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ORIGINAL PAPER

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EVALUATION OF SEED YIELD, OIL AND MINERAL CONTENTS INBRED PUMPKIN LINES (*Cucurbita pepo* L.) UNDER WATER STRESS

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ABSTRACT

Water stress is one of the main constraints which could limits crop productivity, especially in arid and semi-arid regions characterized limited water resources. This study was conducted to investigate the seed yield, oil and mineral contents of 44 lines and 4 commercial pumpkin varieties (2 local and 2 hybrids) in irrigated and drought stress conditions. The study was conceived as a randomized block design with three replications and carried out during the 2017 growing season. On average, the irrigated plots produced 161.27 kg da^{-1} seed yield whereas it was 33.67 kg da^{-1} in non-irrigated plots. The highest yield among the commercial pumpkin varieties was obtained from the G2 hybrid variety in the irrigated conditions. On the other hand, in the non-irrigated plots, higher seed yields were obtained from G9, G34, and G36 pure lines. Drought resulted in a remarkable decrease in the total oil content and significant increase in the amount of Ca and Zn in pumpkin seeds. These results clearly indicated that G9 line, which has the highest seed yield in both irrigated and drought conditions, can be utilized as a recommendable parental pumpkin line in future hybrid breeding efforts.

Key words: breeding, open field condition, water stress, pumpkin

INTRODUCTION

Pumpkin (*Cucurbita pepo*) belongs to the *Cucurbitaceae* family and has a wide range of varieties in terms of plant, fruit, and seed characteristics. It is being cultivated for about 10,000 years in North America and about 500 years in Europe [Paris 1996]. It is one of the most economically important plant species and can be grown in various environmental conditions throughout the world [Paris 1996]. *Cucurbita pepo* is usually cultivated for its fruits, and mature seeds are also nutritious for human consumption.

Pumpkin seeds are used as an additive in bread, salami, sausage, mayonnaise, and many other food products owing to their high protein value, as well as they are considered an appetizer. Besides as food, seeds are also used for medical purposes as well as nutritional supplements in Russia and some African countries [Murkovic et al. 1996]. The medicinal property of seeds includes their use in stomach ache (antispasmodic and carminative), kidney calculi and sand reduction (diuretic), against intestinal para-

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sites, pinworm and taenia reduction (anthelmintic), flake treatment for ear pain (anesthetic), and an anti-inflammatory agent [Günay 2005]. Pumpkin seeds have significant levels of antioxidants (tocopherols and tocotrienols), which have been reported to reduce the risk of some cancer types (such as gastric, breast, lung, and colorectal) [Stevenson et al. 2007]. Further, pumpkin seeds are rich in phytosterols that play a key role in lowering cholesterol levels and reducing benign prostate hyperplasia [Hong et al. 2009]. Owing to their constituents, pumpkin seeds exert a promotive and protective effect on the human immunity system [Chew and Park 2004].

Confectionary pumpkin is cultivated especially for its edible oil in developed countries such as Hungary, Czech Republic, Italy, and Spain and the oil content changes according to genotypes and culture conditions [Murkovic et al. 1996]. The pumpkin oilseeds contain 28–40% of protein and 35–50% of oil [Seymen et al. 2016]. Heart-healthy pumpkin oil contains 78% unsaturated fatty acids [Kreft et al. 2002] along with omega-3 (w-3) and omega-6 (w-6) fatty acids. These fatty acids have very important functions in human metabolism.

Besides, seeds are rich in nutrients such as potassium, phosphorus, calcium, magnesium, and zinc, which are important for human health [Seymen et al. 2016]. Pumpkin is also known as a good source of vitamins A, C and E.

The appetizer pumpkins are *C. pepo* and *C. moschata*, and the latter is least cultivated. Appetizer squashes are considered as an advantageous species compared to many cultivated plants because they can be cultivated with limited irrigation using water more economically in arid and semi-arid areas.

Due to the climate change, rapid population growth, and indiscriminate and excessive consumption, there is a decrease in the water resources leading to irrigation problems [Cosgrove and Loucks 2015]. In current agricultural practices, drought is one of the most important abiotic stress factors limiting crop production. In general, drought has many negative effects on plant growth, and it is known that drought inhibits the uptake of nutrients from plants and their transport from the roots to the stem as drought stress leads to a decrease in transpiration, inhibition of active transport, and also deterioration of membrane permeability [Alam 1999]. At the same time, the decrease in soil humidity also reduces the availability of nutrients that can be absorbed by the roots [Alam 1999]. Consequently, drought slows down the development of plants and reduces product quality due to negative effects on root, stem, and fruit [Seymen et al. 2019].

The plants exposed to arid conditions must be capable of adapting to these environmental conditions such as the water stress in order to result in economically viable crops. Therefore, using genotypes with a high ability to adapt to arid conditions is the main criterion to start the breeding efforts for the development of new drought-tolerant cultivars [Karipçin et al. 2009]. Along with the increase in arid and semi-arid areas in the world, the trend to grow plants that use water more economically, such as appetizers squash, is increasing day by day. Despite an increase in the production, maintaining the desired commercial qualities in a cultivar is one of the most important constraints. In addition, the content of nutritional compounds present in pumpkin seeds is significantly dependent on the growing conditions such as soil structure and climate and the genetic characteristics of the plant [Glew et al. 2006].

The effect of drought on the content of oil and nutrients in the confectionary pumpkin seeds, which are very important in human nutrition, has not yet been determined. Accordingly, this study aimed to reveal the effect of drought stress on yield, mineral and oil content in 48 pumpkin genotypes (4 commercial cultivars and 44 genotypes which are promising parental lines) for the development of new drought-tolerant pumpkin cultivars.

MATERIAL AND METHODS

Soil and climate characteristics of the experimental area

This study was carried out in the Agriculture Faculty of Selcuk University, Turkey, Konya between May and September 2017. The soil of the study area has a silty-clayey-loamy texture and the organic matter content in 0–90 cm soil profile, pH, bulk density values changes from 0.93 to 1.55%, 7.70 to 7.98, 1.25 to 1.35 g cm^{-3}, respectively. The total available water (TAW) is 148.8 mm in the upper 90 cm of the soil profile. The soil of the research area does not constitute a constraint for the pumpkin cultivation in terms of both its physical and chemical properties.

According to the long-term climate data, Konya Plain has a semi-arid climate, and the total amount of rainfall is 320 mm, of which only 90–100 mm falls during the plant growing season (May–September). Some climatic parameters such as temperature, relative humidity, wind speed, and precipitation were measured and recorded hourly from an automated weather station (Davis Vantage Pro 2) located in the research area. The total amount of rainfall that was measured during the period from the planting of pumpkin seeds to harvest was approximately 90 mm in 2017. The temperature was close to 40°C, especially in July and August, and the relative humidity has dropped to 35% level in some months (July and August). The average wind speed was between 2.5–3 m s^{-1}. The climatic data for the experimental year (2017) were in agreement with the long-term average climate data of the region.

Plant material, planting, and irrigation

In the study, pumpkin populations collected from different regions of Turkey were used as plant material. The pumpkin populations have been self-pollinated to the S7 level at Selçuk University Agricultural Faculty for many years. Subsequently, 44 pure lines (G) at the S7 stage were selected from the gene pool. In addition, two-hybrid (G1-Mertbey F1, G2-Senahanim F1) and two local cultivars (G3-Hatuntırnağı, G4-Cercevelik) which have commercial value in the market were used as a control group.

The study followed a randomized block design with three replicates under full irrigated and complete stress conditions (drought stress) with a total of 48 genotypes (44 pure lines and 4 commercial varieties). Each parcel (288 parcels) was designed in 4 × 5 m plots, the parcels were spaced 2 m from each other and 2.5 m from the blocks. A total of 40 pumpkin seeds were sown by hand in 1 m row and 0.5 m inter-row spacing for each parcel.

In this study, a drip irrigation system was used. Round drip irrigation pipes of 5 m length, 16 mm diameter and 4 L h^{-1} discharge rate at the pressure of 100 kPa were placed for each plant rows. The distance between the drippers at the lateral pipes was kept as 50 cm considering the soil characteristics. The lateral pipes were connected to the manifold pipes having a diameter of 40 mm and the manifold pipes were connected to the PE main pipe having a diameter of 63 mm. The amount of irrigation water applied to the irrigated plots was calculated by Equation (1) considering the amount of cumulative water evaporation at seven days intervals from the Class A type pan installed in the experimental area. In the programmed irrigation, water was applied ten times to the irrigated experimental subjects at seven days intervals.

$$I = E_p \times K_p \times K_c \times A \tag{1}$$

where

I – amount of irrigation water (L),
A – parcel area (m^2),
E_p – cumulative pan evaporation measured during an irrigation period of seven days using standard Class A pan (mm),
K_p – pan coefficient (taken as 0.82),
K_c – plant coefficient (the K_c values recommended for the pumpkin by Yavuz et al. [2015] were used).

Throughout the developmental period of plants, the practices such as tillage, fertilization, diseases, and pest management activities were regularly carried out in a timely manner. Twenty days before the harvest time, irrigation was discontinued in the fully-watered plots and the seeds in the fruits were left to mature and the plants were left to dry completely.

Nutrient content of the seeds

After harvesting, the seeds were dried in an air circulating drying cabinet at 70°C until they reached a constant weight and then milled. Of the dried and ground samples, 0.3 g was taken and dissolved in 5 mL HNO_3 (concentrated) in a microwave device (CEM Mars 5) at a high temperature (210°C) and pressure (200 PSI). The samples were cooled by transferring to a 25 mL balloon and filled with deionized water. The solutions were filtered with Whatman no. 42 paper and immediately transferred to 25 mL polyethylene bottles. The plant nutrients in the filtered solution were determined by ICP-AES device (Inductively Coupled Plasma Atomic Emission Spectrometer) (Varian-Vista) [Skujins 1998].

Total oil content of the seeds

Extraction of Samples for GC-MS Analysis. The weighed samples that were completely dried and milled together with seed husks were subjected to continuous extraction at 60°C for 8 h with hexane (Merck Co.) in a Soxhlet apparatus. At the end of the extraction, the hexane phase was concentrated under low vacuum to obtain oil. The oil obtained was measured in proportional to the initial weights and the percentage of oil content was determined [Ramadan and Moersel 2006].

Statistical analyses

The seed yield and mineral matter contents obtained were subjected to analysis of variance and the statistically significant results were grouped at the 5% significant level according to the LSD test results. The analysis of variance and LSD test were performed by using the SPSS 22.0 computer program.

RESULTS

Seed yield. There were significant differences ($P < 0.05$) in the yields of the 48 pumpkin genotypes under the irrigated and drought stress conditions.

We observed that drought stress has a strong effect on seed yield of pumpkin genotypes. The seed yield (kg da^{-1}) varied from 77.35 (G26) to 252.54 (G9) in irrigated lots and from 7.40 (G19) to 95.08 (G9) in drought stress applications. Average seed yield was determined 161.27 kg da^{-1} and 33.67 kg da^{-1}, respectively, in irrigated and drought stress conditions. In commercial cultivars, the highest yield was obtained from the hybrid variety G2 in the irrigated conditions. G9 (252.54 kg da^{-1}), G30 (241.25 kg da^{-1}), G31 (219.61 kg da^{-1}) and G28 (217.33 kg da^{-1}) produced higher yields than the commercial cultivars in the irrigated conditions. G1 hybrid cultivar had the highest yield, and G9 (95.08 kg da^{-1}), G34 (90.16 kg da^{-1}) and G36 (65.91 kg da^{-1}) gave considerably higher yield than commercial cultivars in stress conditions (Tab. 1).

Oil contents. We detected a strong relationship among oil content, genotypes, and irrigation regimes. While 35.13% of the total oil was measured in irrigated conditions, drought lots produced only 33.39% of the total oil on average. Consequently, drought caused a decrease in the total oil content. Regarding the oil contents of genotypes, the highest oil contents were obtained in G2, G5, G10, G16, and G37 genotypes in the irrigated conditions and the overall oil content was more than 40%. Similarly, the lowest oil content was obtained in G9, G11, and G15 genotypes in the irrigated lots. In the drought conditions, G2, G9, G27, G30, G40, and G42 genotypes gave the best oil content ranging from 38.2% to 42.2%. The dry conditions showed a remarkable decrease in oil content and the lowest oil content was obtained from G8, G11, G12, G13, G19, G23, G26, and G33 (Tab. 1). G30, G31, G34, and G36 genotypes, which showed favorable performance in terms of average seed yield in irrigated and drought stress conditions, showed higher oil ratio than the drought stress conditions when evaluated in terms of seed yield and oil ratio. On the other hand, G9, G31, and G36 genotypes, which predominantly yielded seeds in wet and dry conditions, contained a higher amount of oil than the average value in stress conditions.

Mineral contents. Among 48 different pumpkin genotypes, the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) contents were significantly different ($P < 0.01$ and 0.05) (Tab. 2).

When the N contents of pumpkin genotypes were examined, on average it was 57.7 g kg^{-1} and 60.2 g kg^{-1} in irrigated and drought stress conditions, respectively (Tab. 3). Average P content of genotypes was 5.7 g kg^{-1} in the irrigated conditions, while it was 7.6 g kg^{-1} in the drought stress plots (Tab. 3). The pumpkin genotypes produced 6.8 g kg^{-1} of K in irrigated and drought stress conditions on average (Tab. 3).

Ca is an important element in drought studies and its content was 0.50 g kg^{-1} in irrigated plots and 0.63 g kg^{-1} in drought stress plots, on average (Tab. 3). The G9 genotype, which gave a higher yield in irrigated and drought stress plots, showed about 25% more calcium content in arid conditions.

The average value of Mg was 3.16 g kg^{-1} in irrigated plots, whereas this was 3.06 g kg^{-1} in the drought stress plots (Tab. 3). Zinc is an important nutrient element in pumpkin and its average content was 50.23 mg kg^{-1} in the irrigated conditions and 54.22 mg kg^{-1} in the drought stress conditions (Tab. 4). The G31 genotype, which showed the highest yield in irrigated plots, contained 71% more Zn and G30 also had 22% more Zn in dry conditions.

Table 1. Seed yield and oil content under irrigation and drought stress conditions

Genotype	Seed yield (kg da^{-1})		Seed oil percentage (%)	
	irrigated	drought	irrigated	drought
G1	188.48	65.43	36.26	33.10
G2	208.97	33.71	42.06	38.02
G3	197.02	16.49	38.00	35.95
G4	156.69	19.82	35.98	37.00
G5	158.13	30.41	41.67	32.16
G6	171.29	16.66	39.49	31.53
G7	115.65	55.63	35.79	35.56
G8	111.35	14.22	33.97	29.67
G9	252.54	95.08	26.86	39.32
G10	129.23	18.14	40.00	37.01
G11	184.42	27.64	27.57	27.70
G12	156.45	13.45	31.67	27.60
G13	178.21	43.92	32.32	21.04
G14	115.19	51.75	34.57	35.47
G15	154.92	26.77	26.26	35.40
G16	112.50	37.67	42.58	35.61
G17	174.01	21.16	35.03	35.00
G18	151.08	12.23	32.15	33.82
G19	132.83	7.40	32.01	28.38
G20	163.09	38.95	31.76	30.56
G21	189.26	40.63	35.46	36.00
G22	156.02	30.52	35.25	30.64
G23	165.23	41.02	34.34	29.43
G24	102.63	29.29	32.41	31.52
G25	130.41	11.98	31.24	36.20
G26	77.35	29.12	34.20	29.27
G27	173.61	46.89	34.35	39.83
G28	217.33	9.83	38.19	33.34
G29	167.36	36.63	35.60	33.49
G30	241.25	43.14	37.63	42.20
G31	219.64	7.49	30.62	30.91
G32	184.99	63.26	30.88	33.77
G33	127.79	18.68	33.59	24.97
G34	194.97	90.16	35.55	33.00
G35	167.57	20.43	33.32	32.61
G36	168.20	65.91	39.27	34.49
G37	170.98	20.46	40.44	34.46
G38	186.92	54.62	38.33	32.41
G39	187.34	31.49	37.11	34.08
G40	192.54	55.68	37.96	38.22
G41	174.35	14.30	38.46	29.83
G42	127.06	41.16	33.01	38.63
G43	85.68	13.32	35.77	35.79
G44	140.52	28.84	35.29	34.52
G45	156.60	32.21	34.25	33.42
G46	133.68	9.19	35.93	33.13
G47	115.01	44.32	39.36	33.32
G48	174.48	38.81	32.40	33.36
Mean	161.27	33.67	35.13	33.39
$LSD_{0.05}$	55.07	28.51	–	–

Table 2. Mean square valued from the analysis of variance of the mineral elements under irrigation and drought stress

Source of variation	df	Calcium (Ca)		Copper (Cu)		Iron (Fe)	
		irrigated	drought	irrigated	drought	irrigated	drought
Block	2	16529.73^{ns}	5711.58^{ns}	0.989^{ns}	0.562^{ns}	27.301^{ns}	178.835^{ns}
Genotype	47	35530.88^{**}	44852.10^{**}	10.455^{**}	8.848^{**}	496.079^{**}	580.181^{**}
Error	94	11910.65	17574.68	4.053	3.147	165.695	173.869

Source of variation	df	Magnesium (Mg)		Manganese (Mn)		Zinc (Zn)	
		irrigated	drought	irrigated	drought	irrigated	drought
Block	2	189276.44^{ns}	38722.72^{ns}	13.030^{ns}	4.390^{ns}	112.476^{ns}	299.172^{ns}
Genotype	47	389263.44^{**}	349989.67^{**}	58.586^{**}	43.097^{**}	221.086^{**}	235.216^{**}
Error	94	88890.94	68182.28	16.394	9.442	72.350	57.794

Source of variation	df	Potassium (K)		Phosphorus (P)		Nitrogen (N)	
		irrigated	drought	irrigated	drought	irrigated	drought
Block	2	0.001^{ns}	0.001^{ns}	0.001^{ns}	0.001^{ns}	0.049^{ns}	0.326^{*}
Genotype	47	0.008^{**}	0.007^{**}	0.003^{**}	0.002^{**}	1.787^{**}	1.827^{**}
Error	94	0.003	0.003	0.001	0.001	0.068	0.080

^{ns} Statistically insignificant according to $P < 0.01$ and 0.05. *Statistically significant according to $P < 0.05$. **Statistically significant according to $P < 0.01$; df – degrees of freedom

The average Cu and Fe contents were 16.73 mg kg^{-1} and 65.51 mg kg^{-1} in irrigated plots and 17.33 mg kg^{-1} and 66.07 mg kg^{-1} in dry plots, respectively (Tab. 4). Fe is essential for the hemoglobin synthesis and oxygen transfer, and its deficiency causes anemia. The Mn content was 27.51 mg kg^{-1} in the irrigated conditions and 27.9 mg kg^{-1} in the drought stress conditions (Tab. 4).

DISCUSSION

Many physiological factors that determine the productivity of plants are significantly affected by drought. In addition, a drought that occurs during the flowering period causes severe loss of yield. In this study, drought stress caused a loss of approximately 80% in average seed yield (Tab. 1). In the limited irrigation condition for appetizers squash, a yield of 135.2 kg da^{-1} and 48 kg da^{-1} was obtained in irrigated and drought stress conditions, respectively. As recently reported by Yavuz et al. [2015], drought showed a negative effect on the fruit-set and resulted in an extreme loss in the yield. Çakır [2000] obtained seed yield between 49.97 and 126.81 kg da^{-1} from different irrigation regimes in appetizers squash. The earlier studies conducted on the varieties used in this study have shown that drought affects plant growth negatively and causes significant yield losses. However, our findings revealed that some genotypes are drastically affected by drought, while others were much less and showed acceptable yields.

The average seed yield of 81 appetizer pumpkin genotypes was reported to be 114 g plant^{-1} and the highest yield was 226 g plant^{-1} [Türkmen et al. 2016]. A seed yield of up to 496 g per plant was determined in seven pumpkin pure lines and hybrids [Darrudi et

Table 3. "N, P, K, Ca and Mg" contents in the seeds of different pumpkin genotypes in the irrigated and drought stress conditions (g kg^{-1})

Genotype	N		P		K		Ca		Mg	
	irrigated	drought	irrigated	drought	irrigated	drought	irrigated	drought	irrigated	drought
G1	54.4	64.9	6.3	6.7	6.6	6.5	0.72	0.63	3.47	3.03
G2	44.3	59.0	6.2	5.6	5.9	6.1	0.43	0.51	3.01	3.06
G3	57.2	61.8	5.9	5.6	6.0	6.3	0.39	0.61	3.43	3.32
G4	59.2	59.6	6.2	6.1	7.0	6.7	0,48	0.71	3.56	3.24
G5	58.8	62.2	5.9	5.7	8.4	8.4	0.60	0.65	3.84	3.95
G6	61.7	60.2	5.9	5.8	6.4	6.9	0.55	0.59	3.67	3.39
G7	56.8	61.3	5.9	5.9	6.9	5.6	0.56	0.78	4.08	2.80
G8	57.6	49.7	6.2	5.7	5.4	6.4	0.53	0.89	3.28	3.24
G9	48.3	47.3	5.6	5.8	6.8	6.6	0.49	0.61	3.66	3.36
G10	44.0	47.3	6.1	5.6	7.1	5.9	0.42	0.53	3.16	2.96
G11	47.5	47.1	6.1	5.6	7.1	6.6	0.45	0.50	3.57	3.65
G12	45.1	46.4	5.6	5.5	6.6	6.3	0.60	0.61	3.51	3.48
G13	47.4	49.4	5.9	5.8	7.3	6.8	0.42	0.66	3.71	3.46
G14	50.7	52.8	5.4	5.6	5.9	6.7	0.63	0.67	3.42	3.21
G15	48.5	49.8	5.4	5.5	6.8	6.6	0.52	0.60	3.57	3.27
G16	44.6	48.1	5.7	5.4	6.0	6.5	0.52	0.60	3.17	3.07
G17	47.7	48.7	6.1	5.6	7.0	6.6	0.49	60.0	3.06	2.98
G18	44.3	48.0	5.5	5.5	7.3	6.4	0.38	0.55	2.48	2.76
G19	47.7	47.9	5.6	5.4	6.3	7.1	0.50	0.62	3.15	2.64
G20	52.3	55.9	5.7	5.6	7.2	7.4	0.42	0.63	2.93	2.81
G21	51.4	60.2	5.5	5.3	7.1	7.0	0.44	0.58	2.59	2.55
G22	60.2	61.3	5.4	5.8	6.8	6.5	0.40	0.68	2.96	2.82
G23	56.9	55.7	5.6	5.7	7.4	6.2	0.45	0.70	2.71	2.50
G24	65.1	70.6	5.4	5.1	7.0	7.0	0.66	0.86	2.67	2.35
G25	64.3	68.0	5.0	5.6	6.6	7.0	0.73	0.74	2.90	2.63
G26	69.6	72.5	5.6	5.9	7.2	6.9	0.50	0.67	2.74	2.71
G27	67.8	68.7	5.5	5.6	7.3	7.6	0.72	0.93	2.75	2.63
G28	67.3	69.4	5.0	5.4	7.0	6.8	0.62	0.65	2.72	2.73
G29	65.2	68.6	5.4	5.5	7.4	7.3	0.43	0.50	2.68	2.77
G30	67.4	70.0	5.9	5.3	7.0	6.9	0.42	0.64	3.03	2.92
G31	65.4	63.6	5.8	5.7	6.4	7.0	0.36	0.62	3.17	3.69
G32	66.3	67.0	5.8	5.4	6.4	7.6	0.33	0.53	2.86	3.30
G33	65.8	64.3	5.6	5.6	6.6	6.9	0.54	0.60	3.16	3.04
G34	64.5	67.9	5.7	5.9	6.7	7.0	0.36	0.45	2.97	2.62
G35	64.4	69.9	5.9	5.8	6.9	6.8	0.39	0.55	3.05	2.78
G36	65.1	69.9	5.6	5.6	6.6	6.7	0.43	0.48	3.05	2.86
G37	65.7	66.7	5.7	5.8	6.9	6.5	0.45	0.88	3.10	3.21
G38	64.2	64.1	5.7	5.3	6.2	7.3	0.61	0.47	3.21	3.22
G39	58.1	62.8	5.5	5.2	7.1	6.9	0.40	0.60	3.23	3.07
G40	59.7	58.3	5.5	5.6	7.3	6.9	0.35	0.41	2.61	3.39
G41	58.4	60.8	5.4	5.6	6.8	6.9	0.52	0.83	3.62	3.04
G42	57.7	58.9	5.5	6.0	6.4	6.8	0.46	0.57	3.38	2.88
G43	62.6	63.9	6.0	5.5	6.9	6.4	0.50	0.54	3.17	3.19
G44	63.8	65.3	6.4	6.2	7.2	7.8	0.51	0.70	3.13	3.20
G45	61.0	63.8	5.5	5.5	6.9	6.9	0.73	0.78	2.78	3.24
G46	61.5	62.9	5.7	5.8	6.2	7.4	0.66	0.65	3.28	3.31
G47	61.9	66.2	5.6	5.7	6.5	6.9	0.62	0.37	3.35	3.57
G48	51.7	61.6	5.6	5.4	6.9	6.8	0.39	0.53	3.19	2.92
Mean	57.7	60.2	5.7	5.6	6.8	6.8	0.50	0.63	3.16	3.06
LSD$_{0.05}$	4.2	4.6	0.5	0.5	0.9	0.9	0.17	0.21	0.48	0.42

Table 4. "Zn, Cu, Fe and Mn" contents in the seeds of different pumpkin genotypes in the irrigated and drought stress conditions (mg kg^{-1})

Genotype	Zn		Cu		Fe		Mn	
	irrigated	drought	irrigated	drought	irrigated	drought	irrigated	drought
G1	48.30	58.40	17.95	16.81	66.79	60.95	33.58	34.97
G2	40.18	47.71	16.13	17.54	67.54	78.17	28.33	31.33
G3	50.01	55.09	19.85	16.80	77.87	90.57	30.33	29.79
G4	52.52	53.15	18.51	18.27	88.03	89.67	31.52	29.98
G5	77.53	85.53	17.95	21.25	75.47	81.26	31.58	34.38
G6	64.85	70.09	20.02	20.31	104.20	70.62	34.71	31.17
G7	57.92	51.29	21.39	19.32	79.30	79.85	36.67	24.11
G8	51.77	58.18	17.73	17.19	63.15	71.54	24.85	26.87
G9	62.17	53.89	15.19	14.17	83.79	59.45	32.64	31.35
G10	57.44	54.56	18.57	17.83	69.51	56.06	27.00	23.03
G11	48.61	49.05	15.05	16.87	55.89	58.08	24.99	24.03
G12	48.74	50.95	15.05	15.97	71.99	62.94	26.08	28.05
G13	50.31	51.92	18.14	17.44	61.63	69.29	30.15	35.21
G14	55.79	52.95	16.61	18.53	71.91	67.30	34.35	32.07
G15	59.91	66.49	19.11	18.10	65.29	57.66	32.21	28.79
G16	56.09	59.27	16.45	17.76	65.99	91.67	26.71	24.78
G17	53.23	52.73	18.41	19.16	72.91	59.90	25.56	28.70
G18	52.86	64.23	14.13	18.67	48.57	56.87	21.19	25.96
G19	44.27	40.49	15.48	16.25	57.61	51.83	25.74	23.53
G20	48.68	45.74	14.82	16.13	52.36	54.54	23.36	27.03
G21	44.32	56.99	16.97	18.56	55.39	81.97	21.95	23.71
G22	56.02	62.68	18.78	20.10	57.55	67.84	25.41	26.48
G23	46.84	50.10	18.95	17.07	73.40	62.23	26.21	23.96
G24	49.72	44.01	14.73	16.06	63.01	56.91	27.67	25.24
G25	57.43	58.05	19.74	18.47	57.55	52.01	33.05	30.25
G26	44.04	52.55	18.75	20.75	53.22	51.69	21.59	21.80
G27	42.68	51.55	14.40	16.85	52.44	47.11	26.08	28.16
G28	53.99	55.59	16.68	17.83	56.75	46.86	21.13	26.07
G29	45.74	48.31	17.25	17.89	42.92	50.14	26.75	30.49
G30	46.86	57.39	17.74	17.47	57.90	53.27	27.09	27.88
G31	43.69	74.92	14.41	21.00	55.17	63.90	22.29	25.01
G32	41.85	52.49	16.75	17.11	52.47	57.01	22.29	27.31
G33	44.53	48.28	16.83	16.82	58.26	57.99	24.83	24.35
G34	37.70	35.03	14.68	13.64	54.99	49.31	23.18	20.24
G35	38.08	42.67	16.13	18.33	68.66	81.67	28.16	24.87
G36	46.65	41.36	15.03	14.90	63.35	63.37	24.49	24.61
G37	43.91	63.33	15.37	16.81	56.21	82.99	21.73	31.27
G38	47.75	43.06	17.07	14.97	74.47	64.06	28.23	23.05
G39	42.11	52.70	14.66	16.10	62.63	64.89	23.05	29.87
G40	32.07	49.44	13.38	15.59	55.68	62.62	19.75	28.65
G41	57.71	54.77	15.07	15.87	56.17	60.95	26.05	29.07
G42	49.10	53.81	14.49	15.92	68.09	54.07	27.39	26.57
G43	56.83	54.44	16.39	15.65	70.25	93.41	31.18	35.07
G44	47.91	49.27	15.19	15.67	90.48	80.67	33.77	33.12
G45	45.73	61.13	15.34	16.52	66.53	108.67	31.26	33.24
G46	65.18	58.97	17.62	17.26	102.71	62.42	31.98	32.69
G47	57.30	48.93	18.29	15.21	60.27	62.92	36.44	26.40
G48	44.31	58.93	15.67	18.93	58.26	62.43	25.91	24.55
Mean	50.23	54.22	16.73	17.33	65.51	66.07	27.51	27.90
$LSD_{0.05}$	13.79	12.33	3.26	2.88	20.88	21.38	6.57	4.98

al. 2018]. Our results agree with previous studies, and the pure lines in our gene pool seem to be highly productive and superior.

It has been reported that the oil content of pumpkin seeds could go up to 50%, which is closely related to the genetic structure and there are differences between the different genotypes [Murkovic et al. 1996]. Different ecological factors can alter the oil content in pumpkin seeds, which can vary from 22 to 39% depending on the genotypes [Stevenson et al. 2007]. Seymen et al. [2016] reported that hulled pumpkin seeds have more oil content and the oil content varied (33–47%) in ten different hulled pumpkin lines. It was also reported that pumpkin genotypes vary in the oil content from 29 to 39% and the hulled and thin-hulled genotypes could contain up to 48% oil [Meru et al. 2018]. As indicated in this study, there were large differences between the oil contents of the genotypes concording with earlier reports.

Alfawaz [2004] reported that seeds without seed coat contain more oil than the seeds crushed together with the seed coat. A negative correlation was found between the hull ratio and internal ratio in sunflower [Ergen and Sağlam 2005]. In our experimental plots, the drought lots produced weaker seeds with lower internal and more seed coat ratio. For this reason, the oil contents of the genotypes which were grown in drought conditions were lower than the irrigated lots.

P plays an important role in carbohydrate biosynthesis, regulation of body acidity, and transfer of energy reactions [Mir-Marqures et al. 2015]. It has been reported by many researchers that pumpkin seeds are rich in P content [Erdinc et al. 2018] and our findings are in accordance with these reports.

Potassium is one of the main nutrients in plant development and regulates protein and glycolytic enzyme synthesis and photosynthesis. Besides, it can prevent plants from drought damage by maintaining turgor pressure and reducing transpiration in arid conditions. Pumpkin is a rich species in the K content [Kreft et al. 2002]. In our results, K was found to be in high amounts in different genotypes and the relation of drought with potassium intake was found to be non-significant.

It has also been reported by many researchers that pumpkin seeds are rich in Ca [Kreft et al. 2002, Erdinc et al. 2018]. In our study, it was clearly seen that the amount of Ca in seeds obtained under arid conditions was higher than in irrigated conditions. Calcium has an important role in water uptake, membrane structure, stomatal functions, cell division, synthesis of cell walls, and provides direct or indirect repair of plants damaged due to biotic or abiotic stresses [Mclaughlin and Wimmer 1999). Hong-Bo et al. [2008] reported that, under drought stress conditions, calcium operates different signaling mechanisms, has a complex structure and interacts with the entire signal transmission network in the plant. Accordingly, calcium is an important element that increases the resistance toward stress conditions [Nayyar and Kaushal 2002].

Mg is an important element for the synthesis of vitamin D active form and muscle growth [Elinge et al. 2012] and it is found in considerable amounts in pumpkin [Kreft et al. 2002]. Our results are in agreement with previous studies and show that drought reduced Mg content in seed.

Zn is an important element in human nutrition and found in several foods such as pumpkin. It ensures proper functioning of the sensory organs and facilitates DNA and RNA synthesis for cell production [Elinge et al. 2012]. The Zn contents obtained in this study are similar to those reported earlier [Kreft et al. 2002, Seymen et al. 2016, Erdinç et al. 2018]. A considerable increase was observed in the Zn content in stress conditions. Zn and Ca are important elements that play a role in protecting the plant in stress conditions [Rezaei and Abbasi 2014]. Ahmad et al. [2018] reported that Ca and Zn assist in the protection of stress conditions and reinforce the enzyme activities in plants. Zn application at appropriate doses reduces the effect of drought stress and accelerates nutrients uptake [Jeshni et al. 2017]. Moreover, Zn applications have the ability to regulate multiple antioxidant defense systems at the transcriptional level against drought stress [Ma et al. 2017].

Mn helps in oxygen transport, which is essential for all neural functions and its deficiency causes delayed growth and skeletal disorders [Elinge et al. 2012]. Our results concord well with those reported by Seymen et al. [2016] and Erdinç et al. [2018].

CONCLUSIONS

Drought is one of the abiotic stress factors. It adversely affects plant growth and reduces yield at a high level. Concomitant with the effect of global warming, the arid and semi-arid agricultural lands are continuously expanding. Agricultural production is necessarily shifting toward alternative crops that require low water consumption due to the increasing requirement of water resources in agriculture. In this context, pumpkin is a good alternative crop and has a great importance in terms of breeding and developing new drought-tolerant varieties. In the present study, the performance of 48 pumpkin genotypes (44 pure lines and 4 commercial varieties) was investigated in irrigated and drought conditions.

The G9, G28, G30, and G31 lines gave higher yields under irrigated plots, whereas G9, G34, and G36 had higher yields in drought plots. The pumpkin lines showed an average of 35.13% oil content in the irrigated plots whereas it was 33.39% in the drought plots, thus the drought reduced the oil content. Nutrient analysis of the seeds revealed that pumpkin lines are rich in P, K, Ca, Mg and Zn. The genotype G9, which showed a high yield in both conditions, had about 25% more calcium in drought plots. However, G31, which showed the highest yield in the irrigated plots, contained 71% more Zn and G30 genotype showed 22% more Zn in arid conditions. In arid conditions, Ca and Zn appeared to be important nutrient elements. It is noteworthy that the G9 genotype produced the highest yield in both cases and it could be recommendable as a parental line for future breeding efforts to generate new drought-tolerant hybrid varieties.

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