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Research Article

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Carpel Characteristics, Seed Oil and Protein Contents of Cotton Genotypes under Field Conditions

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Abstract In the world, one of the strategic agricultural products used in different areas is cotton. Its fibers are used extensively in the textile industry. In addition, the crude oil in its seeds is used in the oil industry and the remaining pulp is used in the feed industry. Also the carpel characteristics of cotton bolls at the harvest can be effective in resisting rain and storm. In this study, 46 different cotton genotypes have been evaluated for the crude oil and protein content and carpel characteristics. It was determined that the meaningful variations among the cotton sorts for carpel characteristics, oil and protein contents. As a result of the laboratory analyzes, it was observed that the average crude oil content of cotton sorts was 20.70% and the mean protein content was 25.55%. The seed oil extracted from cotton variety Urania (24.40%) and the seed protein content of variety Primera (28.35%) had the highest level. All varieties were in a very good class with a carpel openness value of less than 36 mm except Urania cultivar. However, all genotypes were in the poor class with carpel depths below 24 mm. While the Urania variety with the highest carpel openness value gave the highest carpel angle value, the Maydos genotype with the lowest carpel openness value gave the lowest carpel angle. The affirmative and significant correlation (0.79**) between the carpel openness and carpel angle were obtained. This result indicated that carpel features for rain and storm durability will be important. Due to the positive and significant relationship between carpel openness and carpel angle, only one of these characteristics would be more appropriate to take into consideration with the carpel depth.

Keywords Cotton, oil ratio, protein content, carpel characteristics

Introduction

Cotton is one of the significant crop cultivated in the world. Countries that produce an important amount of cotton seeds in the world are China (24.5%), India (23.1%), USA (12.8%), Pakistan (7.6%) and Brazil (7.4%), respectively. The amount of these five countries meets 75.4% of the amount of world cotton seed production [1]. Cotton fiber is a natural product for textiles, and cottonseed is a source of edible oil, cotton pulp and nutritional elements for livestock feed [2,3]. Bertrand et *al* [4] stated that cotton seeds are directly or indirectly employed in human food and the livestock. Saxena *et al* [5] emphasized that cotton seeds contain considerable oil and protein. Ahmad *et al* [6], Adelola and Ndudi [7], Kouser *et al* [8], Bellaloui *et al* [9] reported respectable diversity of fat and protein substances in cotton. The fruit of cotton is a capsule or boll, which is separated from the carpel and the cotton fibers appear at the time of harvesting [10]. Late season rain and wind can lead to cotton yield and quality losses. Williford *et al* [11], Parvin *et al* [12] reported that precipitation occurred at the end of season caused high product loss. The adherence ability of the cottonseed to the capsule is effective in the yield and quality losses. Qisenberry and Dilbeck [13] investigated six upland cotton varieties in seven different environments. They were stated that the difference between cotton varieties was significant in terms of wind resistance. This is closely related to the features of the carpels. Genotypes with

a large carpel opening and a low depth may have more losses. Extreme weather conditions may reduce fiber yield and quality of cotton (*G. hirsutum* L.) causing economic loss to the producer [14]. The carpel structure of the cotton boll is an important feature affecting the resistance to rain and wind especially during the harvest period. In addition, the high oil and protein content of cottonseed are valuable characters, particularly due to the utilization as animal feed and human food. For this reason, 46 cotton genotypes having several properties will be displayed for carpel characteristics, oil and protein contents. The final target is to separate the best genotypes having requested characteristics.

Materials and Methods

Forty-six different cotton genotypes (Table 1), two of which belong to *barbadense* and forty-four of *hirsutum* species, were grown during the 2013 and 2014 growing seasons in Kahramanmaras, which is placed in the Eastern Mediterranean region of Turkey. Cotton material was obtained from genetic stocks of Nazilli Cotton Research Institute.

Table 1: Cotton genotypes used in the study

Genotype number	Genotype name	Genotype number	Genotype name	Genotype number	Genotype name
1	ST-468	17	Beli İzvor-432	33	Cosmos
2	ST-488	18	Carmen	34	Özbek-100
3	Primera	19	Neli	35	Hersi
4	Gaia	20	ST-453	36	Samon
5	Nazilli-87	21	Baly-308	37	GSN-12
6	Taşkent-1	22	Flash	38	Dicle-2002
7	Eisa	23	Julia	39	Famosa
8	Flora	24	İs-1	40	Veret
9	Candia	25	Urania	41	Gosipolsüz-86
10	Sahel-I	26	Orgost-644	42	Tamcot-24
11	Gedera-10	27*	Giza-45	43	Maydos
12	BA-119	28	Bulgar-33	44	BA-525
13	Cascot-2910	29	Gacot-79	45	Gloria
14	ST-373	30	Fibermax-832	46	Furkan
15	Aleppo-1	31*	Giza-70		
16	Zeta-2	32	Claudia		

*) *barbadense* cotton cultivars.

The soils where the experiment was established are alluvial soils carried by rivers and they are deposited horizontally in different layers. The slope of the land is close to flat, deep, good drainage, clayey-loam body and first class agricultural land. The pH of the experimental area soils is 7.5, slightly alkaline, lime content is high (20.24 %) and organic matter content (0.96 %) is very low [15]. Kahramanmaras province displays a Mediterranean climate with hot and dry summers and rainy winters. During the growing season, mean temperature altered from 17.2°C (April) to 28.8°C (July) in 2013, and from 12.5°C to 26.7°C in 2014, respectively. The temperature of field research area was convenient for cotton farming, while the temperatures of July and August were higher than the other months. There was prominent versatility in amount and distribution of precipitation from month to month. The highest precipitation was occur in May, and this was followed by April. The months of July and August were dry and hot with only 1.9 mm of precipitation. September was warm, with 37.9 mm and 44.6 mm of rainfall, for 2013 and 2014, respectively.

The trial was set up with 4 replications to the random blocks pattern. Genotypes with 70 cm row spacing and five meters length were sown on 10 May 2013 and 2014. Post emergence, seedlings were thinned by hand as 20 cm plant spacing. Cultural practices were carried out for cotton production during each growing season. In both years, the field area was fertilized with 80 kg N and 80 kg P_2O_5 ha^{-1} with sowing and additional 80 kg N ha^{-1} was given during the square period. Overall six watering were implemented and plant protections measures

were taken in all plant parcels. In the experiment, the harvest was done twice by hand. The first picking was done at 70% boll opening and second picking 3 weeks later. In the study carpel characteristics (carpel openness, depth and angle), oil and protein content were investigated. Pickedseed cotton was processed in a cotton gin machine and separated from its seeds. After gin processing, seeds sampled from each plots were acid delinted and ground. Soxhlet and Kjeldahl extraction methods were applied to the samples for oil and protein ratio. Carpel openness, carpel depth and carpel angle were determined by studying ten boll samples[16].Analysis of variance was performed for each characteristic by the MSTAT-C statistical program and where F- test indicated significant effects ($p<0.05$), means were separated using Duncan test. The correlation coefficients between the carpel openness, depth and angle were also determined.

Results and Discussion

Carpel Characteristics

The results of variance analysis showed significant differences between genotypes for carpel characteristics. The measured average values of the carpel openness, carpel depth and carpel angle of the cotton varieties are presented in Table 2.First year, genotypes ranged from 22.1 to 40.4 mm for carpel openness. Maximum carpel openness was recorded in Urania cultivar (40.4 mm), followed by Özbek-100 (34.2 mm), Hersi (33.9 mm), Baly-308 (33.6 mm), Is-1 (33.5 mm), Samon (33.4 mm) and Flora (33.3 mm). The carpel openness was minimum in Maydos (22.1 mm). In the second year, genotypes ranged from 24.8 to 34.2 mm for carpel openness. The carpel openness was maximum in Urania cultivar, minimum in Gacot-79. Urania cultivar was followed by Gürelbey (34.0 mm) and Siokra-133 (33.4 mm). Mean values for carpel openness revealed that Urania cultivar produced maximum value (37.3 mm) and Maydos produced minimum value (24.0 mm). For carpel depth, genotypes in the first year were ranging from 15.1 to 19.5 mm while the second year varied from 17.0 to 24.6 mm. Maximum carpel depth were observed in four cultivars Hersi (19.5 mm), Tamcot-24 (19.3 mm), Özbek-100 (19.1 mm) and Aleppo-1 (19.0 mm) in first year, and also observed in three cultivars Baly-308 (24.5 mm), Flora (24.2 mm) and GSN-12 (24.2 mm) in second year. Minimum carpel depth values were observed for Flash (15.1 mm) and Primera (15.2 mm) cultivar in the first year. However, it was found in Furkan cultivar with 17.9 mm value in second year. Mean values for carpel depth revealed that Baly-308 cultivar produced maximum value (21.4 mm) while Candia (17.4 mm), Flash (17.4 mm) and Orgost-644 (17.4 mm) produced minimum values.

Table 2: Average values of carpel characteristics of cotton genotypes

Genotypes (Num. and Name)	Carpel openness (mm)			Carpel depth (mm)			Carpel angle (degree)		
	First year	Second year	Mean	First year	Second year	Mean	First year	Second year	Mean
1. ST-468	30.6	27.7	29.1	16.8	20.5	18.6	61.2	53.5	57.3
2. ST-488	31.4	28.1	29.7	18.5	23.5	20.8	59.5	50.0	54.7
3. Primera	33.2	28.4	30.8	15.2	21.7	18.4	65.3	52.8	59.0
4. Gaia	32.4	30.2	31.3	16.0	20.3	18.1	63.7	56.0	59.8
5. Nazilli-87	32.9	31.6	32.2	15.6	21.0	18.3	64.5	56.3	60.4
6. Taşkent-1	32.1	31.9	32.0	15.8	21.3	18.5	63.7	56.6	60.1
7. Eisa	30.5	29.8	30.1	17.3	21.4	19.3	60.2	54.3	57.2
8. Flora	33.3	31.0	32.1	17.4	24.2	20.8	62.3	52.1	57.2
9. Candia	30.7	30.1	30.4	15.9	19.0	17.4	62.6	57.7	60.1
10. Sahel-I	32.0	27.7	29.8	16.2	21.9	19.0	63.1	51.6	57.3
11. Gedera-10	30.1	29.8	29.9	16.6	19.6	18.1	61.0	56.6	58.8
12. BA-119	30.3	30.4	30.3	15.5	22.7	19.1	62.8	53.2	58.0
13. Cascot-2910	32.0	29.7	30.8	17.6	23.4	20.5	61.1	51.7	56.4
14. ST-373	33.2	30.1	31.6	15.7	18.0	16.8	64.6	59.1	61.8
15. Aleppo-1	29.3	29.3	29.3	19.0	21.2	20.1	57.0	54.2	55.6
16. Zeta-2	32.2	30.1	31.1	16.9	19.7	18.3	62.3	56.8	59.5
17. Beli İzvor-432	30.5	30.1	30.3	16.6	20.2	18.4	61.5	56.2	58.8

18. Carmen	32.7	29.8	31.2	16.5	20.4	18.4	62.9	55.6	59.2
19. Neli	32.3	26.9	29.6	18.8	18.9	18.8	59.6	54.9	57.2
20. ST-453	30.9	28.6	29.7	16.7	21.3	19.0	61.5	53.3	57.4
21. Baly-308	33.6	30.0	31.8	18.4	24.5	21.4	61.2	50.8	56.0
22. Flash	31.4	27.5	29.4	15.1	19.8	17.4	64.2	54.1	59.1
23. Julia	32.2	30.4	31.3	16.4	21.2	18.8	62.8	55.0	58.9
24. İs-1	33.5	30.3	31.9	17.3	20.4	18.8	62.3	56.1	59.2
25. Urania	40.4	34.2	37.3	16.4	21.4	18.9	67.6	57.9	62.7
26. Orgost-644	30.0	31.4	30.7	16.4	18.5	17.4	61.0	59.2	60.1
27. Giza-45	30.2	31.9	31.0	16.4	19.6	18.0	61.4	58.4	59.9
28. Bulgar-33	26.8	27.6	27.2	17.2	20.3	18.7	57.1	53.6	55.3
29. Gacot-79	31.2	24.8	28.0	17.0	20.7	18.8	61.5	50.3	55.9
30. Fibermax-832	33.1	27.8	30.4	17.1	21.3	19.2	62.5	52.7	57.6
31. Giza-70	31.7	27.4	29.5	15.9	20.1	18.0	63.2	53.7	58.4
32. Claudia	30.6	29.0	29.8	16.8	23.3	20.0	61.1	51.1	56.1
33. Cosmos	30.7	29.6	30.1	16.6	23.5	20.0	61.4	51.4	56.4
34. Özbek-100	34.2	29.4	31.8	19.1	21.8	20.4	60.8	53.4	57.1
35. Hersi	33.9	31.6	32.7	19.5	22.8	21.1	60.0	54.1	57.0
36. Samon	33.4	28.8	31.1	18.8	21.8	20.3	60.4	53.2	56.8
37. GSN-12	32.3	30.5	31.4	16.9	24.2	20.5	62.2	51.5	56.8
38. Dicle-2002	28.8	28.3	28.5	16.6	19.9	18.2	59.8	54.9	57.3
39. Famosa	28.2	28.4	28.3	17.7	19.6	18.6	57.7	55.4	56.5
40. Veret	30.9	27.6	29.2	17.9	21.6	19.7	59.8	51.6	55.7
41. Gosipolsüz-86	28.8	30.0	29.4	18.5	21.5	20.0	56.0	54.3	55.1
42. Tamcot-24	29.8	26.7	28.2	19.3	18.4	18.8	57.7	55.4	56.5
43. Maydos	22.1	26.0	24.0	18.2	19.2	18.7	50.5	53.5	52.0
44. BA-525	29.3	28.9	29.1	16.9	22.2	19.5	59.9	52.4	56.1
45. Gloria	30.6	29.2	29.9	18.4	18.3	18.3	58.8	57.7	58.2
46. Furkan	33.2	31.4	32.3	17.1	17.9	17.5	62.6	60.2	61.4
Average	37.6	29.3	30.3	17.1	20.9	19.0	61.1	54.4	57.8
LSD (0.05) :	1.98	1.32		0.98	1.10		3.00	2.50	

Carpel openness and carpel depth of three cotton varieties (N-84 S, BA-119 and Carmen) were examined by [17].They reported that carpel openness and carpel depth values were between 36.50 mm and 42.53 mm, and between 26.53 mm and 27.42 mm respectively. For carpel angle, genotypes ranged from 57.0 to 67.6 degree in first year and from 50.0 to 60.2 degree in second year (Table 2). Maximum carpel angle was recorded in Urania (67.6 degree) and Furkan (60.2 degree) cultivars in first and second year, respectively. Minimum carpel angle values were observed for Aleppo-1 (57.0 degree) and Bulgar-33 (57.1 degree) cultivars in the first year while they were observed for ST-488 (50.0 degree) and Carolina Queen (50.1 degree) in the second year. Coşkun [16] examined features such as carpel openness, carpel depth and carpel angle of cotton cultivar N-84. As a result of the study, it was reported that carpel openness, carpel depth and carpel angle was 39.96 mm, 22.95 mm and 40.97 degree, respectively.

The results of analysis of correlation coefficients between carpel characteristics (Table 3) show that highly significant and positive correlation (r = 0.79**) was noticed for carpel openness with carpel angle. The relationship between the carpel opening and carpel depth were negative but insignificant (-0.13). However, results revealed that highly significant negative correlation (r = -0.69**) was displayed by carpel depth with carpel angle, which showed that carpel angle was greatly influenced by carpel depth. The carpel characteristics of cotton boll at the harvest can be effective in resisting rain and storm. Because seed cotton is located between carpels. Qisenberry and Dilbeck [13] investigated six upland cotton varieties in seven different environment. They were stated that the difference between cotton varieties was significant in terms of wind resistance. Faircloth *et al.*[18]reported that adherence of fibers in the open bolls is an agronomic feature in their study of

cotton resistance to wind. Correlation and regression analysis of carpel character and its contributing components are very important components in determining suitable selection criteria for the improvement of resisting rain and storm.

Table 3: Correlations among carpel characteristics of forty sixcotton genotypes evaluated in two years

	Carpel openness	Carpel depth	Carpel angle
Carpel openness	1.00		
Carpel depth	-0.13	1.00	
Carpel angle	0.79**	-0.69**	1.00

Oil and Protein Contents

Oil and protein contents of cotton genotypes were significantly different (Table 4). First year, genotypes ranged from 16.06 to 25.21% for seed oil contents. Maximum seed oil was recorded in Carmen cultivar (25.21%), followed by Urania (24.29%) and ST-488 (24.25%). The seed oil content was minimum in Primera (16.06%). In the second year, genotypes ranged from 15.70 to 24.11% for seed oil. The seed oil content was maximum in Urania cultivar, minimum in Primera. Urania cultivar was followed by Hersi (24.09%). Mean values for seed oil revealed that Urania cultivar produced maximum value (24.20%) and Primera produced minimum value (15.88%). The variations in seed oil contents of cotton genotypes might be due to the disparity in environmental factors and genetic structure of the cotton cultivars. Oil ratio of cotton seed is managed by multiple genes and is severely influenced by the environmental changes [19]. Gotmare *et al.* [20], Kouser *et al.* [8] reported major diversity in oil ratio of cotton seeds.

For seed protein, genotypes in the first year were ranging from 22.00 to 27.94% while the second year varied from 22.87 to 28.85%. Maximum seed protein were observed in four cultivars Giza-45 (27.94%), Primera (27.85%), Bulgar-33 (27.54%) and Sahel-I (27.48%) in first year, and also observed in four cultivars Primera (28.85%), Urania (27.73%), Giza-45 (27.21%) and ST-453 (27.19%) in second year. Minimum seed protein value was observed for Tamcot-24 (22.00%) cultivar in the first year. However, it was found in Julia cultivar with 22.87% value in second year.

Table 4: Average values of seed oil and protein content of cotton genotypes.

Genotypes (Num. and Name)	Seed oil content (%)			Seed protein content (%)		
	First year	Second year	Mean	First year	Second year	Mean
1. ST-468	20.04	18.57	19.30	26.68	25.56	26.12
2. ST-488	24.25	20.11	22.18	25.15	23.59	24.37
3. Primera	16.06	15.70	15.88	27.85	28.85	28.35
4. Gaia	21.61	18.77	20.19	25.92	25.93	25.92
5. Nazilli-87	22.21	19.61	20.91	25.81	23.08	24.44
6. Taşkent-1	23.04	17.07	20.05	26.39	25.16	25.77
7. Eisa	21.73	19.92	20.82	24.46	23.98	24.22
8. Flora	22.64	18.76	20.70	23.99	23.72	23.85
9. Candia	23.70	20.42	22.06	24.03	25.57	24.80
10. Sahel-I	22.44	17.78	20.11	27.48	24.33	25.90
11. Gedera-10	21.69	21.22	21.45	25.67	25.10	25.38
12. BA-119	21.53	20.29	20.91	25.70	23.59	24.64
13. Cascot-2910	23.00	19.80	21.40	25.58	25.05	25.31
14. ST-373	21.64	19.91	20.77	25.31	24.89	25.10
15. Aleppo-1	22.24	19.35	20.79	26.06	25.89	25.97
16. Zeta-2	21.77	17.08	19.42	26.05	25.25	25.65
17. Beli İzvor-432	21.29	20.37	20.83	26.78	25.67	26.22
18. Carmen	25.21	20.22	22.71	23.42	24.26	23.84
19. Neli	23.39	21.54	22.46	24.29	24.30	24.29
20. ST-453	21.50	16.97	19.23	25.62	27.19	26.40

21. Baly-308	21.36	19.93	20.64	26.30	24.38	25.34
22. Flash	21.24	18.25	19.74	25.58	24.09	24.83
23. Julia	22.99	23.10	23.04	24.89	22.87	23.88
24. İs-1	20.29	20.90	20.59	26.46	26.11	26.28
25. Urania	24.29	24.11	24.20	26.13	27.73	26.93
26. Orgost-644	20.43	20.03	20.23	26.19	24.87	25.53
27. Giza-45	23.72	21.96	22.84	27.94	27.21	27.57
28. Bulgar-33	22.30	20.28	21.29	27.54	25.03	26.28
29. Gacot-79	22.59	19.75	21.17	26.65	24.85	25.75
30. Fibermax-832	22.51	19.04	20.77	25.61	25.63	25.62
31. Giza-70	22.18	19.79	20.98	25.48	25.05	25.26
32. Claudia	18.52	17.04	17.78	26.43	26.52	26.47
33. Cosmos	20.84	19.49	20.16	26.69	24.23	25.46
34. Özbek-100	22.48	20.56	21.52	24.41	26.58	25.49
35. Hersi	23.30	24.09	23.69	26.07	24.97	25.52
36. Samon	23.03	19.22	21.12	26.47	25.62	26.04
37. GSN-12	21.77	18.87	20.32	26.46	26.10	26.28
38. Dicle-2002	20.72	18.88	19.80	25.02	26.09	25.55
39. Famosa	21.00	17.55	19.27	26.40	25.22	25.81
40. Veret	20.45	17.81	19.13	26.65	26.29	26.47
41. Gosipolsüz-86	19.70	21.71	20.70	25.84	26.70	26.27
42. Tamcot-24	20.91	18.84	19.87	22.00	26.47	24.23
43. Maydos	19.84	19.02	19.43	25.38	23.66	24.52
44. BA-525	21.49	17.54	19.51	24.21	24.75	24.48
45. Gloria	22.61	19.50	21.05	26.11	26.72	26.41
46. Furkan	23.42	19.39	21.40	26.43	26.66	26.54
Avarage	21.85	19.57	20.70	25.77	25.33	25.55
LSD (0.05) :	0.96	0.99		1.80	2.10	

Mean values for seed protein content revealed that Primera cultivar produced maximum value (28.35%) while Carmen (23.84%), Flora (23.85%) and Julia (23.88%) produced minimum values. The crude protein ratio of the analyzed seed of cotton genotypes (25.55%) was comparable to that stated in the literature, 22.31% [21] but was lower than that examined earlier (34.0-36.2%) from Pakistan [6] as well as for some Nigerian cotton varieties, 37.4% [22]. Protein ratio results in this study were higher than that reported as 15.40 - 19.40% for cotton by [7]. The variations in seed protein contents of cotton genotypes might be due to the disparity in climatological factors and genetic make-up of the cotton cultivars. It has been reported that the share of genotypic variance within the total phenotypic variance is higher than the environmental variance for oil and protein ratio [23]. The percent of oil and protein in the cotton seeds evaluated in the study changed from 15.70 to 25.21% and 22.00 and 28.85%, respectively. Urania cultivar gave the highest seed oil ratio, but Primera cultivar gave the lowest. Primera and Giza-45 displayed high seed protein. Flora, Carmen and Julia displayed low seed protein. Most studies reported negative relationship between seed oil and protein [24, 25]. Oil and protein ratio in cottonseeds are quantitative characters and they are generally negatively related [26].

Conclusions

The findings of this study showed that carpel features, oil and protein ratio of 46 cotton genotypes were significantly different. While the average crude oil content of the genotypes was 20.70%, the mean protein content was determined as 25.55%. Higher levels of seed oil content were recorded in Urania (24.30%), Hersi (23.69%), Julia (23.04%), Giza-45 (22.84%), Carmen (22.71%) and Neli (22.46%) varieties. Primera (28.35%) and Giza-45 (27.57%) varieties showed higher seed protein content compared with the others. The results showed that carpel characteristics of cotton genotypes were significantly different. Urania genotype with the 40.42 mm carpel opening value gave the highest and Maydos genotype with the 22.15 mm openness value gave

the lowest. All genotypes except Urania took place in a very good class with a lower carpel openness value than 36 mm. All genotypes in terms of carpel depth under 24 mm values were in the poor class. Urania variety with the highest carpel openness gave the highest carpel angle while Maydos genotype with the lowest carpel openness gave the lowest carpel angle. The relationship between the carpel openness and the carpel angle were positive and significant (0.79**). The relationship between the carpel opening and carpel depth were negative but insignificant (-0.13). The negative and significant (-0.69**) relationship between the carpel depth and carpel angle were obtained. The result indicated that carpel features for rain and storm durability will be important. Due to the positive and significant relationship between carpel openness and carpel angle, only one of these properties (carpel angle or carpel openness) would be more useful to take into consideration with the carpel depth.

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