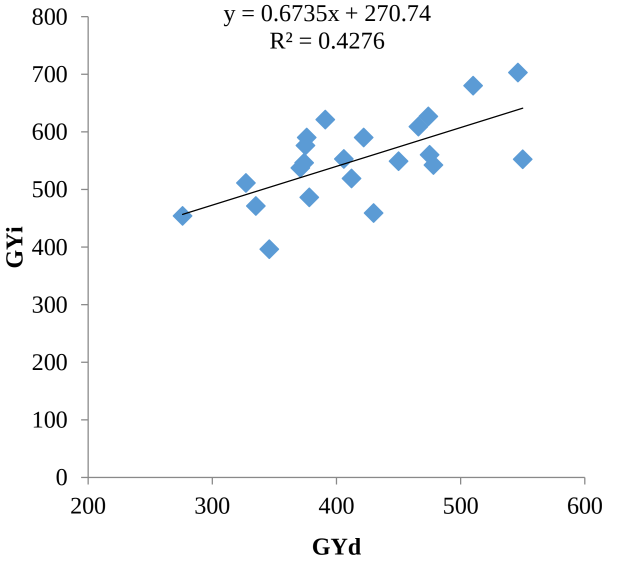

Fig. 2. Regression relation between grain yield under irrigated (GY_i) and grain yield under drought stress (GY_d) conditions, (r=0,654).

An average GY of durum and bread wheat was 539 and 558 g/m^2 under irrigated, 383 and 436 g/m^2 under drought stress conditions, reduced by 29% and 22% in durum wheat and bread wheat, respectively. Deep reductions of GY was detected in genotypes Garagylchyg 2 (32%), Vugar (37%), Shiraslan 23 (35%), Sharg (36%), Gyrmyzybugda (31%), Pirshahin 1 (37%), 4th FEFWSN№50 (39%), Gunashli (29%). Less reductions of GY was detected in genotypes Nurlu 99, Akinchi 84, Giymatli 2/17 and Saratovskaya 29. There was not difference in GY of irrigated and stressed plants of genotype Gobustan. Thus, the decrease in the GY and yield components was more pronounced in the tallest genotypes Sharg and Gyrmyzybugda.

Table 4. Correlations coefficients between various traits of wheat genotypes.

Drought (above diagonal) / Irrigated (below diagonal)

	DH	PH	PL	SN	BY	SL	SW	SM	SNS	GNS	GMS	TKM	GY	Hİ
DH	1	0.211	0.223	0.117	-0.038	-0.063	-0.044	-0.175	-0.110	-0.065	-0.210	-0.371	-0.097	-0.079
PH	0.578**	1	0.909**	-0.280	-0.086	-0.146	-0.169	-0.024	0.097	-0.360	-0.036	0.045	-0.350	-0.492
PL	0.512*	0.903**	1	-0.389	-0.248	-0.256	-0.049	0.085	0.242	-0.290	0.061	0.109	-0.504*	-0.540*
SN	-0.160	-0.290	-0.397	1	0.528*	-0.069	-0.586**	-0.731**	-0.637**	-0.283	-0.602**	-0.479*	0.457*	0.135
BY	-0.197	0.125	0.008	0.417	1	-0.067	-0.086	-0.053	-0.073	0.054	0.150	0.249	0.799**	0.005
SL	-0.187	-0.090	-0.208	-0.061	-0.113	1	-0.264	0.035	-0.220	0.451*	-0.060	-0.012	0.216	0.387
SW	-0.227	-0.217	0.087	-0.487*	0.003	-0.274	1	0.746**	0.692**	0.338	0.704**	0.387*	-0.126	-0.130
SM	-0.050	0.234	0.327	-0.660**	0.210	-0.136	0.592**	1	0.784**	0.468*	0.937**	0.685**	-0.056	-0.107
SNS	0.151	0.310	0.397	-0.611**	0.111	-0.312	0.411	0.740**	1	0.386	0.784**	0.449*	-0.232	-0.341
GNS	-0.427*	-0.122	-0.130	-0.359	0.255	0.188	0.406	0.558**	0.555**	1	0.408	0.095	0.280	0.297
GMS	-0.091	0.282	0.345	-0.595**	0.332	-0.206	0.572**	0.969**	0.742**	0.567**	1	0.725**	0.060	-0.163
TKM	0.189	0.186	0.304	-0.737**	-0.101	-0.230	0.489*	0.644**	0.420	0.100	0.633**	1	0.264	0.057
GY	-0.403	-0.373	-0.405	0.331	0.679**	0.044	0.146	0.138	-0.180	0.215	0.207	0.177	1	0.599**
HI	-0.305	-0.620**	-0.542**	-0.041	-0.212	0.215	0.180	-0.047	-0.388	0.037	-0.094	0.357	0.566**	1

*, ** significant at $p<0$, 05 and $p<0$, 01, respectively. Note: DH-days to 50% heading, PH- plant height, PL- peduncle length, SN- number of spikes per 1m^2, BY-biological yield, SL- spike length, SW- spike width, SM- spike mass, SNS- spikelet number per spike, GNS- grain number per spike, GMS- grain mass per spike, TKM- thousand kernels mass, GY- grain yield, Hİ-harvest index.

Despite the fact that there was not strong linear dependence between GY under irrigated and GY under drought (Fig. 2), the existance of positive regression relation (r=0,654) indicate that high productivity can be used as favorable selection criteria under drought stress.

GY negatively correlated with days to heading (DH), PH and PL under both irrigated and drought consitions (Table 4). Positive and siginificant correlations between GY and SN, BY, HI were revealed under both irrigated and rainfed conditions. Positive but non-significant correlations were also revealed between GY and GNS, GMS, TKM. SM was positively and siginificantly correlated with SNS, GNS, GMS and TKM. The highest positive and significant correlation was found between SM and GMS. Al-Karaki (2012) reported that grain yield was strongly associated with SN but not with GNS.

Conclusion

Thus, drought intensified dry matter remobilization. Although tall genotypes have a high BY, post-anthesis translocation of photoassimilates from vegetative parts into grains does not occur at a sufficient level, the HI decreases. We found that in the condition of drought GY positively and significantly associated with the BY, SN and HI. High productivity of the genotype is also considered a good criterion for breeding in the condition of drought.

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