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Seed Characteristics, Oil Content and *Gossypol gland* of Different Cotton (*Gossypium spp.*) Genotypes

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Abstract The experiment was conducted to determine the seed characteristics (100-seed weight, seed yield, seed coat ratio, seed coat thickness, seed chalaza end diameter), seed oil content and number of gossypol gland of two-hundred different cotton (Gossypium spp.) genotypes in Kahramanmaras (Turkey) conditions using a randomized complete block design with three replications in 2018. At the end of the study, it was determined that there were statistically significant differences among the cotton genotypes for all investigated characteristics. The results showed that 100-seed weight, seed yield, seed coat ratio, seed coat thickness, seed chalaza end diameter, seed oil content and number of seed gossypol gland for cotton genotypes ranged between 7.23 – 15.43 g, 95.60 – 489.62 kg da^{-1}, 15.53 – 38.27%, 0.41 – 1.00 mm, 2.12 – 5.28 mm, 13.16 – 38.46% and 7.46 – 80.16 no. $seed^{-1}$, respectively. As a result of the study, Shazbaz for seed yield, TAMB147-21 for oil ratio and Giza 75 for number of gossypol gland had the highest value.

Keywords Cotton, seed weight, seed coat, seed yield, oil content and gossypol.

Introduction

Cotton is an important product for the textile, food and feed industry. It is the raw material of the textile and cellulose industry with fiber, the vegetable oil industry with seed oil, and the feed industry with seed pulp. Cotton constitutes approximately 90% of the fiber crops cultivation area in the world. In Turkey, total cotton acreage of 359 thousand hectare resulted in production of 1.77 million tons of seed cotton [1]. Seed cotton harvested from the field contains fiber and seeds and it is ginned and separated into fiber and seed [2]. Seed cotton consists of an average 35-40% fiber and 60-65% seeds. The seed consists of 60% kernel, 28% seed coat, 9% linter and 3% foreign materials. Today, all products released after the ginning process were evaluated. Cotton seeds contain about 19-28% oil [3]. Saxena et al. [4] emphasized that cotton seeds contain considerable oil and protein. Ahmad et al. [5], Adelola and Ndudi [6], Kouser et al. [7], Bellaloui et al. [8] reported respectable diversity of fat and protein substances in cotton. The toxic substance called "gossypol" found in cotton seeds limits the use of cotton cake as feed [4]. In the cotton plant, the number of glands containing gossypol depends on the species, cultivars, environmental conditions and plant organs. Lusas and Lividin [9] stated that gossypol content in commercial upland cottons was changed between 0.6% and 2.0%. Percy et al. [10] emphasized that gossypol content was changed between 0.81% and 1.04% (8.1 – 10.4 g kg^{-1}) in cultivar of *Gossypium barbadense* L., and also between 0.64% and 1.09% (6.4 – 10.9 g kg^{-1}) in *Gossypium hirsutum* L. cotton cultivars. In recent years, glandless cotton varieties have been developed in breeding studies and they do not have gossypol producing glands. Since the by-products produced from these varieties do not contain toxic pigments, they are much more suitable for nutrition [11].

In this study, 100 seed weight, seed yield, seed coat ratio, seed coat thickness, seed chalaza end diameter, seed oil content and number of seed gossypol gland properties were investigated in 200 different cotton genotypes in Kahramanmaras (Turkey) conditions.

Materials and Methods

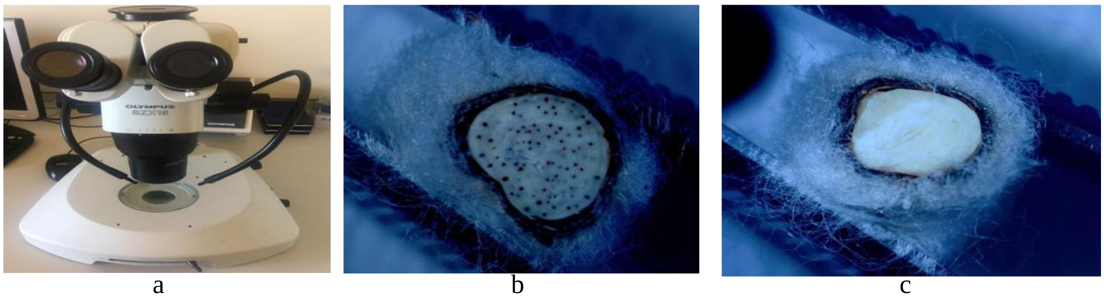
Two hundred different cotton (*Gossypium spp*.) genotypes (Table 1) were grown during the 2018 growing season in Kahramanmaras, which is located in the Eastern Mediterranean region of Turkey (between 37º 36' north parallel and 46º 56' east meridians). The soils of the experimental area are alluvial soils carried by rivers and they are deposited horizontally in different layers and first class agricultural land. The pH of soils is 7.53, slightly alkaline, lime content is high (20.24%) and organic matter content (2.65%) is low [12]. Kahramanmaras province has typical Mediterranean climatic conditions with hot and dry summers and mild, rainy winters. In 2018, Average air temperature during the growing season changed from 14.20°C (April) to 29.50°C (August). The temperature at the experimental field during the growing season was convenient for cotton farming, while the temperatures of July and August were higher than the other months. There was considerable versatility in amount and distribution of precipitation from month to month. The rainfall was highest in October (115.00 mm), and there was an extended dry and hot period during July and September [13]. The experimental design was a randomized complete block with three replications. Cultivars, consisting of one rows 5.0 m long with 0.70 m spacing between rows, were planted on 11 May 2018. Cotton cultivars were sown by hands, and after emergence, plants hand-thinned to the desired intra-row spacing of 0.20 m. Recommended insect and weed control methods were employed during the growing season as needed. The experimental area received 60 kg N and 60 kg P_2O_5 ha^{-1} as a seedbed application. Additional band-dressing of 90 kg N ha^{-1} was applied at the square stage. Overall 7 irrigations were applied and weeds were controlled by hoeing.

Table 1: Cotton genotypes used in the study

Genotypes									
No	**Name**	**No**	**Name**	**No**	**Name**	**No**	**Name**	**No**	**Name**
1	MNH-786	41	Carolina Queen	81	Viky (ES-20021)	121	Acala 1064	161	Mex 68
2	BH-118	42	AfricaES(20025)	82	Sorbon	122	Acala Cluster	162	Europa
3	Ziroatkar-68	43	AcalaTex	83	AĞDAŞ 3	123	Auborn 56	163	TX No: 1389
4	Sindh-1	44	Tx No: 1412	84	Sugdiyon-2	124	TAM 94 L 25 P1	164	Ionia
5	AGC 85	45	Karnak 55	85	CIM-240	125	Aden	165	Helius
6	CIM 401	46	Mex 106	86	Sure Grow 125	126	Acala Okra VA2-4	166	NIAB 874
7	Frego Cluster	47	Dpl 5540-85-subokra	87	AzGR-3775	127	Deltapine 905	167	Ligur
8	AzGR-11468	48	Deltapine 120	88	Ujchi 2 Uzbek	128	Acala 29	168	NIAB 777
9	CIM-506	49	Acala 1517-70	89	Ziroatkar-64	129	Giza 45	169	Tex 2167
10	Sohni	50	TAM C155 - 22 ELS	90	AGC 208	130	Earlipima	170	Fibermax 819
11	CIM-70	51	Deltapine 45 – vert	91	B557	131	Acala 1517 SR2 – vert	171	Tex 843
12	994	52	Acala 44	92	CRIS-342	132	Acala N 28-5	172	Acala 32
13	VH 260	53	Deltapine 15A	93	MNH-814	133	Deltapine 26	173	Acala 1-13-3-1
14	Stoneville 474	54	Brown Egyptian	94	KORİNA	134	AzGR-11835	174	Deltapine 61
15	Malmal-MNH-786	55	Deltapine 12	95	FH 142	135	RANTOS	175	Deltapine 15
16	AzGR-11836	56	Deltapine 25	96	TX No: 1416	136	AĞDAŞ17	176	Deltapine 14
17	Marvi	57	AcalaNunn's	97	Stoneville 213	137	NIAB-111	177	AcalaShafter Station
18	Ziroatkar-81	58	Acala 1517 D	98	ACALA SJ 3	138	Tex 1216	178	Acala 1517-91

19	AzGR-11834	59	AcalaMorell	99	Mex 123	139	Mex 122	179	AcalaTex
20	AzGR-11839	60	TAM B147 – 21	100	Fibermax 832	140	Tx No: 2700	180	Deltapine 714 GN
21	Stoneville 506	61	TAM 87 G3- 27	101	Giza 75	141	Stoneville 014	181	Acala 1517 C
22	NIBGE-2	62	AcalaGlandless	102	Tex 844	142	Stonville 108 SR	182	Acala 44 WR
23	MNH-990	63	Acala 4-42	103	Tx No: 2383	143	TX No: 2382	183	Deltapine 50
24	Sadori	64	Acala 442	104	Bulgar 6396	144	Hopicala – vert	184	Acala SJ1
25	Penta	65	TAM C66 - 26	105	Deltapine 20	145	Eva	185	Crumpled
26	Aboriginal79	66	DeltapineStaple	106	AgalaSindou	146	Mex 102	186	Deltapine 41
27	Nova	67	TOGO	107	Tex 1152	147	NIAB 78	187	TAM C66 - 16
28	Shazbaz	68	NIAB-KIRN	108	NIAB 111	148	Stoneville 731N	188	TAM 01 E - 22
29	Deltapine 5816	69	Sivon	109	Mehrgon	149	Taashkent	189	AcalaHarper
30	Deltapine 565	70	AlbaAcala 70	110	CAMPU	150	Stonville 504	190	Acala-55-5
31	Stoneville 2B	71	NIA-UFAQ	111	Stoneville 3202	151	CASCOT L7	191	Deltapine 80
32	Deltapine 50 – vert	72	Giza 7	112	Stoneville 62	152	Avesto	192	Tropical 225
33	MNH-493	73	CRIS-134	113	Giza 70	153	Darmi	193	TAM 04 WB - 33
34	Stoneville 508	74	AcalaNaked	114	Deltapine 62	154	Giza 59	194	AcalaMexican
35	AzGR-7711	75	SAMOS	115	Acala Okra	155	Tadla 25	195	Acala 3080
36	Stoneville 256	76	AĞDAŞ 6	116	AcalaYoung's	156	New MexicanAcala	196	Acala 51
37	Stoneville 5A	77	Zeta 2	117	TAM B182	157	Giza 83	197	TAM A106-16ELS
38	TamcotSphinx	78	AĞDAŞ 7	118	Deltapine SR-5	158	Stoneville 256-315	198	TAM B139 - 17 ELS
39	Bulgar 73	79	AGC 375	119	TAM C147 - 42	159	Arcota-129	199	Deltapine SR4
40	Stoneville 618 BBR	80	Haridost	120	Giza 75	160	NIAB 846	200	Acala SS 2280

In the experiment, the harvest was done twice by hand. The first harvest commenced when the cotton was approximately 70% open; the second harvest was three weeks later. In the experiment, harvested seed cotton from each plot was ginned with the machine of roller gin and separated as seed and fiber. One hundred randomly seeds with four replications were weighed and the average of 100 seeds weight was determined. Seed yield (kg ha^{-1}) was calculated as: [seed percentage (%) X seed cotton yield (kg ha^{-1})] [3]. After gin processing, 100 seeds sampled from each plots were acid delinted and dried at room temperature for 48 hours [14]. Then, the seeds were cut in the middle with a scalpel, divided into two and their inner parts were removed. After the obtained seed coats are weighed, the seed coats are obtained according to the formula below. Seed coat ratio (%): [100 seed coat weight (g) / 100 seed weight (g) X 100]. Seed coat thickness, coats of 100 cotton seeds were measured from 3 different places with a digital compass and averaged [14]. The chalaza end diameter was determined by measuring 100 cotton seeds from the chalaza end with a digital caliper. Seed samples were collected from each plots and ground with an electric coffee mill. A small portion of ground seeds (5 g) was transferred to a disposable filter column and seed oil content was determined by the Soxhlet apparatus. The number of gossypol glands was determined by counting the glands under the Olympus SZX16 Stereo microscope on 30 cotton seeds divided into two from the middle parts with a scalpel (Figure 1). Data of all parameters from the study were analyzed using the MSTAT-C statistical programming. The significant of the difference between means was compared by Duncan test ($P < 0.05$). The correlation coefficients between the parameters were also determined.



a b c

Figure 1: a) stereo microscope, b) gossypol glands in cotton seed, c) glandless cotton seed

Results and Discussion

A considerable variation was observed for investigated characteristics among cotton genotypes (Table 1). The distribution of 200 cotton genotypes for 100-seed weight is shown in Figure 2A. According to the two hundred cotton genotypes, 100-seed weight value was 11.3±4.1 g, and it ranged from 7.23 g (Acala 1517 D) to 15.43 g (Acala 1517 SR2-vert). The highest 100 seed weight values were obtained from Acala 1517 SR2-vert (15.43 g), Mex 106 (14.6 g) TAM C66-26 (14.56 g) and Stoneville 213 (14.38 g) respectively. The lowest 100 seed weights were recorded in genotype Acala 1517D (7.23 g), MNH-493 (7.37 g) and Shazbaz (7.72 g). Patel [15] stated that 100 seed weight values differ according to cotton species; Efe et al. [16], 100 seed values of some mutant cotton varieties brought from Azerbaijan in the Southeastern Anatolia region varied between 9.4 and 12.7 g; Yuka (2104) stated that the weight of 100 seeds in 13 different cotton genotypes varied between 8.13 – 10.71 g; Kıllı and Beycioglu [3] reported that the weight of 100 seeds in different cotton genotypes varied between 9.11 – 12.65 g. The fact that the 100 seed weight values we obtained in the study showed a wide variation between about 7 g and 15 g (Figure 2A), and also the differentiation from the findings of the researchers was due to the presence of genotypes from different species and the high number of genotypes.

Table 1: Average values of seed characteristics, oil content and gossypol glands of two hundred different cotton genotypes

	100-Seed weight (g)	Seed yield (kg ha^{-1})	Seed coat ratio (%)	Seed coat thickness (mm)	Seed chalaza end diameter (mm)	Seed oil content (%)	Gossypol glands (no. $seed^{-1}$)
Average	11.3 ± 4.1	2926.1 ± 1970.1	26.9 ± 11.4	0.7 ± 0.3	3.7 ± 1.6	27.1 ± 10.7	43.8 ± 36.3
Analysis of variance for traits							
F value of genotypes	39.14**	1596.1**	6.49**	5.43**	29.90**	5.91**	18.34**
CV (%)	3.43	4.09	12.24	12.31	3.70	14.05	8.54

** Significant at the 0.01 level

Cotton genotypes showed significant differences in terms of seed yield per hectare. Average seed yield value over all genotypes was 2286.3 kg ha^{-1} (Table I). Seed yield values varied between 966 kg ha^{-1} and 2896.2 kg ha^{-1} (Figure 2B). The highest seed yield values were from Shazbaz (4896.2 kg ha^{-1}), Ziroatkar-81 (4878.8 kg ha^{-1}), MNH-493 (4281.1 kg ha^{-1}) and Acala-32 (4191.1 kg ha^{-1}) genotypes, respectively; the lowest seed yield values were obtained from Acala 51 (956.0 kg ha^{-1}), Giza 7 (1016.0 kg ha^{-1}), NAIB 111 (1018.8 kg ha^{-1}) and Acala Nunn's (1039.1 kg ha^{-1}) genotypes, respectively. Sawan *et al.* [17] reported the seed yields per hectare in cotton were 1828 – 2084 kg; Sawan [17] also reported the seed yield per hectare was 1810 – 2130 kg; Tekeli [18], in his study with 46 cotton genotypes, found that the seed yield was significantly different between genotypes and the seed yields per hectare were 596.9 kg and 2616.6 kg; Kıllı and Beycioglu [3] reported that the seed yield per hectare ranged from 1731.1 to 2721.4 kg. The fact that the seed yield values we obtained in the study showed a wide variation between about 966 kg and 4896.2 kg, and also differing from the findings of the researchers, was due to the fact that there were different genotypes, the number of genotypes was quite high, and the seed cotton yield and ginning yield values were different.

Figure 2: Distribution of 200 cotton genotypes for investigated traits ((100-seed weight, seed yield, seed coat ratio, seed coat thickness, seed chalaza end diameter, seed oil content and number of gossypol gland)

The distribution of 200 cotton genotypes for seed coat ratio is shown in Figure 2C. According to the two hundred cotton genotypes, seed coat ratio was 26.9 ± 11.4 %, and it ranged from 15.33% to 38.27%. The highest seed coat ratio values were obtained from Stoneville 474 (38.27%), AcalaTex (36.25%) and AfricaES20025 (136.27%) respectively. The lowest seed coat ratios were recorded in genotype TxNo: 1416 (15.53%) and TxNo: 1412 (17.31%). The fact that the seed coat ratio values we obtained in the study showed a wide variation between about 15% and 38%, the presence of genotypes from different species, the fact that the number of genotypes was quite high, and the seed coat thickness and 100 seed weight values were different.

A significantly variation was recorded for seed coat thickness among cotton cultivars (Table 1, Figure 2D). According to the two hundred cotton cultivars, average seed coat thickness was 0.7 ± 0.3 mm, and it ranged from 0.41 mm to 1.00 mm. The variety 994 produced highest seed coat thickness (1.00 mm) followed by FH142 (0.83 mm) and Acala 1517SR2-vert (0.82 mm). However significantly minimum seed coat thickness (0.41 mm) was recorded in variety Stoneville 618BBR, and it was followed by Stoneville 2B (0.43 mm), B557 (0.43 mm), Sorbon (0.43 mm) and Agdaş 7 (0.44 mm). Average seed chalaza end diameter was 3.7 ± 1.6 mm (Table 1), and it was ranged from 2.12 mm to 5.28 mm (Figure 2E). Maximum seed chalaza en diameter was observed in Deltapine 120 (5.28 mm) and TxNo: 1389 (5.28 mm) followed by Acala 442 (5.22 mm), Giza 59 (5.22 mm) and rantos (5.20 mm) while minimum seed chalaza end diameter was observed in Marvi (2.12 mm), Acala Shafter Station (2.17 mm) and Malmal-MNH-786 (2.29 mm).

Average seed oil content values of genotypes were ranged from 13.16% to 38.46% (Table 1 and Figure 2F). The genotype TAMB147-21 (38.46%) gave significantly the highest seed oil content followed by NAIB-KIRN (37.87%), Mex 106 (37.69%), Deltapine 5816 (36.55%), Penta (36.30%), Nova (36.24%), Deltapine 45-vert (36.20%) NAIB-111 (35.48%), Bulgar 73 (35.14%) and TAM C155-22ELS (35.11%). However significantly minimum seed oil content was recorded in genotype AzR-3775 (13.16%) followed by Agdaş 3 (13.56%). According to the two hundred cotton genotypes, seed oil content value was 27.1 ± 10.7%. In studies related with cotton genotypes, different results of seed oil content have been reported by the researchers. Swern [19], Gotmare et al. [20], Sawan et al. [21] and Khan et al. [22] reported seed oil content of 17-26%, 10.26-22.89%, 19.55-19.82%, 27.52-30.15%, respectively. Song et al. [23] also reported that the oil content varied between 30.42% and 37.25% in *G. hirsutum* L. species, and between 34.77% and 38.87% in *G. barbadense* L. species, and there was a wide variation between both species to improve the oil content. The seed oil content values we obtained in the study are similar to the findings of many researchers. The difference between the lowest and highest seed oil content obtained from genotypes was 25%.

A significantly variation was recorded for number of seed gossypol glands among cotton cultivars (Table 1, Figure 2G). According to the two hundred cotton cultivars, average seed gossypol glands was 43.8 ± 36.3 (no. seed^{-1}), and it ranged from 7.46 to 80.16 (no. seed^{-1}). Significantly minimum number of seed gossypol glands were recorded in Acala glandless (7.46 no. seed^{-1}) and Acala 4-42 (9.16 no. seed^{-1}) while maximum number of seed gossypol glands were recorded in Giza 75 (80.16 no. seed^{-1}), Giza 45 (76.36 no. seed^{-1}) Deltapine SR4 (76.13 no. seed^{-1}). Pons et al. (1953), total gossypol production is affected by various factors such as weather conditions and cotton varieties; Sharma et al. [24], the amount of gossypol in the glands is different on the basis of species and genotype; Vroh Bi et al. [25] reported that the number of glands in the cotton plant differed according to species, cultivars, environmental conditions and plant tissues.Obtaining the highest number of seed gossypol gland values in Giza 75 and Giza 45 cultivars in the study confirms the results of Soto-Blanco [26], who reported that *Gossypium barbadense* L. cotton has higher gossypol densities than *Gossypium hirsutum* L. strains.

Conclusions

The present study was aimed to determine the seed characteristics (100-seed weight, seed yield, seed coat ratio, seed coat thickness, seed chalaza end diameter), seed oil content and number of gossypol glands of two-hundred different cotton (Gossypium spp.) genotypes in Kahramanmaras (Turkey) conditions. As a result of the study, it was determined that there were significant differences between genotypes and there were quite wide and significant variations in terms of all the examined characteristics. The breeding of new varieties may be possible by evaluating the wide variation in terms of the examined traits as a result of the study.

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