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Wheat (*Triticum aestivum* L.) Response to Nitrogen and Post-Anthesis Water Deficit

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Abstract: Relationship between post anthesis water deficit and nitrogen on wheat (*Triticum aestivum* L.) in Southern of Iran is not well defined. Therefore, the study was carried out to on a clay loam soil at Shiraz Agricultural Research Station, Iran between 2006 and 2008. Three wheat cultivars were grown under post anthesis water deficit with three nitrogen fertilizer levels. Mean data for two-years showed that number of spikes per square meter and number of kernels per spike were similar both after nonstressed and post anthesis water deficit treatments. Kernel weight reduced by water stress under 0 and 80 kg nitrogen ha^{-1}, but increased under 160 Kg nitrogen ha^{-1} compared to control (nonstressed treatments in both experiments). Under water deficit grain yield reduced by 25 %. Grain yield of the crop that received no nitrogen was 15 % more compared to one receiving 80 kg nitrogen ha^{-1}. Among the three wheat cultivars, cv. Chamran produced the highest grain yield, which was 19% higher than that of cv. Shiraz and cv. Marvdasht. In post anthesis water deficit treatment, straw yields increased with 80 kg ha^{-1} increment of nitrogen but further increments of nitrogen had little effect. Under post anthesis water deficit dry matter remobilization efficiency increased with 80 kg ha^{-1} increment of nitrogen by 29 %, but further increments of nitrogen decreased it. The contribution of dry matter remobilization to the grain ranged 7 to 23 % of grain dry weight. Fertilizing well showed a lower contribution of dry mater remobilization than unfertilized plants. It is concluded that there is great potential to increase winter wheat yield by properly managing nitrogen fertilization in this region. Stored carbohydrate represented an important buffer for yield production when stress occurred during grain filling.

Key words: Wheat · Nitrogen · Post anthesis water deficit · Yield and yield components · Dry mater remobilization

INTRODUCTION

In Mediterranean climate region of Iran, rainfall decreases and evaporation and temperature increases in spring, when wheat enters grain filling stage [1, 2]. Consequently, wheat crops often experience water deficit during grain filling, thereby limiting grain yield [3-6].

Irrigation water and fertilizers are two vital but costly inputs in irrigated farming. Their economic use demands that maximum yield should be obtained per unit application of inputs. The importance of nitrogen fertilization in increasing wheat production has been well documented [7-9], but still it is difficult to determine the quantities to apply under water stress condition [2, 9, 10]. Response of wheat to a given application of nitrogen depends upon availability of soil nitrogen and water. Fan and Li [11] demonstrated that nitrogen fertilization increased nitrogen efficiency of winter wheat, which decreased significantly with increasing drought stress. It seems that in arid and semi-arid regions, heredity of drought tolerance should be included in studies investigating the interaction between nitrogen efficiency and water management. Harold [12] found that the yield of wheat increased with increasing applications of nitrogen for several levels of irrigation. Additional irrigation was profitable only when accompanied by additional nitrogen. Significant interactions between irrigation and nitrogen levels have also been reported by Gregersen and Hejlesen [13], Zhang *et al*. [14].

Grain growth in wheat depends on C from three sources: current assimilation, remobilization of preanthesis assimilates stored in the stem and other plant

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parts and retranslocation of assimilates stored temporarily in the stem after anthesis. In evaluating the reduction in grain yield arising from postanthesis water deficits, it is necessary to identify which of these sources of C is limiting in grain filling. Postanthesis water deficits are known to reduce C assimilation and hence the availability of current assimilates for grain filling, but is not considered to affect the translocation of C to the grain [15]. Water deficits during grain filing increase the proportion of stored assimilates relative to current assimilates in the grain [16-18]. But whether this reflects a larger actual mobilization of stored assimilates rather than simply a reduction in current assimilation is not known [3]. Understanding the effect of water stress and nitrogen on yield formation becomes an essential step in the development of higher- yielding and more stable cultivars.

At present, available fertilizer recommendations are based on adequate water application. There is little information on which to base fertilizer recommendations for wheat grown under postanthesis water deficit in this region. Also wheat production in northern Iran suffers from a continental hot, dry wind usually at the end of the growing season. If crop maturation is unfavorably delayed, such wind may dehydrate the wheat rapidly and lead to reduce grain wheat [2, 17, 19]. So, the objectives of this study were to determine the influence of post anthesis water deficit and nitrogen fertilizer on (i) grain yield and yield components of three wheat cultivars; and (ii) remobilization and contribution of dry matter to grain yield in this condition.

MATERIALS AND METHODS

The studies were conducted at Shiraz Agricultural Researches Station, Iran (52°',36' E, 29°33'N) for 2 years (2006-2008). The experiment was randomized block, split-split plot design with four replications. Main plots consisted of Irrigation treatments which, were I1 (nonstressed) and I2 (Post anthesis water stressed plots with 65% FC). Sub plots consisted of fertilizer treatment, which were nitrogen at rates of 0, 80 and 160 kg ha^{-1}. Sub-sub plots, Cultivars, were Shiraz, Marvdasht and Chamran. To determine the soil characteristics 15 samples from 30 cm depth were collected and analyzed by Shiraz Soil Testing Laboratory for basic soil physical and chemical properties (Table 1). P and K fertilizer were applied according to recommendations of Soil Testing Laboratory of Shiraz Agricultural Research Station in forms of superphosphates and potassium sulfate, respectively. Plots were sown on 11 November 2007 and on 14 November 2008 with a cone seeder and were 8 m long and 1.5 m wide, with 6 rows 0.2 m apart. Plots were plowed and disked after winter wheat harvest in July. The plots were disked again before seeding in November. Irrigation of each main plot was measured volumetrically by field calibrated gypsum block. Six gypsum blocks were installed in each replication randomly. Measurements were made after anthesis, before each irrigation, during the growing period. And change in soil moisture was measured weekly to a depth of 30 cm by it. The irrigation system was operated avoiding runoff losses. Apirus was applied in early April to the crop to control both broad and narrow leaved weeds. Above-ground dry matter production at heading during both years was measured by making cutting at ground level in 0.3 m^2 quadrants per plot. Immediately prior to harvest, number of spikes per m^2 was determined by averaging three counts of 1-m sections of rows with in each plot. The number of kernel per spikes was determined from 20 spikes taken at random from a 1 m section of each plot and counted with an electronic seed counter. And average kernel weight was determined by weighing 250 kernels randomly drawn from the bulk grain sample from each plot. The central four rows (of 6 rows) of each plot were harvested for grain yield and converted to grain yield per hectares. Harvest indexes (HI) [wt. of grain/ (wt. of grain +straw)] were calculated using yield from the square meter samples. Twenty main stems that headed on same day were tagged for each treatment. As the tagged main stems of each cultivar reached anthesis, 10 plants in each plot were removed. At maturity, 10 additional tagged plants were removed. Anthesis was scored when anthers in the central florets of 50% spikes had dehisced and maturity when almost all the spikes in plot showed complete loss of green color. Anthesis dates of the cultivars differed by about 10 d during both years. Samples were dried in a forced-air oven at 70°C for 48 h.

Table 1: Soil properties of the experimental plots

Variable	2006-2007	2007-2008
Texture	Si-C	S-C-L
PH	7.96	7.85
ECdS m^{-1}	1.88	1.25
Organic matter (%)	0.25	0.39
N (%)	0.023	0.036
P mg Kg^{-1}	5.40	16.00
K mg Kg^{-1}	340.00	206.00
Fe	3.70	5.40
Zn	0.64	0.10
Mn	5.80	9.90
Cu	0.48	0.98

The various parameters referring to dry matter that are discussed were evaluated as under:

Dry matter remobilization efficiency (%) =
(dry matter remobilization / dry matter at anthesis) × 100

Contribution of dry matter remobilization to grain (%) =
(Dry matter remobilization/grain yield) × 100

Data were analyzed by analysis of variance [20]. When significant differences were found (*P=0.05*) among means, Duncan's multiple range test (DMRT) were applied.

RESULTS

Weather Condition: The 2 year differed in amount and distribution of rainfall (Table 2). A total of 327 mm of rain was recorded in the period October-June 2006-2007, compared with 295 mm for the same period In 2007-2008. Spring rainfall (March-June) was equal to 29 mm in the first season and 15 mm in the second. A maximum temperature during spring was on average 2°C higher during 2007-2008 compared to 2006-2007. Fall and winter temperatures were near average and spring temperatures were above average during both years (Table 2).

Number of Spikes per Square Meter: Total number of spikes per square meter was similar at both nonstress and water deficit treatments, indicating that the water deficit treatment did not affect number of tillers per plant. Application of nitrogen affected the number of spike per m^{-2} from 718 m^{-2} in wheat receiving no nitrogen to 789 m^{-2} in wheat receiving 80 kg nitrogen ha^{-1} and 743 m^{-2} in wheat receiving 160 kg nitrogen ha^{-1} (mean of 2 years). The crop that received 80 kg nitrogen ha^{-1} produced 10 % more ears m^{-2} compared to the crop that received no nitrogen resulting greater grain yield. Among the three wheat cultivars, cv. Chamran produced the highest number of spikes per square meter at either nitrogen level (Table 6) and the doubling of nitrogen fertilization increased grain yield by 1130 kg ha^{-1}. Grain yield reductions for cv. Shiraz was obtained with up to 80 kg nitrogen ha^{-1} (Table 6).

Number of Grain per Spike: Grain number per plant and in each individual shoot was similar at both nonstress and water deficit treatments, indicating that the water deficit treatment did not affect floret abortion. The crop that received 80 kg nitrogen ha^{-1} produced 10 % more grains per ear than the crop received no nitrogen resulting in grain yield. Number of seeds increased with increasing increments in nitrogen through 80 kg ha^{-1} in non-stressed treatment (Table 4). On the adequately fertilized treatments, limited irrigation treatment reduced number of seeds during both years. The effect of nitrogen on number of grain per spike was similar during two years (Table 3). The varieties differed in numbers of grains per ear. As, cv. Marvdasht produced 11 % and 25 % more grain per spike compared to cv. Shiraz and cv. Chamran, respectively (Table 3). The mean number of grains per ear and the increase in number caused by nitrogen were greatest for cv. Marvdasht and least for cv. Chamran (Table 6). No significant interactions were detected except year × cultivars interaction.

Kernel Weight: Kernel weight was reduced by water stress under 0 and 80 kg nitrogen ha^{-1}, but increased under 160 Kg ha^{-1} with compared with their respective

Table 2: Summary of October to June precipitation and temperature data for 2006 to 2008 at the metrological station of Agricultural Researches Organization, Shiraz, Iran

	October	November	December	January	February	March	April	May	June
			2006-2007						
Precipitation, mm	13	57	95	98	35	20	8	1	0
Temperature-Max °C	21.9	12.9	11.4	9.9	12.4	15.1	22	25.4	30.0
-Min °C	4.4	-1.9	-4.6	-6.4	-5.3	0.8	4.3	9.3	14.3
			2007-2008						
Precipitation, mm	10	19	78	151	24	14	1	0	0
Temperature-Max °C	23	15.6	13.2	11.6	14.1	16.7	23.0	26.2	32.3
-Min °C	6.1	-0.7	-3.4	-5.4	-4.3	-1.1	6.7	9.6	16.1
			1978-2008 Avg.						
Precipitation, mm	10.7	30	84	120	61	25	10	7	0.5
Temperature-Max °C	19.6	16.2	12.0	10.8	7.5	15.7	20.1	24.4	27.9
-Min °C	6.7	1.5	-4.1	-7.2	-6.6	-1.2	3.0	9.2	13.1

Table 3: Average number of spikes, kernel per spike, kernel weight, grain yield, straw yield, harvest index, DM remobilization efficiency, and Contribution of DM To the grain of three wheat cultivars under three nitrogen and two water regimes in 2006-2008

	Year															
	2006-2007								2007-2008							
Treatments	Spikes no. m^{-2}	Kernel $Spike^{-1}$ no.	Kernel weight mg	Grain yield ---Kg ha^{-1}---	Straw yield ---Kg ha^{-1}---	Harvest index (%)	DM remobilization efficiency (%)	Contribution of DM Remobilization. to grain (%)	Spikes no. m^{-2}	Kernel $Spike^{-1}$ no.	Kernel weight mg	Grain yield	Straw yield	Harvest index (%)	DM remobilization efficiency (%)	Contribution of DM Remobilization to grain (%)
Irrigation(I) †																
I1	709	55	31	6684	10654	39	19	7	818	49	37	5109	12121	36	15	8
I2	682	55	26	4922	9465	34	25	14	831	47	29	3897	10247	31	19	15
Avg.	699	55	29	5803	10059	37	22	11	825	48	33	4503	11184	34	17	12
LSD (0.05)	NS	NS	5	1286	1500	6.3	3.9	1.8	NS	NS	5.9	1056	1612	5.3	2.1	1.9
Nitrogen(N) Kg ha^{-1}																
0	648	50	31	5226	8361	35	19	10	789	46	32	4052	11325	32 b	18	16
80	756	55	35	5953	11280	36	22	11	822	49	34	4642	14781	35 a	20	11
160	683	56	36	5831	10536	40	23	13	804	49	37	4614	13448	36 a	13	8
Avg	696	54	34	5670	10059	37	22	11	805	48	34	4436	13185	34	17	12
LSD (0.05)	92	7.1	5.8	1296	1468	5.9	3.2	1.7	106	6.8	6.1	1162	1697	5.7	2.4	1.7
Cultivar(C)																
Shiraz	626	59	33	5841	9842	38	23	11	788	46	35	4257	12991	36	15	12
Marvdasht	644	60	31	5387	10330	35	19	10	802	57	29	4927	13445	30	16	14
Chamran	816	47	38	6182	9951	38	25	13	924	41	36	5824	13118	35	18	8.5
Avg.	695	55	34	5803	10041	37	22	11	838	48	33	5002	13184	34	17	11.5
LSD (0.05)	94	6.9	5.9	1301	1398	6.1	3.3	1.7	104	6.9	4.5	1165	1683	5.6	2.4	1.5

† I1=Nonstress treatment and I2=Post anthesis water stress.

Table 4: Number of spikes, kernel per spike, kernel weight, grain yield, straw yield, harvest index, DM remobilization efficiency and contribution of DM to the grain as affected by irrigation and nitrogen fertilizer treatments

	Treatments	Spikes no. m^{-2}	Kernel $Spike^{-1}$ no.	Kernel weight mg	Grain yield ----------Kg ha^{-1}---------	Straw yield ----------Kg ha^{-1}---------	Harvest index (%)	DM remobilization efficiency (%)	Contribution of DM Remobilization to grain (%)
Irrigation†	Nitrogen Kg ha^{-1}				2006-2007				
I1	0	672	54	33	6571	8733	44	20	9
	80	774	55	30	6899	12100	37	16	7
	160	681	56	29	6582	11129	38	20	7
I2	0	623	53	27	4671	7989	37	20	13
	80	739	55	26	5006	10460	32	25	15
	160	686	57	25	5091	9942	34	18	14
Source of variation	LSD (0.05) ‡	91	7.2	3.1	1234	1654	6.4	2.8	1.1
	Irrigation(I)	NS	NS	**	*	*	*	*	**
	Nitrogen(N)	*	*	*	*	*	*	*	*
	I×N	NS	NS	NS	*	NS	NS	NS	*
CV, %		17	16	11	14	17	18	19	18
					2007-2008				
I1	0	782	46	37	4870	15018	37	16	7
	80	841	50	37	5281	18229	32	16	9
	160	832	51	36	5176	18115	33	13	7
I2	0	797	47	31	3634	13520	33	19	14
	80	923	46	29	4004	17332	27	25	23
	160	776	47	28	4054	14779	34	13	8
Source of variation	LSD (0.05) ‡	101	6.9	3.4	1187	1795	5.9	2.1	0.8
	Irrigation(I)	NS	NS	**	*	*	*	*	*
	Nitrogen(N)	*	*	*	*	*	*	**	**
	I×N	NS	NS	*	NS	NS	NS	*	*
CV, %		16	15	10	13	17	17	16	17

‡Between nitrogen for the same I treatment. *, ** Significant at 0.05 and 0.01 probability levels, respectively. NS=nonsignificant at *P> 0.05*.

† I1=Nonstress treatment and I2=Post anthesis water stress.

nonstressed treatment in both experiment (Table 4). Possibly because only the kernel weight, rather than the number of spikes or number of kernels per spike, was influenced by water deficit during grain filling. Kernel weight was greatest for cv. Chamran and least for cv. Marvdasht. For all these varieties nitrogen resulted in increased kernel weight (Table 6). Kernel weight dose did not show any significant interaction between cultivars and nitrogen rate. But, significant year × cultivar and irrigation × cultivar interactions were detected. The significant effects were on treatment I-2, where seed weights decreased with increasing increments on nitrogen through 160 kg ha^{-1}.

Grain Yield: Similar result was obtained with grain yield (Table 3, 4), possibly because only the kernel weight, rather than the number of spikes or number of kernels per spike, influenced by soil drying during grain filling. Water deficit markedly affected grain yield (Table 4). Under water deficit grain yield was reduced by 25 %. The reduction resulted from a reduction in grain size, but not in grain number. Grain yield of the crop that did n ot receive nitrogen was 15% greater than for that receiving 80 kg nitrogen ha^{-1} (Table 3). There was a significant response to nitrogen in two experiments. Average winter wheat yields ranged 5226 to 5953 kg grain ha^{-1} for the control and 80 kg nitrogen ha^{-1} and from 4052 to 4642 kg grain ha^{-1} in the first and second experiment, respectively (Table 3). In 2006-2007 the maximum grain yield of three varieties were attained with 80 and 160 kg nitrogen ha^{-1} and ranged 5569 to 6199 kg ha^{-1} (Table 6). Among the three wheat cultivars, cv. Marvdasht produced the lowest grain yield at either nitrogen level (Table 6) and the doubling of nitrogen fertilization increased grain yield by 1130 kg ha^{-1}. Grain yield reductions for cv. Shiraz was obtained with up to 80 kg nitrogen ha^{-1} (Table 6). This reduction was caused by decrease in number of spike per meter square (or number of grain per spike) without compensation by mean weight per grain (or number of grain per spike). Cv. Marvdasht and cv. Chamran have the smallest and greatest grain yield, respectively. Grain yield was reduced by water deficit under no nitrogen, but increased under 80 and 160 kg nitrogen ha^{-1} when compared to respective nonstressed treatments (Table 4). However, increase in grain yield beyond 80 kg nitrogen ha^{-1} was marginal. Eighty kilograms of nitrogen ha^{-1} was adequate for maximum grain yields with the I-2 treatment. For the I-2 treatment, water becomes more limiting than fertility and there was no yield response to applied nitrogen. The nitrogen response data may be used in determining nitrogen fertilizer rates for specific yield goals. Highest yields were obtained in nonstressed treatment in 2006-2007. But the irritation-nitrogen interaction was only significant during 2007-2008. The yearly variations were associated with weather, which influenced growth and maturity of the crop. The number of days from seeding to harvest was 235 and 223 days during the crop years 2006-2007 and 2007-2008, respectively.

Straw Yield: Straw DM responded positively to increasingly higher rates of nitrogen. The three cultivars responded similarly to higher rates of nitrogen. With the I-2 treatment, straw yields increased with 80 kg ha^{-1} increment of nitrogen but further increments of it had little effect. Straw yields on treatment I-2 were 13 and 15 % lower than those on treatment I-1 in 2006-2007 and 2007-2008, respectively. No interactions between irrigation, nitrogen and cultivars were observed.

Harvest Index: Stress during grain filling reduced harvest index by reducing grain yields after most of the vegetative growth had been completed. Harvest index varied with nitrogen treatments during both years (Table 3). These results could be explained by separate effects of nitrogen treatments on yields of grain and straw DM at maturity. Cv. Marvdasht, which had the lowest grain yields also, had the lowest HI (8-14 %). Furthermore, since cv. Marvdasht did not always produce the lowest amount of TDM, its low yields were due, at least in part, to a low HI. Harvest index during 2006-2007 was 38 % for cv. Shiraz and cv. Chamran and 35 % for cv. Marvdasht; which increased consistently with increasing nitrogen from 35 % with no nitrogen to 40% with 160 kg nitrogen ha^{-1}. During, 2007-2008 harvest index was greatest for cv. Chamran and least for cv. Marvdasht.

Dry Matter Remobilization Efficiency: Water deficit markedly affected dry matter remobilization efficiency. Under water deficit dry matter remobilization efficiency increased by 29 % (Table 3). With the I-2 treatment, dry matter remobilization efficiency increased with 80 kg ha^{-1} increment of nitrogen but further increments of nitrogen decreased it (Table 4). Cultivars differed in dry matter remobilization efficiency (Table 3). Cv. Chamran showed higher remobilization efficiency (25 and 18 %) during 2006-2007 and 2007-2008, respectively. One explanation for differences in remobilization efficiency is that during grain filling period, the plants retain an amount of dry matter at anthesis that is essential for survival and various

Table 5: Number of spikes, kernel per spike, kernel weight, grain yield, straw yield, harvest index DM remobilization efficiency and contribution of DM To the grain of three wheat cultivars as affected by irrigation treatments

	Treatments	Spikes no. m^{-2}	Kernel Spike^{-1} no.	Kernel weight mg	Grain yield ----------Kg	Straw yield ha^{-1}---------	Harvest index (%)	DM remobilization efficiency (%)	Contribution of DM Remobilization to grain (%)
Irrigation†	Cultivar				2006-2007				
I1	Shiraz	626	57	30	7290	10243	42	18	6
	Marvdasht	699	60	29	6268	12014	35	15	8
	Chamran	801	47	33	6494	9705	40	23	9
I2	Shiraz	627	60	23	4392	9468	33	25	16
	Marvdasht	590	58	24	4506	8726	36	22	12
	Chamran	832	47	29	5869	10196	36	27	15
Source	LSD (0.05) ‡	89	7.8	3.1	1302	1568	6.7	2.8	1.2
of variation	Irrigation (I)	NS	NS	**	*	*	*	*	**
	Cultivars(C)	**	**	**	*	NS	NS	*	*
	I×C	NS	NS	NS	*	*	NS	NS	*
CV, %		17	16	11	14	17	18	19	17
					2007-2008				
I1	Shiraz	737	49	39	4067	17499	30	11	7
	Marvdasht	792	57	33	5369	17097	34	19	10
	Chamran	927	42	38	5860	16767	37	15	7
I2	Shiraz	761	44	30	3417	14482	28	21	17
	Marvdasht	813	58	24	3486	15765	29	16	18
	Chamran	922	39	34	4789	15384	36	20	10
Source	LSD (0.05) ‡	101	7.3	3.5	1185	1786	5.7	2.1	0.8
of variation	Irrigation (I)	NS	NS	**	*	*	*	*	*
	Cultivars(C)	**	**	**	**	NS	*	*	*
	I×C	NS	NS	*	NS	NS	NS	NS	NS
CV, %		16	15	10	13	17	17	16	17

‡Between nitrogen for the same I treatment. *, ** Significant at 0.05 and 0.01 probability levels, respectively. NS=nonsignificant at *P> 0.05*.
† I1=Nonstress treatment and I2=Post anthesis water stress.

Table 6: Number of spikes, kernel per spike, kernel weight, grain yield, straw yield, harvest index DM remobilization efficiency and contribution of DM to the grain of three wheat cultivars as affected by nitrogen fertilizer

	Treatments	Spikes no. m^{-2}	Kernel Spike^{-1} no.	Kernel weight mg	Grain yield ----------Kg	Straw yield ha^{-1}---------	Harvest index (%)	DM remobilization efficiency (%)	Contribution of DM Remobilization to grain (%)
Nitrogen Kg ha^{-1}	Cultivar				2006-2007				
0	Shiraz	626	58	28	6066	8525	43	22	10
	Marvdasht	619	58	27	5096	9029	38	22	12
	Chamran	698	45	34	5719	7530	41	23	11
80	Shiraz	705	60	27	6091	11309	35	18	11
	Marvdasht	692	60	26	5498	11081	34	17	8
	Chamran	880	45	29	6199	11450	35	26	13
160	Shiraz	622	58	26	5367	9733	35	26	13
	Marvdasht	548	61	26	5569	11002	34	17	9
	Chamran	871	49	30	6628	10871	39	26	11
Source	LSD (0.05) ‡	91	7.8	3	1295	1497	6.7	2.8	
of variation	1.2								
	Nitrogen(N)	*	*	*	*	*	*	*	*
	Cultivars(C)	**	**	**	*	NS	NS	*	*
	N×C	*	NS	NS	NS	NS	NS	NS	NS
CV, %		17	16	11	14	17	18	19	17
					2007-2008				
0	Shiraz	684	44	37	3828	13472	32	18	13
	Marvdasht	831	57	30	5087	15075	36	18	11
	Chamran	852	40	35	5013	14262	37	17	8
80	Shiraz	801	48	34	3769	16901	27	17	13
	Marvdasht	866	57	27	3999	19526	27	23	22
	Chamran	978	41	36	5083	16916	33	22	12
160	Shiraz	760	48	34	3674	17600	28	13	10
	Marvdasht	709	58	27	4197	14692	32	12	8
	Chamran	942	42	37	5878	17049	39	14	6
Source	LSD (0.05) ‡	102	7.3	3.6	1169	1789	5.8	2.2	0.9
of variation	Nitrogen(N)	*	*	*	*	*	*	**	**
	Cultivars(C)	**	**	**	**	NS	*	*	*
	N×C	NS	NS	NS	NS	NS	NS	NS	NS
CV, %									

‡Between nitrogen for the same I treatment. *, ** Significant at 0.05 and 0.01 probability levels, respectively. NS=nonsignificant at *P> 0.05*.

biological functions, while the remainder is available for remobilization. It appears that dry matter retained depends on cultivars and prevailing growth conditions, although genetic variability in dry matter remobilization has been reported [21, 22]. Remobilization efficiencies in this study are also considerably greater than that ones reported by Papakosta and Gagianas [23].

Contribution of Dry Matter to the Grain: The contribution of DM remobilization to grain ranged from 7 to 23 % of grain dry weight (Table 3, 4 and 6). Similar values were reported for barley (*Hordeum vulgare* L.) by Gallagher *et al.* [24, 25], who concluded that pre-anthesis storage of carbohydrates is very important for grain yields in barley and wheat. Higher proportions (6-73%) of yield provided by pre anthesis were calculated by other investigators [21, 26]. Contribution of dry matter remobilization to the grain under water deficit was 78% more than nonstressed (Table 3). In our experiments plants fertilizing well showed a lower contribution of stored DM than unfertilized plants (Table 3). Cv. Chamran was higher in contribution of DM to the grain than cv. Shiraz and cv. Marvdasht. Differences were not consistent between the 2 years and dry matter contribution to the grain. In Mediterranean climate, rising temperatures and declining soil moisture prevailing at post anthesis period limit net assimilation rates; therefore, the contribution of post anthesis dry matter to the grain is greater.

DISCUSSION

Water stress at grain filling period induces early senescence, reduces photosynthesis and shortens the grain filling period [16, 17, 27, 28]. Such responses would be resulted to reduce in kernel weight, straw yield and grain yield. We found, however, that the effect of water stress at this time could greatly promote the remobilization of previously restored carbon reserved in plant. Early senescence induced by water stress can improve grain filling when senescence is unfavorably delayed has great significance to wheat production in Iran. The great parts of Iran are limited by adverse weather conditions. Continental hot and dry wind (temperature > 30°C, relative humidity <30% and wind speed >10 km hr) is common in early June to July in this area and can dehydrate wheat before it matures. Water stress may accelerate senescence so that wheat can mature before the adverse condition occurs. The heavy use of nitrogen in Iran results in unfavorably delayed senescence, leading to a low kernel weight. Early senescence induced by water stress could increase the rate of grain filling and improve kernel weight in this case.

Nitrogen fertilizer is one of the major input costs in production of winter wheat in Iran. Our soil test indicated that the experimental field was low in available soil nitrogen. It was not surprising that the response of winter wheat to nitrogen application was dramatic using various nitrogen applications. Our results indicate that there is great potential to increase winter wheat yield by properly managing nitrogen fertilization. The effect of high levels of soil nitrogen on vegetative growth, grain yield and yield components of wheat are well documented [10, 29, 30]. Among the three wheat cultivars tested in this environment, cv. Chamran produced the highest grain yield, which was 19 % higher compred to cv. Shiraz and cv. Marvdasht. Grain yield was highly related to spike per square meter, showing that the number of spikes per square meter is the essential component determining the final grain yield in wheat. Strong relationships between grain yield and number of spikes per square meter in wheat have been reported by other researchers [31-36]. In 0 and 80 kg nitrogen treatments, the kernel weight under water stress treatment was reduced compared to the plants under nonstressed treatments, indicating that the loss of photosynthesis could not compensate for the gain from increased remobilization of carbon reserves. When a high amount of nitrogen was applied, kernel weight was increased under water deficit (Table 4). The obvious explanation for such a result is that, when nitrogen was heavily used, delayed senescence led to a slow grain filling and a poor remobilization and partitioning of assimilates into the grain [1, 2, 8, 37]. For high nitrogen application the gain from an accelerated grain filling and an increased remobilization of preanthesis assimilates outweighed the loss of reduced photosynthesis and early senescence as a result of water stress. When postanthesis photosynthesis is reduced by stress, remobilization of dry matter is increased, which may help sustain kernel growth [7, 18, 24, 38]. Some lodging-resistance wheat cultivars bred recently in Iran have low harvest index and poor grain filling because they stay green for longer period of time and remobilize assimilates poorly to the grains. Water deficit may induce these cultivars to mobilized more presorted assimilates to grain. The cultivar Marvdasht out yielded the two cultivars at high soil nitrogen levels, probably because it was bred to be grown under well fertilized and irrigated conditions.

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