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NUTRITIONAL QUALITY OF MAIZE IN RESPONSE TO DROUGHT STRESS DURING GRAIN-FILLING STAGES IN MEDITERRANEAN CLIMATE CONDITION

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Zea mays

ABSTRACT

Maize is considered one of the most essential dietary components in human food and animal feeding. The objectives of the present study were to quantify the effects of drought stress on qualitative traits of maize at grain-filling stages. Hybrids maize seeds were grown by applying full and water stress conditions during the grain filling stage. Various nutritional properties (crude oil, starch, grain protein content) were determined in 2014 and 2015 at the second crop growing season in Adana, Turkey. Based on the results of this study, genotype and environment were found to influence all quality traits significantly. Further, result of study suggest that water stress caused a significant reduction in major quality traits. Grain weight and grain quality yield as well crude oil, protein and ash yield were significantly decreased due to water deficit condition in the both growing seasons. Significant differences were observed among hybrids in respect of all measurements due to irrigation regimes. The genotypes, Sancia and Calgary were tolerant by producing higher grain weight. Accordingly, grain qualities of 71May69, Aaccel and Calgary maize hybrids were less affected under drought stress.

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1 Introduction

Maize (*Zea mays*) is an important food and feed crop for human and livestock, and the demand of maize production is increasing day by day due to its multipurpose uses which include medicine and textile industries as well as biofuel production (White & Johnson 2003; Ali et al., 2010). As a temperate zone country, Turkey produces about 5.9 million tons of maize per year and it is cultivated in approximately 0.66 million hectares (FAOSTAT, 2014). About 35% of Turkish maize production is used for human consumption, 65% for animal feed (Kusaksiz, 2010).

Water shortage was extended in the crop production area. Hence, Food, feed and industrial demand of quality properties have gradually increasing in maize grain. Maize is a sensitive crop to water stress and its growth is negatively affected by unavailability of water at its growing stages (Byrne et al., 1995). Drought might be severely reduced the various qualitative trait such as grain starch, granule size and increased relative protein content (Balla et al., 2011). Drought stress increased is shortened the grain filling period and reduced grain yield, grain weight and specific weight (Gooding et al., 2003). According to Zhao et al. (2009) maize protein components are very sensitive to drought stress during grain filling stage. The degradation in the dough quality could be due to the decline in the glutenin to gliadin ratio and in the percentage of very large glutenin polymers in response to a biotic stress (Balla & Veisz, 2007).

Maize production program has been primarily aimed for increasing yield, quality and stability under different environments (Ignjatovic-Micic et al., 2014). Therefore, grain yield is the most commonly studied parameters, but grain quality parameters had less attention for hybrids. Rehman et al. (2011) reported grain protein, oil and starch content of maize are generally stable in different environments. Storage

components of mature kernel of maize as a quality traits, starch, protein and oil content are determinators of the final grain weight (Boyer & Hannah, 2001). Based on the above context, the objectives of the current study was to elucidate the effect of drought stress on maize grain weight and, as well as nutritional properties (grain starch, protein, crude oil, ash and yield) for seven maize hybrids under deficit irrigation in Mediterranean climate condition.

2 Materials and Methods

2.1 Experimental design and cultural practices

Field trials were conducted in growing season of 2014 and 2015 as second crop maize at research field of Cukurova University, Adana, Turkey. A summary of climatic data are given in figure 1. The methodologies have been followed as described previously by EL Sabagh et al. (2015). The experimental design used in this study was strip-split plot in four replications. The materials were consist of (1) 7 hybrids variety of maize (Sancia, Indaco, 71May69, Aaccel, Calgary, 70May82 and 72May80) and, (2) two moisture levels (Full irrigation and water stress) and amount of irrigation are given in Figure 1 and treatments were applied at grain growth stages. Hybrids were sown during first and the second year on 28 June, 2014 and 12 June, 2015, respectively. The regular agronomic practices of growing maize were similar to farmers' practice and were followed as necessary. During experiments, nitrogenous fertilizer was utilized within two times of planting, 100 kg N and P₂O₅ ha⁻¹ (20-20-0) and V6-growth stage 200 kg N ha⁻¹ (Urea).

2.2 Measurements

Proximate composition of grain including protein, starch, oil and ash were analyzed based on the method prescribed by AACC (2000).

Table 1 Effects of analysis of variance of maize hybrids under irrigation regimes in both seasons

Source of variation	GW(mg)	TW(kg/hl)	SC(%)	PC(%)	OC(%)	AC(%)	SY (kg/ ha)	PY (kg/ha)	OY (kg/ha)	AY (kg/ha)
2014										
Irrigation	ns	ns	ns	ns	ns	*	***	*	**	**
Hybrids	**	*	ns	ns	***	**	**	***	ns	**
Interaction	ns	ns	ns	*	**	*	ns	***	**	**
CV %	10.7	2.9	5.0	6.0	6.7	6.6	8.1	8.8	7.7	9.8
2015										
Irrigation	*	ns	ns	ns	ns	**	**	*	*	ns
Hybrids	**	**	***	ns	*	**	ns	ns	**	ns
Interaction	**	ns	***	ns	ns	ns	*	ns	**	ns
CV %	5.2	1.8	3.8	4.6	11.6	6.5	8.5	7.6	14.0	9.0

ns: Indicates nonsignificant; *, ** and ***, significant $P < 0.05$, $P < 0.01$ and $P < 0.001$ probability respectively; GW: grain weight, TW: test weight (kg/hl), SC: starch content (%), PC: protein content (%), OC: oil content (%), AC: ash content (%), SY: starch yield (kg/ha), PY: protein yield (kg/ha), OY: oil yield (kg/ha) and AY: ash yield (kg/ha).

Figure 1 Temperature and amount of water during 2014 and 2015 growing season (Arrow indicates pollination) (Source: Meteorological Service of Turkish State, 2016).

Table 2 Irrigation regimes effects on grain quality parameters of maize hybrids in 2014 and 2015.

Traitments	GW(mg)	TW (kg/hl)	S C(%)	PC(%)	OC(%)	AC(%)	SY(kg/ ha)	PY (kg ha)	OY (kg/ha)	AY (kg/ha)
2014 growing season										
Irrigated (Control)	258	77.9	62.8	7.66	2.77	1.08	8060	983	355	138
Deficit irrigated	232	77.9	62.5	8.01	2.79	1.02	6596	849	294	108
Drought reduction	-0.10	0.00	0.00	0.05	0.01	-0.06	-0.18	-0.14	-0.17	-0.22
Probability	ns	ns	ns	ns	ns	*	***	*	**	***
2015 growing season										
Irrigated(Control)	292	72.2	64.0	8.05	2.63	1.07	9159	1150	376	152
Deficit irrigated	275	72.0	64.1	8.09	2.60	1.05	8069	1020	328	133
Drought reduction	-0.06	0.00	0.00	0.01	-0.01	-0.01	-0.12	-0.11	-0.13	-0.13
Probability	*	ns	ns	ns	ns	ns	**	**	*	*

ns: Indicates nonsignificant; *, ** and ***, significant $P<0.05$, $P<0.01$ and $P<0.001$ probability respectively; GW: grain weight, TW: test weight (kg/hl), SC: starch content (%), PC: protein content (%), OC: oil content (%), AC: ash content (%), SY: starch yield (kg/ha), PY: protein yield (kg/ha), OY: oil yield (kg/ha) and AY: ash yield (kg/ha).

Table 3 Maize hybrids grain quality traits and quality yield parameters in 2014 and 2015 growing season.

Hybrids	GW (mg)	TW (kg/hl)	SC (%)	PC (%)	OC (%)	AC (%)	SY (kg/ha)	PY (kg/ha)	OY (kg/ha)	AY (kg/ha)
2014 growing season										
H1	236	76.3	64.5	7.99	2.56	0.96	8219	1020	326	123
H2	271	78.6	63.0	7.85	2.85	1.07	7379	925	332	126
H3	232	78.5	64.2	8.11	2.80	1.09	7912	1000	345	134
H4	263	76.7	60.6	7.59	2.83	1.06	6973	869	324	122
H5	223	76.6	62.3	7.63	2.60	1.09	7401	901	307	129
H6	257	78.6	61.0	8.05	3.01	1.06	6658	879	327	117
H7	234	80.1	62.9	7.62	2.80	1.01	6757	820	309	109
Mean	245	77.9	62.6	7.84	2.78	1.05	7328	916	324	123
LSD _{0.05}	26.7	2.3	ns	ns	0.187	0.072	601.6	81.2	ns	12.3
2015 growing season										
H1	247	70.1	63.8	8.47	2.59	1.08	8715	1155	353	147
H2	294	73.6	63.6	7.93	2.67	1.04	7632	957	321	126
H3	290	72.7	65.2	8.54	2.52	1.03	9386	1232	365	152
H4	298	71.9	64.9	7.78	2.64	1.05	8965	1073	366	145
H5	253	69.5	62.4	7.86	2.62	1.14	7988	1005	336	147
H6	327	73.1	65.2	7.94	2.68	1.02	9484	1155	391	147
H7	275	73.7	63.2	7.98	2.58	1.05	8132	1019	332	135
Mean	283	72.1	64.0	8.07	2.61	1.06	8614	1085	352	143
LSD _{0.05}	15.0	1.32	ns	0.379	ns	0.072	746.1	83.4	ns	13.0

ns: Indicates nonsignificant; GW: grain weight, TW: test weight (kg/hl), SC: starch content (%), PC: protein content (%), OC: oil content (%), AC: ash content (%), SY: starch yield (kg/ha), PY: protein yield (kg/ha), OY: oil yield (kg/ha) and AY: ash yield (kg/ha); H1: Sancia, H2: Indaco, H3: 71May69, H4: Aacel, H5: Calgari, H6: 70May82 and H7: 72May80

For grain weight determination randomly 10 ears were selected and shelling, it was followed by weighed of grain to calculate the percentage of shelling through (grain weight/grain numbers) at 12.5% moisture level of grain.

2.3 Statistical analysis

The obtained results subjected to analyses of variance according to Gomez & Gomez (1984). Significant means were separated by the Least Significant Difference (LSD) at the 0.05 significance level ($P \leq 0.05$). The estimation of correlation for traits was calculated by MSTAT-C computer software package.

3 Results and Discussion

3.1 Effects of irrigation regimes on quality traits of maize

Effect of irrigation regimes was the most prominent source which affects the grain quality during various growth stages (Table 1 & 2). It was reported that grain quality of maize hybrids were significantly influenced by irrigation treatments and, water stress lead to a significant reduction in yield quality traits over control (Table 1 & 2). Amount of maize oil, starch, protein and ash yield were significantly reduced by the deficit irrigation, starch showed higher sensitivity to drought

($P < 0.001$ and $P < 0.01$ of first and second year, respectively) than other traits (Table 2).

It was observed that grain weight was significantly affected by water stress and the highest grain weight (258 and 292 mg) was observed under control while the lowest grain weight (232 and 275 mg) under water stress condition for the 1st and 2nd year respectively (Table 2). Low grain weight due to drought stress, as found in present experiments, may indicate that the plants were unable to fully meet the demand of the growing grain. In present research, the differences between the water regimes were statistically significant for ash content in first season (Table 2). Protein content is also significantly influenced by water stress conditions and, it was slightly increased (non-significant) under limited irrigations (Table 2).

High starch, protein and crude oil yielding genotypes under water shortage condition could be evaluated for the drought tolerance genotypes. The obtained results, oil yield per unit area considerably decreased under water stress (Table 2). Grain qualities are governed by a number of factors particularly the duration and rate of grain filling (Brdar et al., 2008) and availability of assimilates that are negatively influenced under water deficit conditions (Ali & Ashraf, 2011; Barutçular et al., 2016a).

Table 4 Grain quality traits of maize hybrids as influenced by water regimes in 2014 and 2015.

Hybrids	GW (mg)	TW (kg/hl)	SC (%)	PC (%)	OC (%)	AC (%)	SY (kg/ ha)	PY (kg/ha)	OY (kg/ha)	AY (kg/ha)
Irrigated (Control) in 2014										
H1	255	76.8	66.7	7.65	2.66	0.97	8481	972	338	123
H2	282	78.9	63.0	8.18	2.66	1.09	8177	1061	344	142
H3	237	77.6	62.3	7.92	2.77	1.06	8525	1084	378	146
H4	282	76.6	60.2	7.18	2.71	1.11	7833	935	352	144
H5	229	76.8	63.9	7.15	2.54	1.10	8306	929	330	142
H6	266	77.7	61.6	7.96	2.92	1.16	7198	930	340	136
H7	257	80.8	61.8	7.57	3.15	1.06	7903	969	402	135
Deficit irrigated (Water stress) in 2014										
H1	217	75.7	62.2	8.33	2.45	0.96	7957	1067	314	124
H2	260	78.3	63.0	7.52	3.05	1.05	6582	789	320	110
H3	227	79.4	66.2	8.31	2.83	1.11	7299	915	311	122
H4	244	76.7	61.0	8.00	2.95	1.00	6113	803	296	101
H5	217	76.5	60.8	8.11	2.66	1.08	6496	872	284	117
H6	249	79.4	60.4	8.14	3.11	0.96	6117	829	315	98
H7	211	79.5	64.1	7.67	2.45	0.96	5610	672	215	84
LSD _{0.05}	ns	ns	ns	0.676	0.264	0.101	ns	114.9	36.0	17.3
Irrigated (Control) in 2015										
H1	240	70.0	64.1	8.70	2.60	1.05	8978	1216	363	147
H2	302	73.2	64.3	8.50	2.74	1.07	8254	1094	351	138
H3	303	72.3	63.2	8.39	2.56	1.09	10056	1337	409	174
H4	305	71.9	64.9	7.66	2.70	1.03	9543	1126	397	151
H5	260	70.7	61.1	7.55	2.56	1.14	8338	1027	349	155
H6	357	73.4	65.6	7.76	2.66	1.01	9699	1149	393	149
H7	279	73.8	65.0	7.80	2.59	1.08	9248	1104	368	154
Deficit irrigated (Water stress) in 2015										
H1	253	70.1	63.5	8.25	2.59	1.11	8452	1094	343	148
H2	286	74.0	62.9	7.36	2.60	1.00	7009	821	292	114
H3	277	73.1	67.2	8.69	2.48	0.98	8716	1128	322	130
H4	291	71.9	64.9	7.90	2.58	1.08	8386	1020	334	139
H5	247	68.3	63.8	8.17	2.68	1.15	7638	984	324	138
H6	298	72.9	64.9	8.12	2.70	1.03	9269	1161	389	145
H7	271	73.7	61.4	8.17	2.58	1.03	7015	934	296	116
LSD _{0.05}	21.2	ns	ns	0.54	ns	ns	ns	117.9	ns	18.4

ns: Indicates nonsignificant; GW: grain weight, TW: test weight (kg/hl), SC: starch content (%), PC: protein content (%), OC: oil content (%), AC: ash content (%), SY: starch yield (kg/ha), PY: protein yield (kg/ha), OY: oil yield (kg/ha) and AY: ash yield (kg/ha). H1: Sancia, H2: Indaco, H3: 71May69, H4: Aaccel, H5: Calgari, H6: 70May82 and H7: 72May80

Water stress imposed during the grain filling period of wheat, especially at the early filling stage, usually results in a reduction in grain weight (Zhao et al., 2009). Further, Pierre et al. (2008) and EL Sabagh et al. (2015) reported that water deficit stress has a negative effect on grain weight. Protein content is more strongly influenced by environment (Mikhaylenko et al., 2000). Variations in flour quality in a hard-grained were related to changes in protein composition from drought stress during grain filling (Gooding et al., 2003). It was also reported that water limitation significantly decreases seed and oil yields of maize (Ghassemi-Golezani & Dalil, 2011). The reduction in protein and oil yields under water stress could be due to sharp decline in grain yield under stressful condition (Ghassemi-Golezani & Lotfi, 2013) and the

results are also the results are also in agreement with the findings of Rashwan et al. (2016) and Barutçular et al. (2016b).

3.2 Comparative evaluation of various hybrids of maize

Significant differences among various genotypes with respect to grain quality traits were observed which indicates existence of genetic variation and possibility of selection for favorable genotypes in both environments. In this research, a greater reduction in test weight was observed in genotype of Calgari and Sancia (Table 1, 3). The hybrids genotype Indaco, 70May82 and Aaccel showed more positive effect of grain weight.

Table 5 Pearson correlation coefficient between grain quality traits in the irrigation regime (2014 and 2015 growing season).

Traits	GW (mg)	TW (kg/hl)	SC (%)	PC (%)	OC (%)	AC (%)	SY (kg/ha)	PY (kg/ha)	OY (kg/ha)	AY (kg/ha)
Irrigated (Control) in 2014										
GW (mg)	1.000									
TW (kg/hl)	0.161	1.000								
SC (%)	-0.389	-0.236	1.000							
PC (%)	0.266	0.370	0.072	1.000						
OC (%)	0.150	0.769*	-0.437	0.211	1.000					
AC (%)	0.249	0.003	-0.750	0.017	0.126	1.000				
SY (kg/ha)	-0.485	-0.178	0.604	-0.076	-0.516	-0.749	1.000			
PY (kg ha)	-0.027	0.261	0.082	0.681	-0.068	-0.288	0.545	1.000		
OY(kg/ha)	-0.066	0.733	-0.399	0.097	0.782*	-0.157	0.032	0.330	1.000	
AY (kg/ha)	-0.013	-0.033	-0.690	-0.051	-0.158	0.612	-0.014	0.308	0.137	1.000
Deficit irrigated (Water stress) in 2014										
GW (mg)	1.000									
TW (kg/hl)	0.194	1.000								
SC (%)	-0.262	0.497	1.000							
PC (%)	-0.351	-0.311	-0.052	1.000						
OC (%)	0.929**	0.320	-0.250	-0.161	1.000					
AC (%)	0.055	0.055	0.412	0.102	0.213	1.000				
SY (kg/ ha)	-0.179	-0.460	0.252	0.624	-0.247	0.242	1.000			
PY (kg ha)	-0.202	-0.590	-0.041	0.789*	-0.218	0.112	0.939**	1.000		
OY(kg/ha)	0.608	-0.257	-0.187	0.399	0.595	0.283	0.607	0.634	1.000	
AY (kg/ha)	-0.085	-0.508	0.142	0.600	-0.071	0.563	0.904**	0.870*	0.684	1.000
Irrigated (Control) 2015										
GW (mg)	1.000									
TW (kg/hl)	0.704	1.000								
SC (%)	0.544	0.592	1.000							
PC (%)	-0.289	-0.209	0.075	1.000						
OC (%)	0.468	0.371	0.564	0.077	1.000					
AC (%)	-0.572	-0.283	-0.890**	-0.090	-0.589	1.000				
SY (kg/ ha)	0.491	0.256	0.436	-0.073	-0.207	-0.475	1.000			
PY (kg ha)	0.098	-0.076	0.141	0.588	-0.293	-0.219	0.718	1.000		
OY(kg/ha)	0.582	0.239	0.379	-0.092	-0.047	-0.478	0.959**	0.690	1.000	
AY (kg/ha)	0.012	-0.057	-0.352	-0.092	-0.722	0.355	0.646	0.625	0.619	1.000
Deficit irrigated (Water stress) 2015										
GW (mg)	1.000									
TW (kg/hl)	0.758*	1.000								
SC (%)	0.270	-0.030	1.000							
PC (%)	-0.331	-0.242	0.516	1.000						
OC (%)	-0.024	-0.385	-0.341	-0.354	1.000					
AC (%)	-0.668	-.931**	-0.239	0.028	0.507	1.000				
SY (kg/ha)	0.303	-0.118	0.759*	0.516	0.050	-0.018	1.000			
PY (kg/ha)	0.073	-0.205	0.676	0.753	-0.015	0.048	0.941**	1.000		
OY(kg/ha)	0.268	-0.226	0.439	0.292	0.484	0.192	0.888**	0.821*	1.000	
AY (kg/ha)	-0.159	-0.633	0.428	0.392	0.346	0.574	0.798*	0.782*	0.844*	1.000

*, **, significant $P < 0.05$ and $P < 0.01$ probability respectively; GW: grain weight, TW: test weight (kg/hl), SC: starch content (%), PC: protein content (%), OC: oil content (%), AC: ash content (%), SY: starch yield (kg/ha), PY: protein yield (kg/ha), OY: oil yield (kg/ha) and AY: ash yield (kg/ha).

Achieved results revealed that oil content was significantly influenced by water regime and that maximum value was found for genotype 70May82 (3.01%) and minimum for Sancia (2.56%) in the first season. The obtained results also revealed that the highest value of protein content (8.54%) was found in 71May69 and the lowest (7.78%) in Aaccel. In this experiment, genotype Calgari produced the highest value of grain ash content in both seasons. The hybrids Indaco, 71May69 and Sancia showed more positive effects on starch and protein yield/ha. Results of study revealed that ash yield was significantly influenced by water stress conditions and that the maximum value of ash (134 kg/ha) was found in 71May69 and the minimum (109 kg/ha) in 72May80. Drought stress reduced grain weight but increased protein content in wheat as reported by Rharrabti et al. (2003). Availability of assimilates are negatively influenced under water deficit conditions (Ali & Ashraf, 2011). Water deficient at flowering stage greatly decreased starch content due to the decrease of photosynthesis and thus makes an increase of grain protein ratio (Mousavi et al., 2013). Environment is the major source of variation for grain quality as reported by Mikhaylenko et al. (2000); Gulluoglu et al. (2016) and Kurt et al. (2016).

3.3 Effects of maize hybrids and irrigation regimes on quality traits

Genotypes and irrigation regimes were found to influence all quality traits significantly. The treatments interactions showed significant differences on the quality parameters (Table 4). Under drought stress, the hybrids Sancia and Calgari were more stable in grain weight (less reduction) and 71May69, Aaccel and Calgari were less sensitive to grain quality (less grain quality losses), maize quality properties are usually influenced by genotypes, environmental factors and their interactions and final growth stage of maize is dramatically influenced by the water stress and, this adverse effects are mainly reduced grain weight, and this resulted in low starch, crude oil and protein content (Cirilo et al., 2011). Grain filling process is sensitive to environmental conditions, this strongly influencing the final grain development quantitatively and qualitatively as well (Yang & Zhang, 2006). Mansouri et al. (2010) found that, grain weight were decreased under water stress condition. Farhad et al. (2013) observed that grain protein and oil contents were significantly influenced by irrigation regimes among maize hybrids.

3.4 Correlation analysis

Correlation coefficients among the major studied variables were found positive association in both seasons (Table 5). It was found that the grain weight was negatively affected by the starch content in the first season, and protein content and ash content in the second season. The highest correlation was observed in starch, protein yield in both seasons, while, negative correlation between oil content and starch content as well as protein content was found in the first season. It was also observed a negative correlation among grain weight, test weight and ash in the second season. Oury & Godin (2007)

reported that, protein contents were negatively correlated with grain weight under normal and stress conditions. The negative correlation between grain yield and grain gluten content had been established under genotype-by-environment interactions in different studies of wheat (Tayyar, 2010). The positive correlation between grain protein percentage and grain filling rate and which results from irrigation-off at flowering stage, has a significant effect on grain protein percentage increasing. Furthermore, it was observed that, grain protein percentage reduces in relation to starch under water deficient (Mousavi et al., 2013).

Conclusion

In summary, it can be stated that the imposition of water stress significantly influenced the nutritional quality traits of maize. However, high starch, protein and crude oil yielding genotypes could be evaluated for the drought tolerance in the drought environment. In respect to the hybrids, Sancia and Calgari were drought tolerant genotypes for their less sensitivity (more stable) to grain weight under drought stress. The 71May69, Aaccel and Calgari were less sensitive in grain quality traits under drought stress.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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