Published November, 1980

Genetic Studies of Seed Oil in Cotton[1]

Russell J. Kohel[2]

ABSTRACT

Twenty lines with high and low seed-oil percentages were selected from 747 lines in the Upland cotton, *Gossypium hirsutum* L., germplasm collection. These lines were used to transfer a range of seed-oil percentage into agronomic backgrounds and to study its inheritance. The seed-oil lines were crossed as females to five agronomic lines that included glanded and glandless types and full-season and early-maturing types. The characteristics determined were: (1) seed-oil percentage, (2) seed index, (3) embryo percentage, (4) embryo-oil percentage, (5) seed-oil index, and (6) embryo index. Parental and F_3 seeds (from F_2 plants) were analyzed. Variability was significant for all characters. Differences among the maternal and paternal F_3 arrays were highly significant. The maternal × paternal interaction effects for seed-oil index and embryo percentage were small but significant. Heritability estimates based on F_3 genetic variability ranged from 42 to 66% for the characters measured. The heritability estimate for seed-oil percentage was 35% when calculated by the standard-unit regression (F_3 on F_2) method. These results established that seed oil is heritable and can be transferred readily. Variability for seed-oil percentage of the seed-oil parents exceeded that of the agronomic parents only slightly. Seed-oil percentage was not as highly correlated with seed physical properties in the seed-oil parents as it was in the agronomic parents. This result suggests that the seed-oil parents offer unique germplasm for the modification of seed oil content.

Additional index words: Gossypium hirsutum L., Seed size, Embryo size, Germplasm, Seed quality.

A program for cottonseed, *Gossypium hirsutum* L., improvement began with a survey of seed-oil percentage in the germplasm collections (Kohel, 1978). The program was started because of the long-term view that vegetable oil and protein production would increase in importance in world agriculture, and that cotton would continue to be grown as a major fiber crop. It follows, therefore, that cotton breeders should develop the full potential of cottonseed. More immediately, cottonseed has increased in price enough in recent years to represent a greater proportion of the value of the crop. The increase in interest in cottonseed for traditional uses has been accompanied by the expanded interest in the production and use of glandless seeded cotton (Agric. Res. Serv., 1978).

The purpose of this paper is to report the results of selecting lines for a range of seed-oil from the Upland germplasm collection, transferring them into agronomic backgrounds, and studying the inheritance of seed-oil percentage.

MATERIALS AND METHODS

The germplasm selections were obtained from the collection of Upland cottons maintained at Stoneville, Mississippi. In the initial study, 747 germplasm lines were analyzed for seed-oil percentage (Kohel, 1978). I did not know where or when the seeds had been produced, so 25 lines with high and 25 lines with low seed-oil percentage were selected and grown for 2 years at two locations. Ten lines from each group were selected for consistent performance, and they are listed in Table 1 in order of decreasing seed-oil percentage. Evaluation of these 20 lines was continued for an additional 2 years at two locations. The germplasm seed-oil lines represented a range of agronomic and

[1] Contribution from AR-SEA-USDA, College Station, TX, in cooperation with the Texas Agric. Exp. Stn. Received 19 May 1980.

[2] Research geneticist, AR-SEA-USDA, College Station, TX 77840.

Table 1. Mean performance of parents selected to study seed oil and F_2 arrays for six seed traits of cotton.

Identi-fication	Designation	Seed-oil percentage		Embryo-oil percentage		Embryo percentage		Seed-oil index		Embryo index		Seed index	
		Parents	Array	Parents	Array	Parents	Array	Parents	Array	Parents	Array	Parents	Array
		%						g					
Seed-oil parent (S.A. no.†)													
1169	Verden	28.8	26.8	41.1	40.5	70.0	66.3	2.75	2.71	6.66	6.73	9.45	10.10
933	PI 194852	27.6	27.1	41.3	40.6	66.7	66.7	2.37	2.42	5.93	6.31	8.61	8.97
155	Hindi Weed RA 8-24	26.6	26.1	40.6	40.1	65.7	65.1	2.33	2.40	5.97	6.34	8.75	9.15
825	Mexican 102	26.3	26.2	40.8	40.4	64.3	65.0	2.74	2.55	6.57	6.36	10.44	9.70
27	Mead Clean Seed	26.0	26.1	39.8	39.6	65.3	65.9	2.45	2.44	5.86	6.00	9.41	9.40
313	Stoneville 2C	25.8	25.5	39.7	39.2	65.0	64.9	2.58	2.48	6.32	7.04	10.00	9.69
152	U4, Bulk W8	25.6	25.8	38.4	39.2	66.7	65.8	1.98	2.10	5.09	5.38	7.75	8.11
59	Petal Spot	25.6	25.8	40.2	39.7	63.7	65.0	2.08	2.30	4.87	5.71	8.61	8.84
71	Durango Cluster	25.6	25.0	38.9	38.4	65.7	65.3	2.19	2.15	5.82	5.72	8.55	8.53
53	Cook 912 Pope Clean Seed	25.0	26.1	39.1	39.7	64.0	65.7	2.11	2.20	5.03	5.62	8.42	8.46
54	Ballard Clean High Lint	24.7	25.8	40.7	39.6	60.7	65.1	2.36	2.42	5.67	6.21	9.53	9.36
171	Acala Okra	24.4	25.4	37.5	39.2	65.0	64.7	2.06	2.30	5.36	5.93	8.45	9.06
715	Arkansas 8	23.9	24.5	38.8	38.0	61.7	64.5	2.40	2.35	6.35	7.48	10.04	9.59
365	Hart	23.8	24.4	38.8	38.9	61.3	62.9	2.45	2.47	6.52	6.64	10.30	10.17
1006	Lankart Sel. 611	23.4	24.8	37.5	38.7	62.3	64.1	2.38	2.48	6.45	6.60	10.16	9.61
1056	Coker 100A	23.4	24.1	36.2	37.6	64.7	64.1	2.03	2.15	5.57	6.43	8.64	8.92
730	Arkansas 30	23.3	24.6	37.1	38.4	63.0	64.0	2.41	2.56	6.35	7.11	10.36	10.21
153	U4,-78-3-5-2	22.3	24.4	37.9	39.1	59.0	62.5	1.62	1.95	4.57	5.41	7.27	8.09
1060	Fox 4205	22.3	24.1	36.8	37.9	60.7	63.7	1.66	2.08	4.97	5.77	7.44	8.50
229	Laciniate leaf	22.1	23.9	36.2	38.2	61.3	62.7	1.89	2.20	5.58	6.26	8.55	9.21
Agronomic parent													
G1	Lyman	26.4	26.0	41.1	40.2	64.3	64.7	2.60	2.58	6.88	6.36	9.86	9.38
Okra leaf	DOR-S	25.5	25.6	38.9	39.0	65.7	65.6	2.39	2.36	6.01	6.42	9.33	9.18
SP 37	Tamcot SP-37	25.1	24.9	37.2	38.6	67.3	64.6	2.69	2.43	6.98	6.52	10.73	9.67
G-2	GN	24.8	25.9	40.2	40.1	61.7	64.5	1.88	2.46	4.82	6.18	7.61	9.11
S213	Stoneville 213	21.7	24.3	35.3	37.8	61.3	64.1	1.75	2.16	4.85	5.78	8.09	8.57

† S.A. no. = Stoneville accession number.

genetic marker types. As a group, the seed-oil lines were later maturing and less productive than currently grown cultivars.

The germplasm seed-oil selections were crossed as females to self-pollinated lines of the 'Stoneville 213' and 'Tamcot SP-37' cultivars and to a glanded Okra leaf line, and two glandless breeding lines obtained from L. S. Bird, Texas Agric. Exp. Stn. These five agronomic parents were chosen to provide variability for maturity and the glandless trait. My intention was to transfer the range of seed-oil expression into these agronomic backgrounds for evaluation of performance and inheritance of seed-oil percentage.

The parents and F_1 plants were grown in 1977 in the Genetics Nursery at College Station as transplants from seedlings established in the greenhouse. This procedure, in contrast to direct seeding, allows maximum use of limited seed supplies. In 1978, the F_2 and parents were direct-seeded in one-row plots (7.5 × 1.0 m) replicated three times.

Seed characteristics measured were (a) seed-oil percentage: nondestructive measurement by nuclear magnetic resonance of 10-g samples of acid-delinted, dried seeds; individual boll determinations were made with a special probe on a 1-g sample; (b) seed index: weight of 100 acid-delinted seeds; and (c) embryo percentage of seed by weight (10-seed sample). The following characteristics were computed from the above measurements: (d) embryo-oil percentage; (e) seed-oil index: weight of oil in 100 seeds; and (f) embryo index: weight of embryos in 100 seeds.

RESULTS AND DISCUSSION

Correlation coefficients of seed-oil percentage with years or locations or both of the 50 selected lines ranged from 0.54 to 0.74. Those of the 20 parental lines ranged from 0.68 to 0.74. These results indicated that the 20 parental lines were more consistent in performance than the 50 selected lines, but still were subject to a large amount of environmental variability in seed-oil percentage. Plants grown in years in which mean seed-oil percentages were lower also showed a smaller range in values. In the 4 years in which these parental lines were grown, the highest means for 1 year ranged from 23.0 to 31.2%, and the lowest means for 1 year ranged from 17.1 to 23.0%.

The 20 parental seed-oil lines were crossed as females to the five agronomic lines. The correlation coefficient was 0.39 between seed-oil percentages of the F_1 seeds and seeds of the seed-oil parents. Each crossed boll was measured individually. Inspection of the data revealed large boll-to-boll variability in seed-oil percentage. Bolls within individual cross combinations varied in seeds per boll. The hand-crossing process and the duration of the crossing period apparently contributed to the variability. Hand emasculation and pollen transfer may have damaged bolls or caused incomplete pollination.

The 6-week period from first to last boll set also influenced seed properties (Leffler et al., 1977). It was not possible to design the crossing procedure to control this source of variability and still include the necessary number of cross combinations. Therefore, because the large environmental variability included the variation associated with the hand-crossing procedure, we could not evaluate adequately seed-oil production of the F_1 embryos.

The maternal influence on seed development also affects seed oil in the F_1. The oil-bearing tissue of the cottonseed is embryonic and therefore derives its genotype from both parents. However, the maternal parent provides the substrate and nurtures the develop-

Table 2. Mean squares from analysis of variance of four seed traits in F_3 progeny of cotton lines.

Source	df	Mean squares: Seed-oil	Seed-oil index	Embryo	Embryo index
		%		%	
Reps	2	1.82	0.10*	6.80*	0.70
Maternal arrays	19	13.12**	0.55**	20.49**	4.95**
Paternal arrays	4	31.42**	1.36**	18.55**	5.12**
Maternal × Paternal	76	0.82	0.06**	2.40	0.52**
Residual	198	0.61	0.03	1.84	0.33

*,** Significant at the 0.05 and 0.01 levels of probability, respectively.

Table 3. Correlations among seed properties in 20 seed-oil parental cotton lines (upper vlaue) and F_3 array means (lower value).

	Seed index	Embryo index	Seed-oil index	Embryo	Embryo oil
				%	%
Seed-oil %	0.19	0.36	0.65**	0.84**	0.86**
	0.05	−0.11	0.47*	0.88**	0.92**
Embryo-oil %	0.35	0.30	0.66**	0.45*	
	0.11	−0.14	0.48*	0.64**	
Embryo %	0.08	0.30	0.48*		
	−0.03	−0.07	0.36		
Seed-oil index	0.86**	0.88**			
	0.90**	0.69**			
Embryo index	0.91**				
	0.84**				

*,** Significantly different from 0 at the 0.05 and 0.01 levels of probability, respectively.

ing seeds, regardless of genotype. In fact, seed and embryo size are determined predominantly by the maternal parent (van Heerden, 1969).

Comparisons between F_1, F_2, and parental seeds also indicated problems from handcrossing and maternal effects. The correlation coefficient between F_1 and F_2 seed-oil percentages was 0.16, whereas that between the parents in the 2 years was 0.63. These results indicated large differences in F_1 non-genetic variation, confounded with differences due to genetic control.

Analysis of variance of parental and F_3 seeds (F_2 plants) revealed highly significant differences among entries (Table 2). The F_3 seeds were analyzed for differences among maternal and paternal arrays and their interaction. The mean squares for both the maternal and paternal effects were highly significant for seed-oil percentage, seed-oil index, embryo percentage, and embryo index. Maternal × paternal interactions were highly significant for seed-oil index and embryo index. Mean performance of parents and F_3 arrays are given in Table 1 to provide detailed information for selection of material with improved seed-oil performance.

Alternative methods were used for expressing the oil content and physical charatceristics of the seed because differences in seed-oil percentages could reflect differences in physical characteristics of the seeds and not in amount of seed oil itself. This result was suggested in the survey of germplasm (Kohel, 1978) that included wide ranges in seed characteristics. An analysis of covariance of seed-oil percentage with seed index for the seed-oil parental lines showed that the linear deviation was not significant (F = 0.64). This result was encouraging, because it showed no significant association between seed-oil content and seed size of these parents.

Table 4. Correlations among seed properties in agronomic parental cotton lines.

	Seed index	Embryo index	Seed-oil index	Embryo	Embryo oil
				%	%
Seed-oil %	0.55	0.70	0.77	0.60	0.84
Embryo-oil %	0.05	0.28	0.34	0.08	
Embryo %	0.92*	0.88*	0.91*		
Seed-oil index	0.95*	0.98**			
Embryo index	0.97**				

*,** Significantly different from 0 at the 0.05 and 0.01 levels of probability, respectively.

Table 5. Genetic components (standard errors) for four seed properties of F_3 progenies from cotton plants selected for seed oil percentage.

Genetic component	Seed properties: Seed-oil	Seed-oil index	Embryo	Embryo index
	%		%	
Maternal arrays	0.82	0.03	1.20	0.30
	(0.27)	(0.011)	(0.42)	(0.10)
Paternal arrays	0.51	0.02	0.27	0.08
	(0.30)	(0.013)	(0.18)	(0.05)
Maternal × Paternal	0.07	0.01	0.19	0.06
	(0.05)	(0.003)	(0.14)	(0.03)
Total phenotype	2.01	0.09	3.50	0.77

Simple linear correlation coefficients within the 20 seed-oil parental lines revealed highly correlated values among measurements of weight (index) and among measurements of percentage, but not between these two groups (Table 3). As the embryo size increased, the amount of oil increased. However, embryo percentage was not significantly correlated (r = 0.08) with seed size (seed index), even though embryo size (embryo index) increased with seed size. Correlation coefficients for the means of the maternal F_3 arrays were similar to those obtained for the parents (Table 3). A major concern was that the use of seed-oil percentage as the only measure of seed oil content might result in selection for embryo percentage at the expense of the seed coat. The positive correlation (r = 0.84) supported this concern. The use of the seed-oil isdex as a measure of seed oil favored selection for seed size (r = 0.86). These observations indicated the need to measure both the chemical and physical properties of seeds in genetic and improvement investigations.

Correlation coefficients were also calculated for the agronomic parents (Table 4). Because there were only five lines, the relations were less reliable than those of the 20 seed-oil lines. However, higher coefficients, even though not significant, suggested that the physical properties of the seed had a greater role in determining seed-oil percentage in the agronomic parents than in the seed-oil parents.

The genetic components from the F_3 seed population were calculated (Table 5) for seed-oil percentage, seed-oil index, embryo percentage, and embryo index. The ratios of genetic components from the parental arrays to total phenotypic variability (heritability estimate) were 0.66, 0.56, 0.42, and 0.49, respectively. The heritability estimate from the standard-unit regression of F_2/F_3 seed-oil percentage was 0.35. The lower heritability estimate via the standard-unit method reflected the differences between years and probably was a more realistic estimate than those based on F_3 genetic variances.

This study established that seed-oil percentage is heritable and can be transferred readily. The range of variability of the selected lines exceeds that of the agronomic parents slightly, but the variability does not appear to be as highly correlated with seed physical properties in the seed-oil parents as it does in the agronomic parents. Therefore, the seed-oil parents represent unique germplasm that may allow us to modify oil content in cottonseed.

REFERENCES

Agric. Res. Serv., U.S. Dep. Agric. 1978. Glandless cotton: its significance, status, and prospects. USDA, Agric. Res. Service, Beltsville, Md. 184 p.

Kohel, R. J. 1978. Survey of *Gossypium hirsutum* L. germplasm collections for seed-oil percentage and seed characteristics. USDA-ARS-S-187. 38 p.

Leffler, H. R., C. D. Elmore, and J. D. Hesketh. 1977. Seasonal and fertility related changes in cottonseed protein quantity and quality. Crop Sci. 17:953-956.

van Heerden, H. G. 1969. Analysis of seed components in upland cotton and their associations with lint percentage. Ph.D. Dissertation, Texas A&M Univ. 93 p. (Diss. Abstr. 70-09728).