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Determination of Grain Yield and Some Quality Parameters of Popcorn (*Zea mays* L. *everta*) Genotypes

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Abstract

In this study, it was aimed to determine grain yield and quality parameters of some popcorn genotypes. Study was carried out in Şanlıurfa conditions during the second crop growing season of 2017. The experiment was designed complete randomized blocks design with three replicates. In the research 13 popcorn genotypes were used as a crop material. In the study, ear diameter ranged from 29.99 to 37.62 mm, ear length from 17.68 to 22.95 cm, kernel number of ears from 425.0 to 598.0 number ear^{-1} and kernel weight of ear from 56.2 to 120.9 g. And also, another characteristic such as thousand kernel weight values were between 149.06 and 241.81 g, hectoliter weight between 83.93 and 89.00 kg hL^{-1}. While the lowest grain yield was obtained from 123AYN04 genotype as 342.37 kg da^{-1}, the highest grain yield was obtained from 411KTR05 genotype with 967.91 kg da^{-1}. Popping volume values were between 18.06 and 26.5 cm^3 g^{-1}, unpopped kernel ratio 0.04% and 3.01%, protein content 9.3% and 11.40%. When the grain yield, popping volume, unpopped kernel number and protein content evaluated together it was determined that 411KTR05, 5YTR1305, ELACİN, AYCİN R-997 and KUM1347 popcorn genotypes was found better than others.

Keywords: popcorn, grain yield, popping volume, protein content, hectoliter

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INTRODUCTION

Popcorn (*Zea mays* L. *everta*) is a nutritious product consumed as a snack. Due to it contains the vitamins and minerals, popcorn is a preferred food item in terms of nutrition. It is also a good diet product with its satiety and stomach acid absorption feature.

Consumers want the popcorns they buy to have a high explosion volume, the popped product to be soft, tasty and less crust residue (Babic and Pajic, 1992). The types of popcorn to be grown in a region vary depending on the ecological conditions of the region, the adaptability of the variety and the wishes of the consumers (Hallauer, 1994).

In order to increase the yield and quality obtained in a unit area in popcorn, it is important to use quality seeds as well as to spread hybrid varieties in production. Because it is important that the product is homogeneous in terms of explosion quality in popcorn.

Previous studies on popcorn are summarized below. Dofing et al. (1990) stated that there are significant changes between varieties in terms of popping volume and unexploded grain rate.

It was stated that higher non-popped kernel ratio was observed in coarse grained varieties compared to small grained. It has been determined that the popping volume has a negative relationship with the non-explosive grain rate.

Ertaş et al. (2008) stated the explosion volume was found as 22.92 cm3 g^{-1} in Nermincin, 20.09 cm3 g^{-1} in Koçcin and 19.79 cm3 g^{-1} in Antcin-98. Vural and Dağdelen (2008) stated that the grain yield varied between 108.8 and 641.6 kg da^{-1}. İdikut et al. (2015) stated that grain yield was between 369 and 498 kg da^{-1}. Öz and Kapar (2011) found that the grain yield in popcorn varied between 353.5 and 539.9 kg da^{-1} and the explosion volume was between 38.2 and 46.5 cm^3 g^{-1}.

Jele et al., (2014) reported that the explosion volume was determined between 12.88 and 25.75 cm^3 g^{-1}. It was determined that there is a negative relationship between the popping volume and the grain size, and a positive relationship between the explosion volume and the number of popped kernels. Öztürk et al. (2016) stated that the detonation volumes varied between 8.3-29.3 cm^3 g^{-1} and the non-explosive grain rates varied between 1.8% and 35.4%.

Özsoy (2017) stated that the highest grain yield was obtained in Elacin variety with 447.6 kg per decare, but SH9201-Cin, Baharcin and Ateşcin varieties gave high yield. It was reported that the explosion volume in popcorn varieties varied between 28.23 and 35.75 cm^3 g^{-1}, and the largest explosion volume was obtained from the Ateşcin variety. non-explosive grain rate in the varieties was between 7.38% and 8.68%. Elacin and Ateşcin varieties were found to be prominent in terms of yield and quality characteristics.

Önem (2018) reported that thousand grain weight was between 128.8 and 181.1 g, yield per decare 240.6 and 808.6 kg da^{-1}, non-bursting grain rate 0.018 and 0.075%, explosion volume 15.550 and 21.780 cm^3 g^{-1}, protein content 8.43 and 16.65%.

The aim of this study was to determine grain yield and some quality parameters of popcorn genotypes.

MATERIAL and METHOD

This study was conducted in 2017 second crop conditions, Şanlıurfa, Turkey. The experimental field is located in Harran Plain where the climate varies from arid to semi-arid. Table 1. provides the climatic data obtained from Şanlıurfa City Meteorological Station. As can be seen from Table 1. that the weather is hot and dry in the months of June, July and August where maximum temperatures were all above 40 ^oC while the relative humidity was below 50%.

Table 1. Monthly some climatic data during 2017 popcorn growth period in Şanlıurfa[†].

Climatic parameters	**2017**							
	May	June	July	August	September	October	November	December
Av. Temp. (°C)	23.2	29.8	33.0	33.2	26.4	22.1	12.6	5.4
Max. Temp. (°C)	35.0	42.0	43.0	43.0	39.3	33.9	24.4	13.7
Min. Temp (°C)	10.7	18.9	20.9	21.2	14.7	12.3	3.0	-2.2
Av. Humidity (%)	38.3	28.0	25.4	30.6	32.1	35.9	42.9	70.1
Rainfall (kg m^{-2})	12.3	0.6	0.2	-	-	22.0	23.3	101.1

[†]Data collected from the Şanlıurfa Meteorological Station in 2017.

The research area is in Harran Soil Series which has a widespread area in the region. The soils of this series are alluvial base material, flat and deep profile soils. The soil of the research field was clay, slightly alkaline, high in lime and very low in salt contents. Organic matter was low. The research soil has A, B, C horizons and pH ranges between 7.3 and 7.8.

Organic matter content is low and cation exchange capacity is high. KDK is increasing towards the lower layers depending on the clay content (Dinç et al., 1988). Field capacity of the soil was 33.8% on dry basis, permanent wilting point was 22.6% and bulk density was 1.41 g cm^{-3}. Some physical and chemical properties of research soil were given in Table 2.

Table 2. Some chemical properties of research soil in 2017

Deep (cm)	Organic Matter (%)	Total Salt (%)	pH	Lime (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})	Fe (ppm)	Zn (ppm)
0-20	1.37	0.098	7.5	22.3	2.8	93.4	1.23	0.67

Thirteen popcorn genotypes (*Zea mays* L. *everta*) were used as crop material. Land was ploughed and cultivated then prepared for planting with a single pass of a disk-harrow. The experiment was laid out in a randomize block design with four replications. Each plot area was 14 m^2 (5 m x 2.8 m) and consisted of four rows of 5 m in length. The plants were grown 70 cm apart between the rows with 18 cm spacing in each row. The seeds were sown in second part of June at a 50-60 mm depth. At sowing, 80 kg ha^{-1} of pure N, P and K, as a 15-15-15 composed fertilizer, was applied to each plot; this was followed by 160 kg ha^{-1} of pure N as urea when the plants reached 30-40 cm in height.

After sowing, parcels were irrigated by sprinkler irrigation method and germination of seeds was provided. After the emergence of plants, plots were irrigated equally by the furrow irrigation system. Ear and kernel characteristics were measured on randomly selected 25 plants in the center of each plot. After the nitrogen (N) content of the kernel samples was determined by the Kjeldahl method, the crude protein content was calculated with the formula Nx6.25. All the popcorn plants on the two rows in the middle of each plot were harvested for determination of grain yield. Two rows on the outside of each parcel are left as the edge effect.

An analysis-of-variance (ANOVA) was performed using Jump statistical package program to evaluate statistically differences between results. Means of the data obtained from research were compared using Duncan test at $P \leq 0.05$.

RESULTS and DISCUSSION

Ear Diameter (mm)

The difference between the popcorn genotypes was found to be statistically significant in terms of ear diameter ($P \leq 0.01$) at the variance analyses. As seen from table 3. that ear diameter values were ranged from 29.99 mm (AYCİN R-497) to 37.62 mm (411KTR05). General genotype average of ear diameter was found to be 33.27 mm. According to the results of other studies conducted on popcorn, different ear diameter values have been reported. According to these results, Özkaynak and Samancı (2003) found the diameter of the ear to be between 24.0 and 29.0 mm in lines, 26.0-30.0 mm in hybrids; Tekkanat and Soylu (2005) 33.0-44.0 mm; Özkan (2007) 29.7-33.9 mm; İdikut et al. (2012) 28.3-30.6 mm. Cihangir (2013) reported that it varied between 26.78-30.01 mm. The results obtained are consistent with the findings of other researchers.

Ear length (cm)

In performed variance analyses, differences between popcorn genotypes in term of ear length value was found significant (P≤0.01). Ear length values were varied from 17.68 cm to 22.95 cm (Table 3). The highest ear length value was obtained from AYCİN R-427 genotype whereas the lowest values were seen at ANTCİN-98 genotype. Genotype average was found as 20.72 cm. Similar to our findings, Özsoy (2017) reported the ear length between 17.1 cm and 19.0 cm, and Cihangir (2013) between 15.02 cm and 17.03 cm.

Kernel number of ear (number ear^{-1})

As seen from table 3 that differences between popcorn genotypes for kernel number of ear value was found statistically significant (P≤0.01). Kernel number of ear ranged from 425.0 to 598.0 number ear^{-1} (Table 3). It was seen from Figure 1 that the highest kernel number of ear value was obtained from AYCİN R-997 genotype whereas the lowest values were seen at 235EAD05 genotype. The general genotype average of grain numbers in the ear was found to be 507.68 number ear^{-1}. When we look at the other studies on popcorn, different results are seen. Doğrul (1999) stated that the number of grains in the ear was between 387 and 561 number ear^{-1}, and Cihangir (2013) stated that between 495.27 and 593.55 number ear^{-1}; Özsoy (2017), on the other hand, reported that it ranged between 678.8 and 574.3 number ear^{-1}.

Table 3. Ear diameter, ear length, kernel number of ear, kernel weight of ear and thousand kernel weight values of popcorn genotypes

Genotypes	Ear diameter** (mm)	Ear length** (cm)	Kernel number of ear ** (number ear^{-1})	Kernel weight of ear** (g ear^{-1})	Thousand kernel weight** (g)
123AYN04	30.21 cd	20.46 cd	430.60 d†	56.20 f	149.06 e
413MHT05	31.93 bcd	21.35 abc	486.80 cd	80.73 cd	195.40 bc
237A1K05	31.47 bcd	19.03 de	449.86 d	67.73 e	190.05 cd
4171ED05	33.00 b	20.77 cd	502.20 bcd	71.13 de	164.24 de
KUM1347	36.50 a	22.03 abc	556.33 abc	107.40 b	229.78 a
235EAD05	30.41 cd	18.51 e	425.00 d	65.66 ef	171.29 cde
411KTR05	37.62 a	21.50 abc	570.13 abc	120.93 a	241.81 a
5YTR1305	37.42 a	20.58 cd	580.00 ab	116.60 ab	223.41 ab
AYCİN R-997	32.54 bc	22.85 ab	598.00 a	90.06 c	162.96 de
AYCİN R- 427	29.99 d	22.95 a	480.20 cd	78.60 d	179.68 cd
ANTCİN- 98	33.00 b	17.68 e	503.80 bcd	74.13 de	164.64 de
ELACİN	37.12 a	20.53 cd	570.60 abc	114.60 ab	231.40 a
BAHARCİN	31.40 bcd	21.18 bc	446.33 d	77.73 d	185.12 cd
Average	33.27	20.72	507.68	86.26	176.83
LSD	2.48	1.75	90.84	9.96	28.22

†There is no statistical difference among values annotated with the same letter according to Duncan test at P≤0.05, ** : denotes P≤0.01.

Kernel weight of ear (g ear^{-1})

Differences among tested popcorn genotypes for kernel weight of ear value was significant (P≤0.01). It was seen from Table 3 and figure 2 that kernel weight of ear values ranged between 56.20 g ear^{-1} (123AYN04) and 120.93 g ear^{-1} (411KTR05). Genotype average was found as 86.26 g ear^{-1}. Similar results were obtained by some researchers. Özkan (2007) found that the weight of the grain in the ear was between 76.4 and 85.9 g ear^{-1}, Cihangir (2013) reported that it ranged between 59.45 and 68.83 g ear^{-1}.

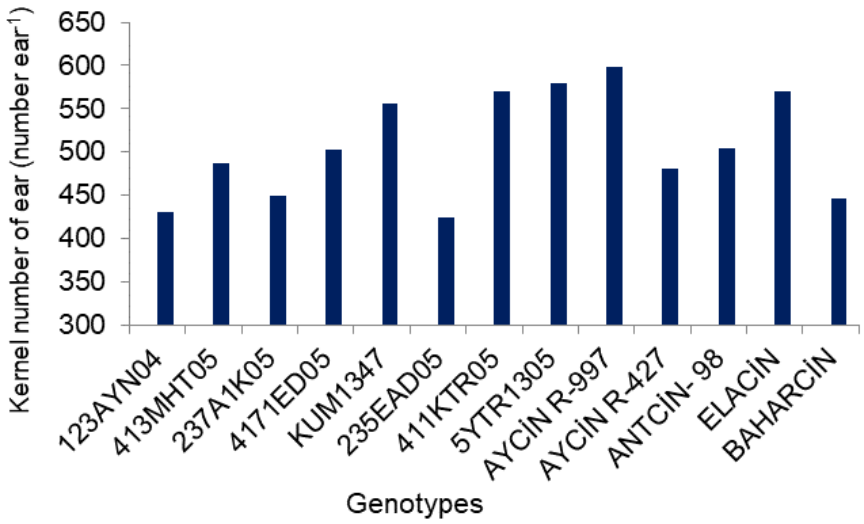

Figure 1. Kernel number of ear values of popcorn genotypes

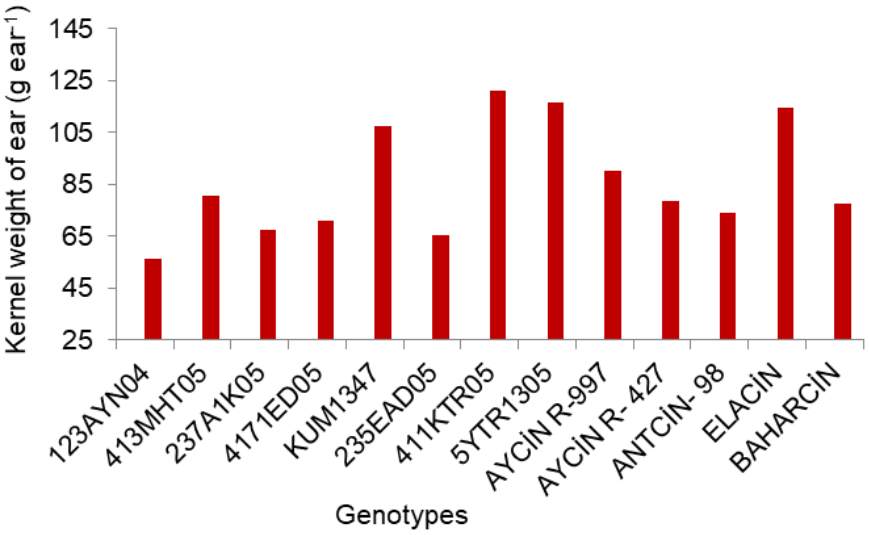

Figure 2. Kernel weight of ear values of popcorn genotypes

Thousand kernel weight (g)

According to variance analyses, differences between popcorn genotypes for thousand kernel weight value was found statistically significant (P≤0.01). Thousand kernel weight was the highest in 411KTR05 genotype as 241.81 g whereas the lowest thousand kernel weight value was seen at 123AYN04 genotype as 149.06 g (Figure 3). The average of genotype was found to be 176.83 g.

Different results have been obtained in other studies. Doğrul (1999) found the weight of thousand grain in popcorn between 104.2 and 208.3 g; Özkan (2007), between 127 g and 135 g; Vural and Dağdelen (2008), between 115.7 g and 130.0 g. Cihangir (2013) stated that thousand kernel weight was between 122.5 g and 138.7 g. Özsoy (2017) emphasized between 106.7 g and 124.5 g thousand kernel weight. Önem (2018) reported that it ranged from 128.8 g to 181.1 g. In addition, some researchers emphasized that environmental conditions and genotypes affect thousand grain weight (Pajic, 1990; Gökmen, 1997; Yılmaz, 1998 and Pajic and Babic, 1991).

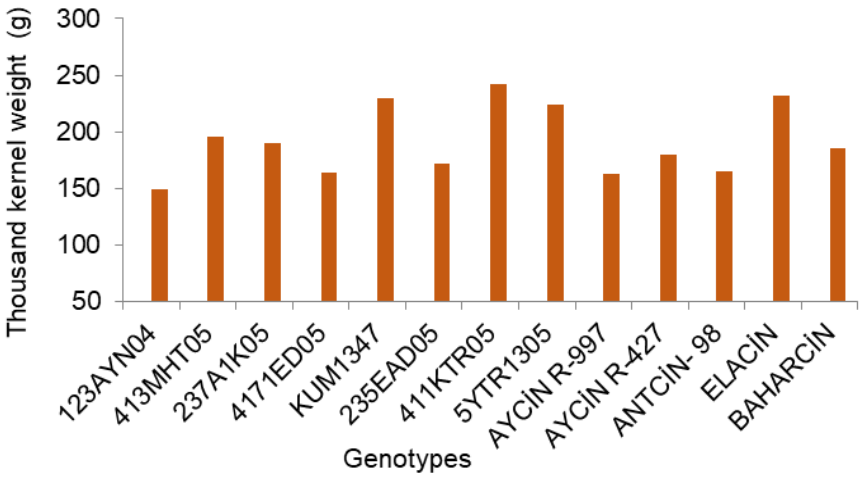

Figure 3. Thousand kernel weight of popcorn genotypes

Table 4. Hectoliter weight, grain yield, popping volume, unpopped kernel ratio and protein content values of popcorn genotypes

Genotypes	Hectoliter weight (kg hL^{-1})	Grain yield** (kg da^{-1})	Popping volume** (cm^3 g^{-1})	Unpopped kernel ratio** (%)	Protein content** (%)
123AYN04	85.80	342.37 h†	26.53 a	1.40 abc	11.20 ab
413MHT05	85.36	562.40 de	21.46 abc	1.74 abc	10.40 abc
237A1K05	86.06	383.99 gh	19.40 bc	1.65 abc	10.60 abc
4171ED05	83.93	493.23 ef	22.33 abc	0.63 bc	10.90 ab
KUM1347	84.76	765.49 c	19.00 bc	0.31 bc	11.40 a
235EAD05	87.53	359.64 gh	23.26 abc	1.98 ab	11.10 ab
411KTR05	86.30	967.91 a	23.93 abc	0.29 bc	9.30 d
5YTR1305	86.33	894.45 ab	21.80 abc	0.42 bc	9.80 cd
AYCİN R-997	89.00	774.46 c	24.86 ab	0.41 bc	10.70 abc
AYCİN R- 427	87.30	602.80 d	24.06 abc	0.54 bc	10.80 abc
ANTCİN- 98	88.43	593.98 de	18.06 c	3.01 a	11.00 ab
ELACİN	87.56	860.77 bc	23.20 abc	0.04 c	10.90 ab
BAHARCİN	86.13	454.78 fg	19.80 bc	0.58 bc	10.30 bcd
Average	86.49	619.71	22.13	1.00	10.64
LSD	5.97	106.21	6.59	1.85	1.06

†There is no statistical difference among values annotated with the same letter according to Duncan test at P≤0.05, ** : denotes P≤0.01.

Hectoliter weight (kg hL^{-1})

According to variance analysis there was no statistically significant difference (P≤0.01) between popcorn genotypes on hectoliter weight (Table 4). The highest hectoliter weight was obtained from AYCİN R-997 genotype (89.0 kg hL^{-1}), while the lowest value was found at 4171ED05 genotype (83.93 kg hL^{-1}). The average hectoliter weight of the cultivars was determined as 86.49 kg hL^{-1}.

When we look at the previous studies on popcorn, it has been reported that the hectoliter weight was between 84.4 and 84.8 kg hL^{-1} (Özkan, 2007), between 75.62 and 81.29 kg hL^{-1} (Cihangir, 2013), between 87.8 and 88.6 kg hL^{-1} (Yerdoğan, 2015), between 76.53 and 80.27 kg hL^{-1} (Özsoy, 2017).

Hectoliter weight in corn is affected by varieties, environmental and growing conditions like plant density, sowing date, fertilizer amount and type, irrigation amount and methods.

Grain yield (kg da^{-1})

Differences among tested popcorn genotypes for grain yield was significant at 0.01 level. Grain yield values and Duncan groups were given Table 4. Grain yield values ranged between 342.37 and 967.91 kg da^{-1} (Table 4). It was seen from Figure 4 that the highest grain yield value was obtained from 411KTR05 whereas the lowest values were seen at 123AYN04 genotype. Mean grain yield value was found as 619.71 kg da^{-1}.

In previous studies conducted with popcorn, Doğrul (1999) stated that grain yield ranged from 386 to 638 kg da^{-1}. Özkan (2007) emphasized that grain yield ranged from 340 to 453 kg da^{-1}, Cihangir (2013) stated that grain yield was between 421.27 and 526.54 kg da^{-1}. It was reported that grain yield was between 244 and 350.4 kg da^{-1} (Özsoy, 2017), 372.1 and 447.6 kg da^{-1} (Yerdoğan, 2015).

Grain yield in corn is affected by varieties, environmental conditions and growing conditions such as plant density, sowing date, fertilizer amount and type, irrigation amount and methods.

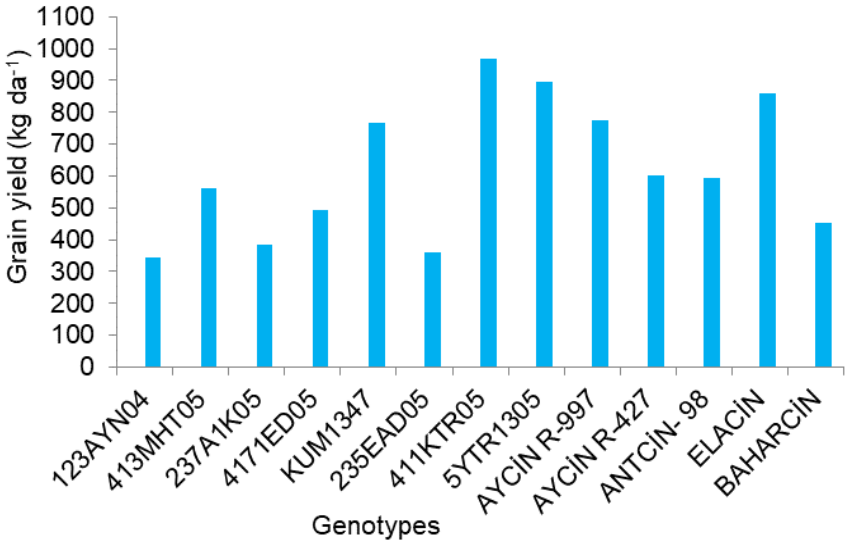

Figure 4. Grain yield values of some popcorn genotypes

Popping volume (cm^3 g^{-1})

According to variance analyses differences among tested popcorn genotypes was significant (P≤0.01) in terms of popping volume. It was seen clearly from Figure 5 that popping volume was the highest in 123AYN04 genotype as 26.53 cm^3 g^{-1} whereas the lowest popping volume value was seen at ANTCİN-98 genotype as 18.06 cm^3 g^{-1}. Average of genotypes was found as 22.13 cm^3 g^{-1}.

Cihangir (2013) emphasized lower popping values than our findings as 17.2 -19.7 cm^3 g^{-1}. Some researchers stated higher popping values than ours as 31.3-35.8 cm^3 g^{-1} (Güven, 2006), 34.6-34.1 cm^3 g^{-1} Yerdoğan (2015) and 32.41 -31.37 cm^3 g^{-1} Özsoy (2017).

Research results was in accord with some previous studies. Similar results were obtained by some researchers. Özkan (2007) stated that popping volume values were between 28.1 cm^3 g^{-1} and 28.7 cm^3 g^{-1}. Önem (2018) found the values of popping volume as 15.6 - 21.8 cm^3 g^{-1}.

Commercially popping volume is very important, because commercial buyers buy popcorn hybrids by weight and sell the popped corn by volume (Oktem and Oktem, 2020). Also, from a commercial stand point, popcorn genotypes with high expansion volumes will produce more popped corn than genotypes with low expansion volumes. The difference arising from the popping volume aspect may be due to the soft/hard starch ratio and distribution in the grain.

Since popcorn is used directly in human nutrition, the grain quality is required. It is especially desired to have a high proportion of popping volume and protein content. Popping volume depends on many factors such as 1000 kernel weight, moisture contents, test weight and genotype. Higher 1000 grain weight increase the popping volume (Oktem and Oktem, 2020). It is seen clearly from table 4 that genotypes have higher thousand weight values give more popping volume values. It is reported that popping volume is positively correlated with the 1000 kernel weight (Hallauer et al., 2010).

However, explosion percentage and burst volume decrease in extremely coarse grains. Dofing et al. (1990) stated that higher non-popped kernel ratio was observed in coarse grained varieties compared to small grained. It has been determined that the popping volume has a negative relationship with the non-explosive grain rate.

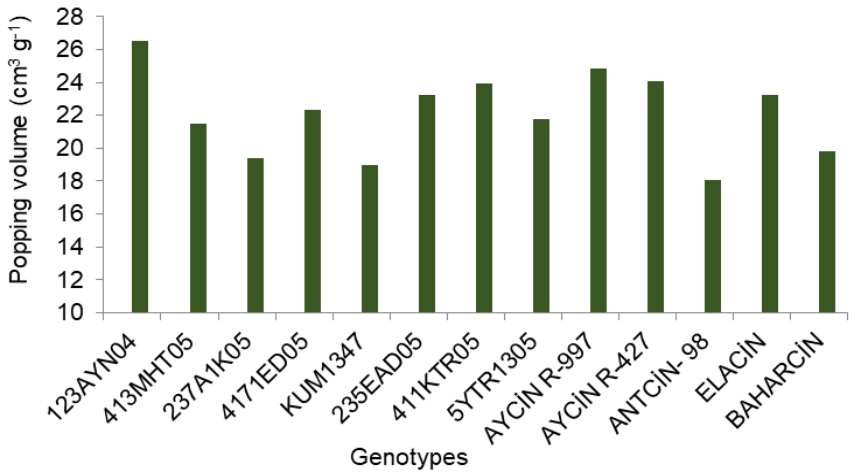

Figure 5. Popping volume values of popcorn genotypes

Jele et al. (2014) reported that there is a negative relationship between the popping volume and the grain size, and a positive relationship between the explosion volume and the number of popped kernels.

Unpopped kernel ratio (%)

According to the results of variance analysis, a statistically significant difference was found among popcorn genotypes in terms of unpopped kernel ratio compared at 1%. Unpopped kernel ratio ranged from % 0.04 to % 3.01.

The highest unpopped kernel ratio was obtained from ANTCİN-98 genotype, while the lowest value was found at ELACİN genotype (Table 4).

When looking at other studies on the ratio of unpopped kernel ratio in popcorn, it is seen that there are different results. Güven (2006) reported higher nonpopped kernel ratios ranging between 13.21% and 19.24%. Özsoy (2017) found that the rate of non-exploding grains varied between 7.38% and 8.68%. Cihangir (2013) stated the unpoped kernel ratio varying between 3.65% and 5.92%.

Our findings are supported by some researchers' findings. Önem (2018) reported that the rate of unpopped kernel ratio ranged from 0.018% to 0.075%, while Özkan (2007) stated that the rate of non-popped grains was between 2.77% and 3.48%. Some researchers stated that the unpopped kernel ratio, which is a parameter that significantly affects the quality of popcorn, differs in varieties (Sakin et al., 2005; Gökmen and Sakin, 2001).

Protein content (%)

A statistically significant difference was found among genotypes in terms of protein content compared to 1% (Table 4). The highest protein content was seen at KUM1347 (11.4%) while the lowest protein content value was obtained from 411KTR05 genotype (9.3%). The average protein content of genotypes was found to be 10.64%. Research results was in accord with Tekkanat and Soylu (2005) that stated protein content of popcorn kernel was between % 9.00 and % 11.34. Özkan (2007) stated the grain protein content between 8.03% and 8.89%, Cihangir (2013) between 12.3% and 16.3%, and Önem (2018) between 8.43% and 16.65%.

The grain protein content, which is one of the important quality parameters, varies according to the variety and environmental conditions. Considering the findings obtained in other studies on popcorn, it is seen that there are different results regarding the grain crude protein content.

CONCLUSION

At the light of research results, when the grain yield, popping volume, unpopped kernel ratio and protein content evaluated together it was determined that 411KTR05, 5YTR1305, ELACİN, AYCİN R-997 and KUM1347 popcorn genotypes was found better than others.

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