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Seed Yield and Characteristics in a Half-Diallel Pumpkin Population

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ABSTRACT

In addition to fresh and roasted pumpkin seeds used in human nutrition, they are used as an additive to bread, salami, sausage, mayonnaise and many food products because of their high protein content. The most common problem encountered in the cultivation of confectionary pumpkin is the lack of varieties with good seed yield and quality in the market. In this study, it was aimed to reveal the promising hybrids with superior characteristics by determining the yield and seed characteristics of the 13 pumpkin inbred lines (*Cucurita pepo*) and 74 hybrid lines which are obtained by crossing between inbred lines and two local varieties (3-Hatun Tirnagi and 4-Cercevelik) as control. As a result of the study, the highest positive correlation was found between seed thickness and 1000 seed weight and between seed length and seed width. The crosses of 31x34, 23x28, 13x23, 38x40, 29x37, 30x31 and 23x29, especially 40x29, in the positive region of both components showed superior performance compared to their parents in all parameters. These hybrids have emerged as promising crosses to develop the F_1 hybrid confectionary pumpkin varieties.

1. Introduction

The Cucurbitaceae family includes important species such as melon, watermelon and pumpkin, which have economic importance in the world. Species included in the family differ greatly in aspects such as plant characteristics, fruit and seed structure. Pumpkin fruits, one of the important species of the family, are used as fresh consumption and making desserts, as well as mature seeds, are used in human nutrition.

A total of 27.6 million tons of squash is produced on an area of approximately 3 million ha in the world. China (8 million tons) takes the first place in this production, while India (5.5 million tons), Ukraine (1.3 million tons) and Russia (1.1 million tons) are important producer countries. Turkey meets 2.23% of world production and in eighth place with a production of about 0.6 million tons (FAO, 2018). In the confectionary pumpkin, Turkey production is 50.265 tons at 706.894 da area. The provinces with the highest production are Kayseri (16 706 tons), Nevşehir (16 673 tons), Aksaray (4 849 tons), Konya (4 468 tons) and Eskişehir (2 598 tons) (TUİK, 2019).

In addition to fresh and roasted pumpkin seeds used in human nutrition, they are used as an additive to bread, salami, sausage, mayonnaise and many food products because of their high protein content (Rangahau, 2002). On the other hand, it has medical uses in terms of human health. Some researchers reported that it improves the immune system (Chew and Park, 2004), reduces the risk of stomach, breast, lung and colon cancer (Stevenson et al., 2007), plays an important role in lowering cholesterol levels and treating advanced prostate utilizing phytosterols (Hong et al. al., 2009). Pumpkin seeds are among the oilseeds with 28-40% protein (Achu et al., 2005) as well as 35-50% oil content (Seymen et al., 2016; Türkmen et al., 2015). Besides, it is rich in minerals such as potassium, phosphorus, calcium, magnesium and iron, which are important in human nutrition (Seymen et al., 2016), and is known as a good source of vitamins A, C and E (Eleiwa et al., 2014).

Production is increasing day by day because confectionary pumpkin farming can be done mechanically in large areas, yielded in less irrigated semi-arid regions, there is no storage problem and it is more profitable than some agricultural products in some regions. However, the most common problem encountered in cultivation is the lack of varieties with good seed yield and quality in the market. The way to produce high-yield and quality seeds is a variety of breeding studies. In the breeding studies, heterosis has been applied to many species and varieties with high commercial value have been developed (Gergerli et al., 2018). Although heterosis occurs in different plant species, it is seen at

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different rates from species to species. In general, heterosis is higher in open-pollinated plants such as squash compared to self-pollinated plants. Many methods are used to determine heterosis. One of these methods is principal component analysis (PCA) and thus superior hybrids can be revealed (Chahal and Gosal, 2002).

In this context, it is aimed to determine the yield and seed characteristics of 13 confectionary pumpkin inbred lines selfed at S7 stage, 74 hybrid lines obtained by half-dial hybridization between these inbred lines and 2 local varieties (3-Hatun Tirnagi and 4-Cercevelik) and put forward the promising candidates with superior features

2. Materials and Methods

The study was conducted at the research area of Selcuk University, Faculty of Agriculture for two years. 13 ibred lines (6, 9, 13, 17, 23, 29, 30, 31, 34, 37, 38, 40 and 41) which are collected from different parts of Turkey, selfed and their purities are determined by the molecular test used as plant material.

In the first year, the seeds were planted at 1x0.5 m distances on 13 May 2019. Sixty plants were cultivated from each inbred line for crossing and selfing without repetition. In the flowering time, crosses were made according to the half-diallel hybrid program, as well as selfing was realized in inbred lines to the production of the seeds of the parents. As a result of the cross-breeding, 74 confectionary pumpkin hybrid candidates were obtained. During the experimental year, cultural practices such as fertilization, irrigation, and disease and pest management were made regularly and timely. The fruits obtained by selfing and crossing were harvested on September 16, 2019, and seeds were extracted individually and dried.

In the second year, with 74 hybrids, 13 parent lines, 2 local cultivars (3-Hatun Tirnagi and 4-Cercevelik) with the highest cultivation in the market and have different seed characteristics were used as plant material. On May 15, 2020, seed sowing was made with a total of 15 plants from each genotype at a distance of 1x0.5 m without repeating. Cultural processes were carried out regularly in plants until harvest. The seeds of the fruits harvested on September 14, 2020, were extracted individually and dried.

After the seeds dried, the parcel yields were determined and the seed yield was expressed as g / plant according to the number of plants in each plot. The total number of fruits in the parcel was divided by the number of plants in the parcel and the number of fruits per plant was determined. 100 seeds from each plot were counted and weighed on precision scales and the weight of 100 seeds was calculated as g. The length, width and thickness of 10 seeds from each parcel were measured with a digital calliper and the average was taken and the seed length, width and thickness were determined.

PCA analysis was carried out to evaluate the seed yield and quality measurements taken from the parents and crosses of confectionary pumpkins and reveal the superiority of the hybrid lines. As a result of the multiple comparison test performed with the JMP 14 statistics program, the Loading plot and Score plot graphs were drawn and the parent and hybrid lines were interpreted.

3. Results and Discussion

The average seed yield was 73.43 g/plant. Among the hybrids, 40x29 (167.0 g), 9x41 (160.05 g) and 31x34 (149.2 g) gave the highest seed yield (Table 1). Turkmen et al. (2016) reported that the average seed yield of 81 different genotypes in confectionary pumpkins was 114 g / plant and the highest yield was 226 g / plant. In another study conducted in Turkey, seed yield ranged from 98 to 107 kg (Ünlükara and Bakır, 2018). Our results are following previous reports and the yields of hybrid lines were found to be above the country average. When the number of fruits per plant was examined, an average of 1.12 fruits was obtained. The number of fruits in confectionary pumpkin is directly correlated with the yield and generally, 1 fruit is obtained per plant. 9x41 hybrids had the highest number of fruits per plant with 2.5, 6x29 and 40x29 hybrids with 2 fruits (Table 1). Turgut (2015) found an average of 1.96, Seymen et al. (2012) and Yegül (2007) reported 1.2 and 1.45 fruit per plant, respectively. The high number of fruits obtained from hybrids has made significant contributions to the yield.

An average of 1000 seeds weight was 226.58 g. The highest 1000 seed weights were obtained from 31x41 (378 g), 34x41 (368 g) and 40x30 (360 g) hybrids (Table 1). 1000 seed weights were reported 134 g (Warid et al., 1993), 203 g (Joshi et al., 1993) and 178 g (Türkmen et al., 2014). The high 1000 seed weights in our study are thought to be due to heterosis effect and well designed a fertilizing program. The average seed length was measured as 20.25 mm, and the highest seed lengths were obtained from 37x38 (23.68 mm) and 31x37 (23.56 mm) hybrids. The average seed width was 10.84 mm and the highest values were obtained from 13x41 (13.61 mm), 40x23 (13.48 mm), 17x38 (13.36 mm) and 38x40 (13.00 mm) hybrids (Table 1). The average seed thickness was 2.94 mm and the highest value was obtained as 4.13 mm from inbred line 29. In different studies, it has been reported that the seed lengths are 20.05 mm (Türkmen et al., 2016) and 16.91 mm (Joshi et al., 1993). Seed widths were reported to vary between 8.78-10.73 mm (Ermiş, 2010). Seed thickness varied between 3.20-4.32 mm (Paris and Nerson, 2003). Our results following the previous reports, and the seed size changes according to the seed structure in confectionary pumpkin seeds and seed shape directly affects the ease of cracking.

Table 1
Seed yield and characteristics of inbred and crosses pumpkins

Inbred line/Crosses	SY	NF	TSW	SL	SW	ST
3	63.13	1.25	198	21.35	8.33	3.23
4	74.52	1.00	204	20.34	9.87	3.01
6	49.65	1.00	196	20.37	9.56	2.76
9	55.48	1.50	202	18.64	8.92	3.02
13	54.43	1.00	162	18.56	9.77	2.79
17	61.87	1.00	288	20.19	11.63	3.11
23	79.50	1.00	210	20.11	10.34	3.11
29	85.97	1.67	198	16.77	8.99	4.13
30	44.30	1.00	212	21.23	11.09	2.33
31	42.83	1.00	246	22.71	11.66	3.17
34	11.80	1.00	64	18.75	9.84	1.95
37	58.95	1.00	240	21.26	10.66	3.66
38	28.33	1.00	170	19.91	10.69	2.67
40	27.80	1.00	218	19.69	10.68	3.03
41	51.05	1.00	220	18.83	11.32	2.97
6x13	44.70	1.00	156	18.50	9.25	2.45
6x17	74.70	1.33	238	20.62	10.01	2.40
6x23	80.60	1.00	282	22.05	11.08	3.39
6x29	109.9	2.00	190	17.62	9.63	2.40
6x34	54.23	1.00	162	19.38	10.08	2.36
6x37	69.07	1.00	224	18.67	10.57	2.59
6x41	46.10	1.00	208	19.57	10.41	2.55
9x13	88.07	1.33	198	18.55	10.35	3.17
9x17	75.45	1.00	218	19.32	10.79	3.10
9x23	46.17	1.00	158	18.43	9.07	3.36
9x29	88.70	1.33	234	19.18	10.22	2.84
9x30	94.80	1.00	282	18.37	10.32	3.62
9x31	106.00	1.00	260	21.86	10.88	3.37
9x34	55.93	1.00	186	20.61	10.67	3.53
9x41	160.05	2.50	236	18.85	9.71	2.87
13x17	97.05	1.00	286	20.35	10.87	3.34
13x23	125.97	1.33	238	20.97	10.95	3.15
13x29	84.17	1.00	240	22.26	12.39	3.18
13x30	93.00	1.00	220	19.75	10.27	3.08
13x34	118.30	1.00	284	19.53	10.75	2.59
13x38	71.77	1.33	242	20.94	11.49	2.66
13x41	79.73	1.00	220	22.07	13.61	3.12
17x23	45.60	1.00	156	18.98	10.68	2.24
17x29	80.80	1.00	196	18.09	10.26	2.97
17x30	37.75	1.00	204	18.94	11.25	3.29
17x34	38.35	1.00	126	17.88	9.40	2.24
17x38	104.45	1.00	316	23.49	13.36	3.33
17x40	98.25	1.00	278	21.26	11.13	3.25
17x41	37.15	1.00	166	17.59	9.76	2.55
23x29	105.30	1.50	206	21.43	12.11	2.83
23x30	76.03	1.00	268	21.65	11.36	3.01
23x31	70.10	1.00	202	22.61	10.23	2.97
23x34	41.25	1.00	186	20.16	9.95	2.57
23x38	135.10	1.50	254	20.41	11.31	2.84
23x41	61.25	1.00	210	19.59	10.57	2.84
29x30	43.95	1.00	168	17.88	10.76	2.81
29x34	28.55	1.00	120	17.19	9.45	2.48

Table 1
Seed yield and characteristics of inbred and crosses pumpkins

29x37	108.20	1.33	280	21.79	12.37	3.36
29x38	101.10	1.00	324	21.55	12.28	3.38
29x41	58.35	1.00	174	18.62	10.19	2.42
30x6	32.20	1.00	212	20.86	11.66	2.82
30x31	94.90	1.50	220	20.33	11.61	2.91
30x34	44.65	1.00	204	20.58	11.43	2.62
30x37	46.45	1.00	182	19.85	10.45	3.12
30x41	51.60	1.00	208	19.55	10.46	3.18
31x6	68.25	1.00	230	20.37	11.08	2.66
31x13	75.97	1.00	188	19.74	9.71	2.74
31x29	61.17	1.00	188	18.93	10.07	2.92
31x34	149.20	1.50	214	20.58	10.17	3.08
31x37	102.95	1.00	308	23.56	11.24	3.15
31x38	59.50	1.00	226	21.93	12.49	2.94
31x40	66.60	1.50	184	19.83	9.59	2.82
31x41	57.50	1.00	378	18.88	12.55	3.34
34x37	36.80	1.00	192	20.63	11.18	2.81
34x38	25.85	1.00	134	20.15	11.81	2.31
34x40	25.25	1.00	146	18.96	10.03	2.21
34x41	128.40	1.00	368	23.28	13.15	3.32
37x9	85.65	1.00	252	20.37	10.46	2.94
37x13	88.55	1.00	240	15.62	11.12	2.69
37x17	43.40	1.00	174	18.60	9.26	2.86
37x23	77.20	1.00	340	23.44	11.35	3.47
37x38	86.67	1.00	342	23.68	11.88	3.54
37x40	104.50	1.00	306	22.05	11.31	3.32
38x6	108.25	1.00	310	22.05	11.39	2.92
38x9	66.97	1.00	228	22.32	11.65	2.50
38x40	115.63	1.67	256	23.45	13.00	2.46
38x41	50.80	1.00	182	19.52	10.57	2.29
40x6	85.35	1.00	308	21.52	10.78	3.33
40x9	90.53	1.67	188	19.07	10.36	2.58
40x13	56.40	1.00	276	21.28	11.69	2.99
40x23	46.80	1.00	266	22.08	13.48	3.73
40x29	167.00	2.00	220	19.22	11.17	3.15
40x30	97.80	1.00	360	23.23	12.17	3.70
40x41	110.80	1.00	312	21.56	11.54	2.93
Mean	73.43	1.12	226.58	20.25	10.84	2.94

Seed yield-g/plant (SY); Number of fruit-number/plant (NF); 1000 seed weight-g (TSW); Seed length-mm (SL); Seed width-mm (SW); Seed thickness-mm (ST).

PCA was made with yield and seed properties obtained from different inbred lines and hybrids (Table 2). As a result of the PCA. the study was explained in two components. and it had a rate of 72.82%. It has been reported that PCA analyzes were used in different studies and the study was strongly explained by PCA (Kamrani et al., 2018; Mozafari et a, 2019; Seymen et al., 2019; Yavuz et al., 2020; Seymen, 2021). As a result of PCA, the first component (PC1) explained 47.41% of the study, and the SY, TSW, SL, SW and ST were the most positively explained parameters. The second component (PC2) explained 25.41% of the study, and the SY and NF parameters were strong and positive parameters.

Using PC1 and PC2 components, a loading plot chart was created to examine the correlative relationship between seed yield and characteristics (Figure 1). It has been reported that there is a positive relationship if the angle between the vectors in the figure is $<90^o$, there is a negative relation if the angle is$> 90^o$, and if the angle between the vectors is 90^o, there is no significant relationship (Yan and Kang, 2003; Yavuz et al., 2020). When the figure is examined, the highest positive relationship was seen between ST and TSW and SL and SW. Likewise, a score plot graph was created using PC1 and PC2 components to evaluate the seed yield and characteristics of confectionary pumpkin inbred lines and hybrids (Figure 2). In the figure, 34x41, 40x30, 17x38 and 37x38 hybrids located in the positive direction of PC1 have emerged as the best hybrids in terms of the parameters explained in PC1. The 40x29 and 6x29 hybrids were the best hybrids in

terms of the parameters described in PC2 and located in the positive region of PC2. The hybrids 40x29, 31x34, 23x28, 13x23, 38x40, 29x37, 30x31 and 23x29, which are prominent in terms of seed yield and characteristics in the positive region of both components, performed better results than their parents.

Table 2
PCA results regarding of seed yield and characteristics of inbred and crosses pumpkins

Items	PC1	PC2
Eigenvalue	2.84	1.52
Percentage of variance	47.41	25.41
Cumulative variance	47.41	72.82
Eigenvectors		
SY	0.37000	0.56330
NF	0.01542	0.75056
TSW	0.54147	-0.02025
SL	0.46443	-0.23490
SW	0.44385	-0.25087
ST	0.39619	0.02882

Principle component (PC); Seed yield (SY); Number of fruit (NF); 1000 seed weight (TSW); Seed length (SL); Seed width (SW); Seed thickness (ST).

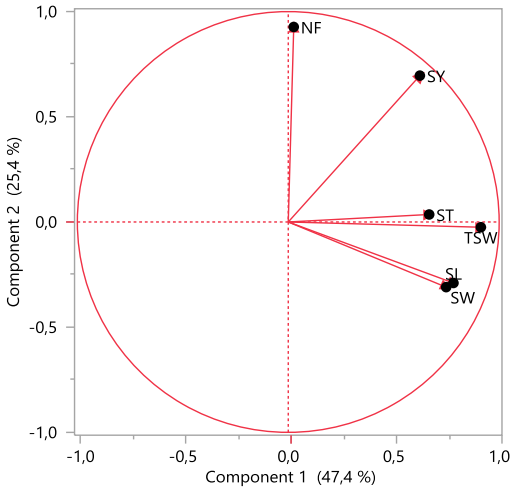

Figure 1
Loading plot based on PC 1 and 2 obtained from PCA using seed yield and characteristics of inbred and crosses pumpkins.

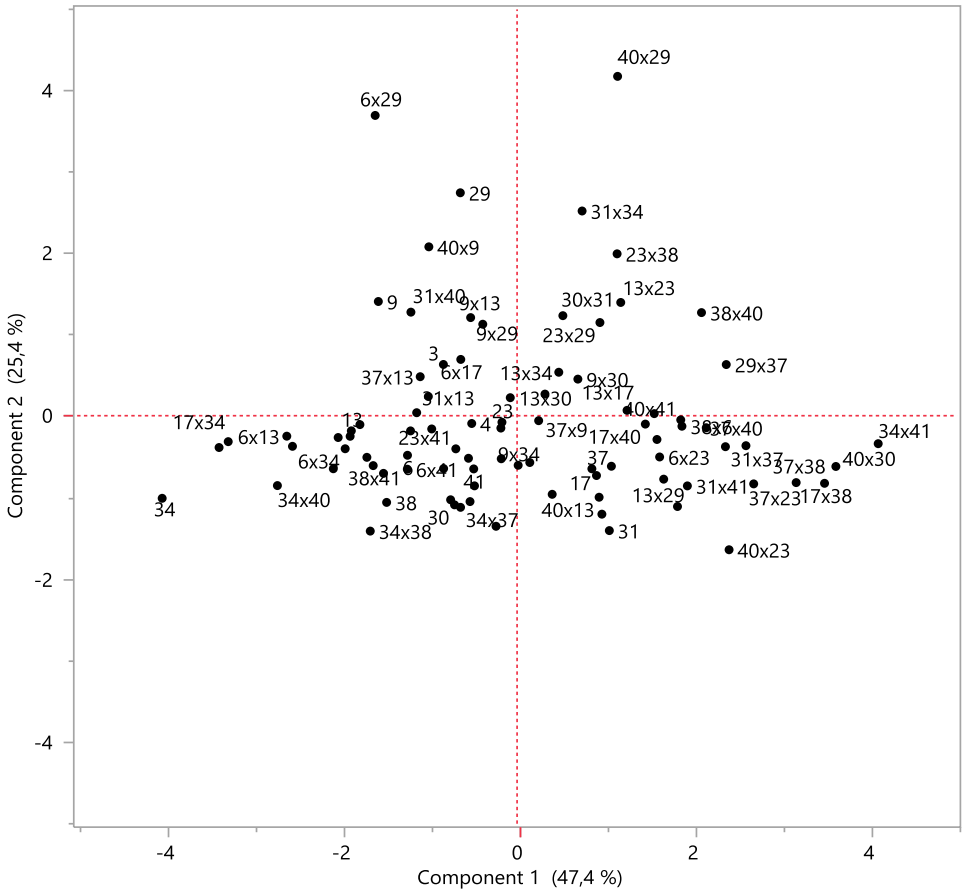

Figure 2
Score plot based on components 1 and 2 obtained from PCA using seed yield and characteristics of inbred and crosses pumpkins.

4. Conclusion

In the study conducted to determine the hybrids that show heterosis effects in terms of seed yield and properties in confectionary pumpkins. it has been revealed that some hybrids show superior traits than rootstocks. As a result of the PCA, all parameters are explained in the study described in two components. The highest positive correlation between the parameters was found between seed thickness (ST) and 1000 seed weight (TSW) and between seed length (SL) and width (SW). The crosses of 31x34, 23x28, 13x23, 38x40, 29x37, 30x31 and 23x29, especially 40x29, in the positive region of both components showed superior performance compared to their parents in all parameters. These hybrids have emerged as promising to develop the F_1 hybrid confectionary pumpkin variety. Determining the performance of these hybrids in larger trial fields by reproducing will give clearer results and give more clear information in the development of F_1 varieties.

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