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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Irrigation effect on some quality characteristics of popcorn (*Zea mays everta* Sturt.)

Cin mısırının (*Zea mays everta* Sturt.) bazı kalite özelliklerine sulamanın etkisi

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Ö Z E T / A B S T R A C T

Aims: This study was conducted under Hatay, Turkey ecological conditions in the second crop season and aimed to determine the effect of irrigation numbers and amounts on some quality characteristics of popcorn (*Zea mays everta* Sturt.)

Methods and Results: Antcin 98 popcorn cultivar was cultivated in Hatay Mustafa Kemal University Research Area in the second crop season of 2015 under five irrigation managements as follows: (I1) 12 times (1757 mm), (I2) 8 times (1449 mm), (I3) 6 times (1148 mm), (I4) 5 times (989 mm) and (I5) 4 times (800 mm). After harvest, quality analysis were carried out with 4 repetitions for each irrigation treatment and kernel size, crude protein, crude oil and crude ash ratios were determined. It's revealed that all the parameters investigated significantly affected by irrigation managements. According to the results; the lowest grain size (89.00 grains 10 g^{-1}) and the highest crude protein ratio (10.59%) were obtained from the I5 treatment, while the highest crude ash (2.04%) and crude oil (5.74%) ratios were obtained from the I4 treatment. It was determined that as the number of irrigation decreased, the crude protein ratio increased, the crude ash and crude oil ratios increased to a certain level and then decreased. With the correlation analysis performed, significant and positive relationships were determined between kernel size and crude protein (r = 0.686) and between crude oil and crude ash (r = 0.852).

Conclusions: The results showed that excessive irrigations cannot increase kernel size, which directly affects the popping volume, which is one of the most important quality criteria of popcorn, However, the nutritional values can be changed by applying different irrigation managements. It can be concluded that under similar growing and climatic conditions, popcorn can be produced with 5 irrigations and a total of 989 mm of irrigation water.

Significance and Impact of the Study: The study revealed the effects of different irrigation numbers and amounts on some quality characteristics of popcorn grown under second crop season conditions.

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INTRODUCTION

Maize is the world's most important grain product after wheat and rice. In addition to irrigated areas, it can be grown in regions with sufficient rainfall. Botanically known as *Zea mays* L. and belongs to the Poaceae family (Imran et al., 2015). Maize is a C4 plant that uses solar energy and water efficiently and produces high grain yield and high dry matter from a unit area. Due to the widespread use and evaluation areas, it has a wide cultivation area all over the world (Akçalı and Şahin, 2016). Corn variation is defined as dent, flint, flour, sweet, pop and pod corn, according to its kernel type. These divisions are based on the quality, quantity and pattern of endosperm composition in the kernel (Brown and Darah, 1985).

Popcorn (*Zea mays everta* Sturt.) is a snack food which is consumed widely all over the world. Its kernel contains almost entirely hard starch. Besides that, there is a very hard pericarp and outer layer on the endosperm. In this way, the popping of kernel are provided by sufficient internal pressure and temperature. It is separated from other corn varieties by these characteristics (Karababa, 2006) and it can be easily distinguished by plant and seed characteristics among other maize varieties (Zulkadir and İdikut, 2021). Popcorn is a nutritionally preferred food due to the vitamins and minerals it contains. One-fourth of the corn produced in the world is used in human nutrition and rest of them are used as animal feed. In developing countries, 46% of the corn production is used for animal nutrition, 54% for human nutrition and as an industrial raw material.

In 2020, corn cultivation was carried out on an area of 202 million hectares and it became the plant with the highest production amount in the world with more than 1.1 billion tons of production (FAOSTAT, 2022). Maize production and yield in Turkey increased 183% and 126% respectively, in last two decades with the development of the irrigation systems, the widespread use of hybrid seeds and improvement of the agricultural techniques. Besides, during this years maize production area increased 25% from 552k ha to 690k ha, and Turkey produced 6.5 m tonnes maize with 941 kg da^{-1} yield average (Akçalı and Gözübenli, 2020; FAOSTAT, 2022). In Turkey, popcorn cultivation is carried out on an area of approximately 8-10 thousand hectares. Although popcorn was grown intensively in the Aegean and Mediterranean regions in the previous years, it has been determined that almost half of the production is carried out in Kahramanmaraş, then in Adana, Mersin, Aydın, Denizli, Kayseri, Konya, Karaman and Kırşehir provinces (Öztürk et al., 2019).

Cereal grains consist mainly of carbohydrates, which are in the form of starch, with a significant amount of protein, some lipids, vitamins and minerals. Genetic and environmental factors significantly affect these components' amounts and quality (Ülger, 1998; Öztürk et al., 2020; Öktem, 2021). Park et al. (2000) reported that kernel physical characteristics, like kernel size, showed some statistical relationship with chemical composition of the six popcorn hybrids used in the study. Tekkanat and Soylu (2005) conducted a field experiment with 12 popcorn varieties and reported that selection of cultivar affected significantly crude protein content, and its varied between 9.42-11.34%. Paraginski et al. (2016) reported that crude protein, oil and ash contents were affected significantly from kernel colour, size and shape. Studies showed that popcorn grains contains 8.1-13.4% crude protein, 3.8-5.5% crude fat, 61.0-72.0% starch and 0.88-2.00 % ash (Park et al., 2000; Tekkanat and Soylu, 2005; Paraginski et al., 2016).Because popcorn is not producing in large areas like other varieties of corn, researches and studies on popcorn have remained in limited numbers.

This study aims to reveal the effects of irrigation number and amounts on some quality characteristics of popcorn and the relationships between them.

MATERIALS and METHODS

Materials

Popcorn cultivar Antcin 98 was grown in Hatay Mustafa Kemal University Research Area (36°18'19.9"N 36°13'29.4"E, 84 m) in the second crop season of 2015. The experimental area has a clay loam soil, unsalted (0.04%), alkaline (7.94%), with low organic matter (0.66%) content.

Climatic conditions

During the field experiment, monthly average maximum temperature was 33.9 °C in August and monthly average minimum temperature was 17 °C in October. Average temperatures increased until August and then decreased. There was no significant precipitation during the growing period (Table 1).

Table 1. Monthly average temperature, monthly average minimum temperature, monthly average maximum temperature and total precipitation values during the field experiment

	June	July	August	September	October
Average Temperature (°C)	24.4	27.4	29.2	28.2	24.6
Maximum Temperature (°C)	27.1	28.9	33.9	32.1	31.3
Minimum Temperature (°C)	22.6	25.1	25.2	25.5	17.2
Total Precipitaiton (mm)	2.00	0.90	5.00	0.20	106

Hatay Provincial Directorate of Meteorology

Methods

Sowing was handled with 16.2 cm inter-row and 70 cm intra-row spacing on June 25. Compound fertilizer (15-15-15) was applied as equivelant of 8 kg da^{-1} pure N,P_2O_5,K_2O. In V6-V7 stages, 10 kg da^{-1} N was applied as urea form. For assessing the effects of irrigation on some quality characteristics, the plants were irrigated during the growing period as follows; (I1) 12 times (1757 mm), (I2) 8 times (1449 mm), (I3) 6 times (1148 mm), (I4) 5 times (989 mm) and (I5) 4 times (800 mm). Irrigations started when the available water level in the soil fell to 50%. One day before irrigations, soil samples were taken from the parcels with a soil auger and the amount of water required to reach the field capacity was calculated and the water required to reach the field capacity was given with the help of a meter. Seedling emergence were observed on July 2 and the harvest was made on October 21. After the cobs harvested separately from each parcel, they were stored in a refrigerator at +4 °C till the use for quality analysis. Quality analysis were carried out with 4 repetitions for each irrigation treatment. Kernel size was determined according to Ziegler et al. (1984), which is measured by the number of kernels in 10 grams and defined as large (52-67), medium (68-75) and small (76-105). The nitrogen content was determined with Kjeldahl distillation unit (Behrotest S2, Germany) according to the Kjeldahl method (AOAC, 1990), and 6.25 was used as a conversion factor for maize (Paraginski et al., 2016). Crude oil was determined with automatic soxhlet device (Buchi B-811, Switzerland) using n-Hexane as solvent. Crude ash ratio was determined with automatic muffle furnace (Miprolab, Turkey).

Statistical analysis

The data obtained were analysed according to completely randomized design utilizing R v4 statistics software and grouped by Duncan multiple range test ($p < 0.05$).

RESULTS and DISCUSSION

Variance analysis results were given in Table 2 and it was determined that kernel size, crude protein, crude oil and crude ash ratios are significantly affected ($p < 0.001$) by irrigation number and amounts.

Table 2. ANOVA table for studied parameters

	Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F Value	C.V. (%)
Kernel Size	Irrigation	4	296.30	74.07	60.88 ***	1.35
	Error	15	18.25	1.22		
Crude Protein	Irrigation	4	4.47	1.18	10.65 ***	3.30
	Error	15	1.57	0.10		
Crude Oil	Irrigation	4	8.48	2.12	290.42 ***	1.86
	Error	15	0.11	0.01		
Crude Ash	Irrigation	4	1.76	0.44	63.01 ***	5.68
	Error	15	0.10	0.01		

*C.V.: Coefficient of Variation,*** $p < 0.001$*

Mean values of the studied parameters were presented in Table 3. Kernel size ranged from 79.00±0.41 to 89.00±0.58 number 10^{-1} g. The smallest kernels were obtained from I5 which was in another group. Increasing irrigation did not increase kernel size linearly. However, in I5, which applied about 200 mm less water than the previous irrigation treatment, it was determined that kernel size decreased significantly. Kernel size is an important parameter for popcorn. Previous studies (Pajic and Babic, 1991; Song and Eckhoff, 1994; Singh et al., 1997; Ceylan and Karababa, 2001) shows that kernel size significantly affect flake size, which is an indicator of

popping quality. Jele et al. (2014) reported that there is a negative relationship between flake size and grain size. Because of producing more tender flakes with few hulls when popped, home consumers usually prefer small yellow types of popcorn (Karababa, 2006; Öztürk et al., 2021). The crude protein ratio was found to be significant and ranged between 9.36±0.28%-10.59±0.09%. It was increased as the number and amount of irrigation increased. The highest protein ratio was determined in I5 (10.59±0.09%), where the least irrigation was performed, and the lowest protein ratio was determined in I1 (9.36±0.28%), where the most irrigation was performed. Park et al. (2000) determined that crude protein ranged between 8.1-10.50%. Josipovic et al. (2014) and Leogrande et al. (2016) reported the crude protein was not affected significantly by different irrigation levels. They indicated these average values of 10.05% and 9.0%, respectively.

Table 3. Mean values of the studied parameters

Irrigation Treatments	Kernel Size (number 10 g^{-1})	Crude Protein (%)	Crude Oil (%)	Crude Ash (%)
I1	79.25±0.63 b	9.36±0.28 b	4.18±0.03 d	1.18±0.03 c
I2	79.25±0.63 b	9.52±0.06 b	4.52±0.08 c	1.33±0.02 b
I3	80.25±0.48 b	9.46±0.06 b	4.70±0.04 b	1.41±0.06 b
I4	79.00±0.41 b	10.14±0.19 a	5.74±0.00 a	2.04±0.06 a
I5	89.00±0.58 a	10.59±0.09 a	3.80±0.01 e	1.39±0.01 b
Mean±SEM*	81.35±0.91	9.81±0.13	4.59±0.15	1.47±0.07

** SEM: Standard Error of Mean*

However, Liu et al. (2013) investigated the effects of five irrigation levels (102, 178, 254, 356, 457 mm) on the crude protein of maize and concluded that there were significant ($p < 0.05$) effects on maize crude protein (9.24-11.30%) content. Protein content was reported to be decreased if the amount of water was above or below a certain level (Kresovic et al., 2018). These findings were similar to the present study.

The crude oil ratio was found to be significant and varied between 3.80±0.01%-5.74±0.00%. It increased up to I4 (5.74±0.00%), which is the highest ratio was determined, while it decreased in I5 (3.80±0.01%), which had the lowest amount of oil among applications. Park et al. stated that popcorn hybrids contained approximately 3.8-4.6% crude oil. Contrary to this study, Liu et al. (2013), Josipovic et al. (2014) and *Leogrande* et al. (2016) indicated irrigation levels had no significant effect on crude oil ratio of maize. They reported the average crude oil ratios were 3.36%, 3.77% and 4.59%, respectively. *Kresovic* et al. (2018) indicated that full irrigation increased crude oil content and the lower irrigation levels resulted in a reduction.

As the number and amount of irrigation decreased, the crude ash ratio increased up to I4 (2.04±0.06%) and decreased in I5 (1.39±0.01%), where the least water was applied. Kara et al. (2016) and Kresovic et al. (2018) reported that irrigation has a significant effect on corn mineral composition.

According to the correlation matrix provided in Table 4, the highest significant positive correlation ($r = 0.852$) was observed between crude oil and ash, followed by correlation between crude protein and kernel size ($r = 0.670$). Unlike these results, it was found that crude oil and kernel size had a significant and negative correlation ($r = -0.584$). Saleem et al. (2008) stated that there was a significantly negative correlation between protein and oil ratio ($r = -0.597$). However, protein ratio was significantly positive correlated with ash ($r = 0.240$) ratio. Also, ash ratio and oil ratio were significantly positively correlated. Kahrıman et al. (2017) determined that there was a negative correlation between oil ratio and protein ratio. Sweley et al. (2012) reported that there was a positive correlation between thousand grain weight and oil content ($r = 0.467$). However, protein and thousand grain weight showed a negative correlation ($r = -0.160$). Park et al. (2000) stated that individual kernel volume, showed some statistical relationship with chemical composition of the popcorn hybrids. Kernel size negatively correlated with oil ($r = 0.67$) and protein ($r = 0.49$). There was no correlation between oil and protein ($r = 0.06$).

Table 4. The correlation coefficients for the parameters

	Kernel Size	Crude Protein	Crude Oil	Crude Ash
Kernel Size	1			
Crude Protein	0.670**	1		
Crude Oil	-0.584**	-0.032	1	
Crude Ash	-0.155	0.413	0.852**	1

** $p < 0.05$

In conclusion, considering all the data evaluated, it can be said that kernel size, which affects popping quality of popcorn, cannot be increased by excessive irrigation, but insufficient irrigation can cause significant reduction in kernel size. The nutritional quality properties such as crude protein, crude oil and crude ash ratios are also affected significantly by irrigation. It can be concluded that the nutritional values can be changed by applying different irrigation managements and 5 irrigations (989 mm) can be suggested for popcorn production under similar growing and climatic conditions.

ÖZET

Amaç: Bu araştırma, farklı sulama sayısı ve miktarlarının cin mısırının bazı kalite özelliklerine etkisini belirlemek amacıyla Hatay ekolojik koşullarında ikinci ürün mevsiminde yürütülmüştür.

Yöntem ve Bulgular: Antcin 98 cin mısırı çeşidi Hatay Mustafa Kemal Üniversitesi Araştırma Arazisi'nde 2015 yılı ikinci ürün mevsiminde (I1) 12 kez (1757 mm), (I2) 8 kez (1449 mm), (I3) 6 kez (1148 mm), (I4) 5 kez (989 mm) and (I5) 4 kez (800 mm) sulanarak yetiştirilmiştir. Hasattan sonra kalite analizleri her bir sulama konusu için 4 tekrarlamalı olarak yürütülmüş ve tane iriliği, ham protein, ham yağ ve ham kül oranları belirlenmiştir. İncelenen tüm özelliklerin sulama yönetimlerinden önemli derecede etkilendiği belirlenmiştir. Elde edilen sonuçlara göre; en düşük tane iriliği (89.00 tane 10 g^{-1}) ve en yüksek ham protein oranı (%10.59) I5 konusundan elde edilirken, en yüksek ham kül (%2.04) ve ham yağ (%5.74) oranları I4 konusundan elde edilmiştir. Sulama sayısı azaldıkça ham protein oranının arttığı, ham kül ve ham yağ oranlarının ise belirli bir düzeye kadar artarak sonrasında azaldığı belirlenmiştir. Yapılan korelasyon analizi sonucuna göre ise tane iriliği ile ham protein oranı (r = 0.686) arasında ve ham yağ ile ham kül oranı (r = 0.852) arasında önemli ve pozitif ilişkiler tespit edilmiştir.

Genel Yorum: Sonuçlar, aşırı sulama ile cin mısırının patlamış mısırın en önemli kalite kriterlerinden biri olan ve patlama hacmini doğrudan etkileyen tane iriliği özelliğinin artırılamayacağını göstermiştir. Bunun yanında, tane besin değerleri farklı sulama uygulamaları ile değiştirilebilmektedir. Elde edilen veriler, benzer yetiştirme ve iklim koşullarına sahip bölgelerde patlamış mısırın 5 sulama ve yaklaşık 989 mm sulama suyu ile üretilebileceğini göstermiştir.

Çalışmanın Önemi ve Etkisi: Çalışma, ikinci ürün mevsimi koşullarında farklı sulama sayısı ve miktarları ile yetiştirilen cin mısırının bazı kalite özelliklerinin nasıl etkilendiğini ortaya çıkarmıştır.

Anahtar Kelimeler: Cin mısırı (*Zea mays everta* Sturt.), sulama miktarı, tane iriliği, ham protein oranı, ham yağ oranı, ham kül oranı.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Summary of this study was presented as a poster presentation at 12th Turkey Field Crops Congress.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

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