Relations Between Oil, Nitrogen, and Gossypol in Cottonseed Kernels[1]

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ALTHOUGH the amounts of oil and nitrogen in cottonseed are taken into account in its marketing, processing, and utilization, relatively little attention has been given to the interrelationships between oil, nitrogen, and gossypol contents of the kernels. Literature reports on the subject are not conclusive and are difficult to interpret satisfactorily, owing to the unsymmetrical design of experiments, limited scope of sampling, or analysis of whole seed including variable amounts of hull and residual lint (13). Though a minor constituent, the pigment gossypol influences the color of the oil and the utility of the meal, particularly as a protein supplement in feeding poultry and swine. It is presumed that it reacts with amino acids, such as lysine, of the protein when "bound" or otherwise inactivated during processing (6, 7). Further knowledge of the ranges and causes of variability in the amounts of oil, nitrogen, and gossypol should be helpful in improving the quality and utility of cottonseed products. Information on the relationships between these constituents has resulted from a symmetrically designed investigation, cotton-belt wide in scope, on the influence of variety and environment on the composition of cottonseed. Phases of this investigation concerned with oil and gossypol individually have been reported previously (12, 8).

Samples and Methods of Analysis

The cottonseed used were of eight commercial varieties of cotton grown in experimental plots at 13 locations, across the cotton belt, during 1947, 1948, and 1949. The locations were Statesville, N. C.; Florence, S. C.; Tifton, Ga.; Auburn, Ala.; Jackson, Tenn.; Stoneville, Miss.; St. Joseph, La.; Chickasha, Okla.; Greenville and College Station, Texas; State College, N. M.; Sacaton, Ariz.; and Shafter, Calif. The cottons were grown under irrigation at the three western stations.

The seed cotton samples were picked from freshly opened bolls for all varieties at one date from each plot. They were air-dried under cover to avoid deterioration from weathering.

The kernels were mechanically separated and analyzed for moisture, oil, nitrogen, and gossypol by official methods of the American Oil Chemists' Society (2), Ba 2-38, Ba 3-38, Ba 4-38, and Ba 7-55, respectively. The grams of oil, nitrogen, and gossypol per 100 kernels were calculated from the weights per 100 moisture-free kernels and the percentages of the constituents found to be present.

Summary of Oil, Nitrogen, and Gossypol Contents

The analytical data for the 312 samples of kernels are summarized in Table I, expressed as percentage of moisture-free and of moisture- and oil-free substance and in grams per 100 kernels. As previously noted in the case of oil and gossypol contents (12, 8), analysis of variance indicated that both variety of cotton and environment have a highly significant influence on nitrogen content of the kernels. Similarly, the same factors have a highly significant influence on the grams of these three constituents per 100 kernels. Of particular interest are the extreme differences in nitrogen content of the moisture- and oil-free kernel (8.38–10.99%), which is equivalent to a range from 52.4 to 68.7% in protein (N x 6.25). The hull requirement to adjust to a conventional protein content of 41% would be from 11.0 to 32.2% of the finished meals.

TABLE I

Summary of Oil, Nitrogen, and Gossypol Contents of Cottonseed Kernels

	Oil, moisture-free basis	Nitrogen		Gossypol		Nitrogen-gossypol ratio
		Moisture-free basis	Moisture- and oil-free basis	Moisture-free basis	Moisture- and oil-free basis	
Percentage in kernels						
Rain-grown and irrigated cottons, N = 312						
High %	43.4	7.34	10.99	1.70	2.97	18.15
Low %	26.8	4.75	8.38	0.39	0.57	2.93
Mean %	36.4	6.31	9.90	1.14	1.80	6.00
Std. dev.	2.98	0.513	0.528	0.255	0.457	2.15
Rain-grown cottons, N = 240						
High %	43.4	7.34	10.99	1.70	2.97	18.15
Low %	26.8	4.75	8.38	0.39	0.57	2.93
Mean %	36.4	6.31	9.92	1.12	1.79	6.11
Std. dev.	3.08	0.562	0.534	0.264	0.479	2.31
Grams per 100 kernels						
Rain-grown and irrigated cottons, N = 312						
High g	3.40	0.636	......	0.135	......	......
Low g	1.24	0.247	......	0.020	......	......
Mean g	2.44	0.422	......	0.077	......	......
Std. dev.	0.440	0.0695	......	0.0227	......	......
Rain-grown cottons, N = 240						
High g	3.39	0.576	......	0.135	......	......
Low g	1.24	0.247	......	0.020	......	......
Mean g	2.40	0.412	......	0.074	......	......
Std. dev.	0.438	0.0645	......	0.0224	......	......

The average values recorded in Table II indicate the genetical differences between the eight varieties with respect to oil, nitrogen, and gossypol contents and weight per 100 kernels. When the data are expressed in terms of the amount of constituent in the kernel (grams per 100 kernels), rather than on a relative basis (% constituent in the kernel), the inverse relationship between oil and nitrogen disappears and the amount of both oil and nitrogen tend to be related to the size of the kernel. Both of these constituents increase with increased kernel size.

The nitrogen-gossypol ratios (Tables I and II) may become an important consideration in the processing and feeding of cottonseed meal to poultry. It has been shown that total gossypol content of pre-pressed solvent-extracted meals, which is essentially equivalent to "bound" gossypol, is negatively correlated

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TABLE II

Average Oil, Nitrogen, and Gossypol Contents and Nitrogen-Gossypol Ratios of Moisture-Free Cottonseed Kernels

Constituent and ratio	Variety of cotton							
	Acala 4-42	Acala 1517W	Rowden 41B	Mebane, Watson's	Stoneville 2B	Deltapine 15	Coker 100W	Coker Wilds
	Percentage in moisture-free kernels							
Oil, %	35.4	37.7	36.5	35.8	37.4	35.6	36.5	35.9
Nitrogen, %	6.54	6.28	6.41	6.43	6.01	6.36	6.25	6.20
Gossypol, %	0.84	1.14	1.32	1.15	1.20	1.21	1.22	1.01
Nitrogen—gossypol ratio	8.37	5.88	5.03	5.83	5.22	5.53	5.40	6.77
	Grams per 100 moisture-free kernels							
Weight, g	6.59	7.26	7.53	7.37	6.45	5.45	5.78	7.25
Oil, g	2.34	2.74	2.75	2.64	2.41	1.95	2.11	2.61
Nitrogen, g	0.430	0.455	0.481	0.472	0.387	0.345	0.361	0.448
Gossypol, g	0.056	0.084	0.100	0.085	0.078	0.066	0.071	0.075

N = 39.

with nutritive value as determined by the chick test (4). In present commercial cottonseed processing methods from 80 to 95% of the gossypol present in the seed is "bound" during processing (9, 10), and it has been suggested (6, 7) that the reaction of gossypol and lysine is one of the factors in the reduction of lysine availability in cottonseed meal. To illustrate the possible influence of the widely varying nitrogen-gossypol ratios, the actual nitrogen and gossypol contents of the individual samples giving the extreme nitrogen-gossypol ratios (2.93 and 18.15) in Table I were used to calculate the proportion of total lysine in the protein (N x 6.25) which could theoretically react with the gossypol present, on the basis of the reaction of one mole of gossypol with two moles of lysine. A lysine content of 4.7% in the protein (1) was assumed in these calculations. The calculations indicate the possibility of gossypol binding from 10.5 to 65.5% of the lysine present in the protein of cottonseed meals. A value of 34.8% was obtained by using the average nitrogen and gossypol contents of the 312 samples. It is to be noted that published results (6, 7) have indicated reductions in lysine availability of commercial hydraulic-, screw-press, and prepress-solvent extracted cottonseed meals, ranging from 17.4 to 49.3% and averaging about 33%.

Interrelations Between Oil, Nitrogen, and Gossypol

Factors which influenced the amounts of oil, nitrogen, and gossypol in the kernels, *i.e.*, variety and environment, also had a significant effect on the interrelations of these constituents as indicated by the analyses of covariance summarized in Table III. The "total" correlation coefficients were highly significant in each case, indicating the over-all significance for the three interrelations. The influence of "location-years" was greater for the gossypol-oil relationship than for the other two relationships. The influence of "varieties" did not reach significance at the 5% level for the gossypol-nitrogen association but was significant in the case of gossypol-oil and nitrogen-oil. Since the correlation coefficients for "error" were all highly significant statistically, a certain amount of variation in these interrelations is due to other factors not considered in this study.

TABLE III

Summarized Analysis of Covariance of Grams of Oil, Nitrogen, and Gossypol per 100 Cottonseed Kernels

Source of variation	Degrees of freedom	Gossypol vs. oil	Gossypol vs. nitrogen	Nitrogen vs. oil
		r	r	r
Total	310	0.82[a]	0.46[a]	0.63[a]
Varieties	7	0.72[b]	0.61	0.94[a]
Location—years	38	0.91[a]	0.35[b]	0.34[b]
Error	265	0.77[a]	0.53[a]	0.64[a]

[a] Significant, 1% level.
[b] Significant, 5% level.

The correlation coefficients for the varietal relations between oil, nitrogen, and gossypol were calculated both on the basis of percentages of moisture-free substance and grams per 100 kernels (Table IV).

TABLE IV

Correlation Coefficients for Relations Between Oil, Nitrogen, and Gossypol in Cottonseed Kernels

Variety of cotton	Correlation coefficients		
	Gossypol vs. oil	Gossypol vs. nitrogen	Oil vs. nitrogen
	On basis of percentage in moisture-free kernels		
Acala 4-42	0.65[a]	−0.59[a]	−0.66[a]
Acala 1517W	0.76[a]	−0.69[a]	−0.81[a]
Rowden 41B	0.66[a]	−0.71[a]	−0.88[a]
Mebane, Watson's	0.68[a]	−0.65[a]	−0.80[a]
Stoneville 2B	0.71[a]	−0.70[a]	−0.84[a]
Deltapine 15	0.68[a]	−0.72[a]	−0.78[a]
Coker 100W	0.67[a]	−0.76[a]	−0.84[a]
Coker Wilds	0.69[a]	−0.66[a]	−0.78[a]
	On basis of grams per 100 kernels		
Acala 4-42	0.88[a]	0.43[a]	0.41[b]
Acala 1517W	0.94[a]	0.45[a]	0.51[a]
Rowden 41B	0.86[a]	0.27	0.25
Mebane, Watson's	0.90[a]	0.48[a]	0.52[a]
Stoneville 2B	0.83[a]	0.04	0.10
Deltapine 15	0.85[a]	0.35[b]	0.42[a]
Coker 100W	0.89[a]	0.23	0.16
Coker Wilds	0.91[a]	0.59[a]	0.57[a]

N = 39.
[a] Highly significant, 1% level.
[b] Significant, 5% level.

The correlation coefficients for the relationship between gossypol and oil on either basis were positive and highly significant for each of the eight varieties, indicating an increase in gossypol with increase in oil. The regression equations for the oil-gossypol relationships are shown graphically in Figure 1. The uppermost curve is for Rowden 41B, the variety which averaged highest in gossypol content, while the lowest curve is for Acala 4-42, the variety averaging lowest in both gossypol and oil. The coefficients for the oil-gossypol relationship on the grams-per-100-kernels basis were larger than on the percentage basis, the average being 0.88 as compared to 0.68. There was a highly significant negative correlation between gossypol and nitrogen contents in the kernels for all of the varieties. However, on the grams-per-100-kernels basis, the correlation coefficients were positive rather than negative and were statistically significant for only five of the eight varieties. In the case of correlations between oil and nitrogen the relationships were similar to those between gossypol and nitrogen, being negative and highly significant on the percentage basis and positive and significant for only five of the varieties on the grams-per-100-kernels basis. Since oil and nitrogen (protein) are the major constituents of the kernel, variation in the percentage of either of them can cause a change in the relative amount of the other. When the data are calculated in terms of grams per 100 kernels this effect is eliminated, resulting in reversals from negative to positive correlations in the two latter cases.

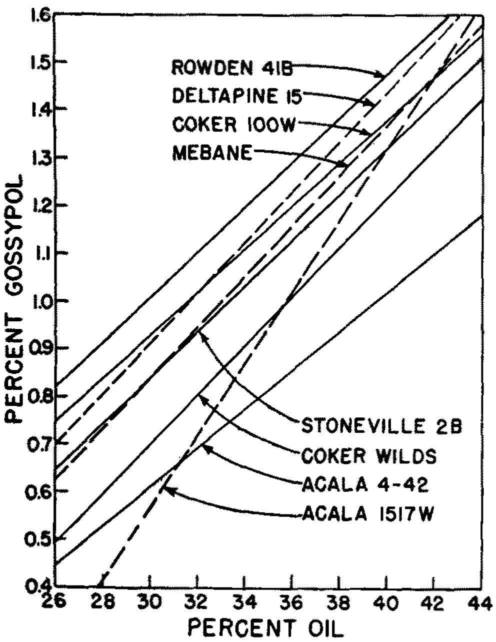

FIG. 1. Relations between oil and gossypol contents of moisture-free cottonseed kernels.

The multiple correlation coefficients indicate highly significant over-all correlations for the gossypol-nitrogen-oil relationships for each variety of cotton (Table V), whether the data are calculated as percent constituent in moisture-free kernels or as grams of constituent per 100 kernels. The partial correlation coefficients ($r_{13.2}$) for the gossypol-oil relationship on the grams-per-100-kernels basis, when nitrogen is held constant, are highly significant and of the same order of magnitude as the simple correlation coefficients for this relationship (Table IV). The fact that both gossypol and oil are known to be synthesized during the same stage of seed development (3, 5) probably accounts for this highly significant relationship. When the correlations are calculated on the percentage-constituent basis, the partial correlation coefficients ($r_{13.2}$) are numerically smaller and generally less significant than the simple correlation coefficients (Table IV). This is essentially in agreement with data reported by previous investigators (11). The partial correlation coefficients ($r_{12.3}$) for the gossypol-nitrogen relationship, independent of oil (Table V), indicate no statistical significance on the grams-per-100-kernels basis and suggest that there is no association between the amounts of gossypol and nitrogen (protein). Although the nitrogen-oil coefficients ($r_{23.1}$) for the percentage-constituent basis are

TABLE V

Multiple Correlation of (1) Gossypol, (2) Nitrogen, and (3) Oil in Cottonseed Kernels

Variety of cotton	Multiple correlation coefficient	Partial correlation coefficients		
	$R_{1.23}$	$r_{13.2}$	$r_{12.3}$	$r_{23.1}$
On basis of percentage in moisture-free kernels				
Acala 4-42	0.69[a]	0.43[a]	−0.28	−0.45[a]
Acala 1517W	0.77[a]	0.47[a]	−0.20	−0.61[a]
Rowden 41B	0.71[a]	0.09	−0.37[b]	−0.78[a]
Mebane, Watson's	0.80[a]	0.36[b]	−0.24	−0.65[a]
Stoneville 2B	0.74[a]	0.32	−0.27	−0.68[a]
Deltapine 15	0.74[a]	0.28	−0.41[b]	−0.58[a]
Coker 100W	0.76[a]	0.09	−0.48[a]	−0.69[a]
Coker Wilds	0.71[a]	0.38[b]	−0.26	−0.60[a]
On basis of grams per 100 kernels				
Acala 4-42	0.88[a]	0.86[a]	0.16	0.07
Acala 1517W	0.94[a]	0.92[a]	−0.11	0.29
Rowden 41B	0.86[a]	0.85[a]	0.12	0.03
Mebane, Watson's	0.90[a]	0.86[a]	0.05	0.22
Stoneville 2B	0.83[a]	0.83[a]	−0.08	0.12
Deltapine 15	0.85[a]	0.83[a]	−0.01	0.24
Coker 100W	0.89[a]	0.89[a]	0.18	−0.08
Coker Wilds	0.91[a]	0.87[a]	0.22	0.08

N = 39.
[a] Highly significant, 1% level.
[b] Significant, 5% level.

highly significant and negative, in agreement with data reported by several investigators (13), this inverse relationship is not indicative of a real association but is the result of the basis of measurement. When the relation is calculated on the basis of grams of constituent per 100 kernels, the partial correlation coefficients are non-significant, indicating non-associated variability of the absolute amounts of nitrogen and oil elaborated in the kernels.

Correlation coefficients, regression equations, and standard errors of estimate (s_{yx}) were calculated for the relationships between nitrogen-gossypol ratio and oil content for each of the eight varieties. These data are given in Table VI. The correlation coefficients were negative and highly significant for each variety. This is not surprising in view of the statistically significant interrelations between oil, nitrogen, and gossypol (Table IV). The spread of the regression lines for these relations (Figure 2) reduces with increase in the oil content of the kernels. Inasmuch as a large nitrogen-gossypol ratio in the kernels would seem desirable from the standpoint of cottonseed processing, the use of low gossypol seed would be advantageous. This would afford a better chance of producing cottonseed meals having lower free gossypol contents as well as improved nutritive value. It is postulated that the desired high nitrogen-gossypol ratio and high oil content may be possible through attention to reduction of gossypol and increase of oil contents of kernels in cotton breeding.

TABLE VI

Correlation Between Nitrogen-Gossypol Ratio and Percent Oil in Moisture-Free Kernels of Cottonseed of Specified Varieties

Variety of cotton	r	Regression equation y=nitrogen-gossypol ratio. x=% oil	s_{yx}
Acala 4-42	−0.63[a]	y=30.466−0.624 x	2.21
Acala 1517W	−0.74[a]	y=28.245−0.594 x	1.30
Rowden 41B	−0.74[a]	y=16.088−0.303 x	0.78
Mebane, Watson's	−0.72[a]	y=20.821−0.419 x	1.01
Stoneville 2B	−0.77[a]	y=17.858−0.338 x	0.85
Deltapine 15	−0.70[a]	y=17.520−0.337 x	1.04
Coker 100W	−0.73[a]	y=17.954−0.344 x	1.10
Coker Wilds	−0.58[a]	y=24.788−0.502 x	2.34

N = 39.
[a] Highly significant, 1% level.

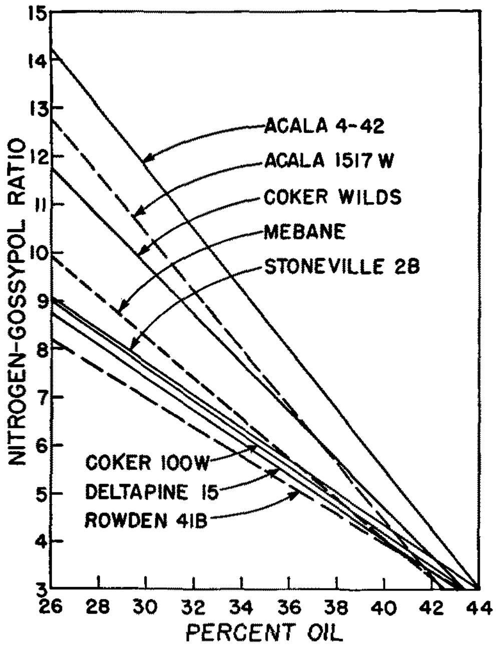

FIG. 2. Relations between nitrogen-gossypol ratios and oil contents of moisture-free cottonseed kernels.

Influence of Environment

A summary of temperatures (°F.) and total rainfall (in inches) during six selected periods of growth of the cotton plants in this investigation are given in Table VII. The six periods were:

Period 1. squaring, 21 days prior to average blooming date, which is considered as 10 days after first bloom.

Period 2. fiber length development, 17 days after average blooming date.

Period 3. maturation, 35 days following period 2 to average boll opening.

Period 4. combination of periods 1 and 2.

Period 5. combination of periods 2 and 3.

Period 6. combination of periods 1, 2, and 3.

TABLE VII
Summary of Temperatures and Rainfalls During the Growth and Development of the Cotton Bolls

Period	Range in average temperatures, °F.[1]			Total rainfall, inches[2]	
	Maximum	Minimum	Mean	Range	Average
1	85.2– 99.8	60.0–71.9	75.4–84.4	0.00– 8.81	2.19
2	85.3–107.2	62.2–80.0	75.2–91.6	0.00–11.12	2.86
3	83.6–107.6	60.2–75.4	71.9–91.4	0.00– 8.38	3.76
4	86.0–101.9	61.0–73.1	75.6–84.2	0.33–13.58	5.04
5	86.1–106.0	61.6–76.8	74.6–89.1	0.86–17.30	6.62
6	85.9–103.8	61.5–73.9	76.9–86.6	1.63–19.76	8.81

[1] All locations, N = 39.
[2] Rain-grown locations, N = 30.

Simple over-all correlation coefficients (not reported in detail here) were calculated for the relationships between nitrogen content of the kernels and mean maximum, minimum, and mean temperatures and rainfall for these six periods of growth. No significant correlations were found. In contrast, it has been reported (8) that gossypol in the kernels is significantly correlated with both total rainfall and either mean or maximum temperature during the maturation period (No. 3). The oil content is similarly correlated with rainfall but not with temperature unless the main effects for locations are removed by calculations on the basis of "years-in-locations" (12).

Simple over-all correlations (not reported in detail here) were also calculated on the basis of grams of nitrogen per 100 kernels. Highly significant negative correlation coefficients were found in the case of mean minimum temperature for each of the six periods. These coefficients were numerically larger than those for mean mean temperature, where significant coefficients were only obtained for periods 3 and 6. There were no significant correlations between rainfall during any of the six periods of growth of rain-grown cottons and the grams of nitrogen deposited in the kernel.

The influence of temperature and rainfall during the maturation period on oil, nitrogen, and gossypol contents of moisture-free kernels and the nitrogen-gossypol ratio for the individual varieties is illustrated by the simple correlation coefficients in Table VIII. The varietal relations of oil and gossypol contents with temperature and rainfall have been discussed previously (8, 12). In the case of nitrogen content the coefficients in Table VIII indicate that there is no significant correlation with mean temperature and only three of the varieties show significant correlation with rainfall.

On the basis of grams of constituent per 100 kernels several significant trends can be noted (Table VIII). The tendency is for grams of oil, nitrogen, and gossypol in the kernel to decrease with increasing temperature. Both oil and gossypol tend to increase with increasing total rainfall while nitrogen is apparently not significantly correlated with rainfall. The nitrogen-gossypol ratio shows a significant negative correlation with rainfall, which is undoubtedly due to the influence of the strong positive correlation of gossypol with rainfall. The positive correlation between mean temperature and the nitrogen-gossypol ratio is not as strong as the rainfall correlation, being significant for only four varieties. The influence of temperature independent of rainfall and of rainfall independent of temperature on the nitrogen-gossypol ratio is shown by the partial correlations recorded in Table IX. For the combined effect of both temperature and rainfall, all varieties except Coker 100W are significantly and positively correlated as evidenced by the multiple correlation coefficients. The net effect is to increase the nitrogen-gossypol ratio. When one of these weather factors is assessed independently of the other (partial correlation coefficients), it can be noted that the rainfall relations are generally more significant than those for temperature. The nitrogen-gossypol ratios for certain varieties, notably Acala 4-42 and Coker Wilds, appear to be influenced more by temperature than by rainfall.

Summary

A study was made of the relations between oil, nitrogen, and gossypol contents of cottonseed kernels from the seed of eight commercial varieties of cotton grown at 13 locations during three years. Both variety of seed and environment had a highly significant influence on each constituent whether expressed as percentage of the kernel or as weight of constituent per 100 kernels. Each variety showed a significant positive correlation between oil and gossypol and significant negative correlations between oil and nitrogen and between gossypol and nitrogen, on the basis

TABLE VIII

Correlation Coefficients for Relations Between Oil, Nitrogen, and Gossypol in Cottonseed Kernels and Temperatures (°F.), and Rainfall (Inches) During the Maturation Period (No. 3) for Rain-Grown Cottons

Variety of cotton	Oil		Nitrogen		Gossypol		Nitrogen-gossypol ratio	
	Mean temp.	Rain-fall	Mean temp.	Rain-fall	Mean temp.	Rain-fall	Mean temp.	Rain-fall
On basis of percentage in moisture-free kernels								
Acala 4-42	−0.16	0.49[a]	0.14	−0.27	−0.60[a]	0.51[a]	0.51[a]	−0.38[b]
Acala 1517W	−0.16	0.38[b]	0.01	−0.29	−0.49[a]	0.52[a]	0.44[b]	−0.44[b]
Rowden 41B	−0.15	0.46[a]	0.11	−0.40[b]	−0.38[b]	0.53[a]	0.35	−0.49[a]
Mebane, Watson's	−0.21	0.48[a]	0.05	−0.39[b]	−0.47[a]	0.58[a]	0.40[b]	−0.53[a]
Stoneville 2B	0.04	0.42[b]	−0.08	−0.32	−0.40[b]	0.58[a]	0.29	−0.52[a]
Deltapine 15	0.04	0.34	−0.03	−0.28	−0.34	0.46[b]	0.31	−0.44[b]
Coker 100W	0.03	0.38[b]	−0.03	−0.32	−0.36	0.45[b]	0.29	−0.42[b]
Coker Wilds	−0.24	0.49[a]	0.02	−0.38[b]	−0.52[a]	0.54[a]	0.74[a]	−0.40[b]
On basis of grams per 100 kernels[c]								
Acala 4-42	−0.44[b]	0.46[a]	−0.33	0.04	−0.63[a]	0.48[a]	......	......
Acala 1517W	−0.41[b]	0.39[b]	−0.47[a]	0.03	−0.52[a]	0.49[a]	......	......
Rowden 41B	−0.43[b]	0.42[b]	−0.46[a]	−0.12	−0.49[a]	0.49[a]	......	......
Mebane, Watson's	−0.30	0.35	−0.31	−0.10	−0.44[b]	0.50[a]	......	......
Stoneville 2B	−0.19	0.37[b]	−0.45[b]	−0.20	−0.46[b]	0.53[a]	......	......
Deltapine 15	−0.15	0.37[b]	−0.28	−0.06	−0.33	0.41[b]	......	......
Coker 100W	−0.18	0.38[b]	−0.39[b]	−0.14	−0.39[b]	0.43[b]	......	......
Coker Wilds	−0.49[a]	0.46[a]	−0.58[a]	0.10	−0.58[a]	0.53[a]	......	......

N = 30.
[a] Highly significant, 1% level.
[b] Significant, 5% level.
[c] Minimum temperature for nitrogen relations.

of percentage-constituent in the kernel. The amount of both oil and nitrogen elaborated in the kernel tends to be related to the size of the kernel; each of these constituents increases with increased kernel size. The highly significant positive relationship between grams of oil and grams of gossypol per 100 kernels which is evident even when nitrogen is held constant can be explained on the basis that these two constituents are synthesized during the same stage of seed development.

Rainfall or temperature had no significant over-all influence on the nitrogen content of the kernels. Grams of nitrogen per 100 kernels showed a significant negative correlation with mean minimum temperature for 5 of the varieties but was not significantly correlated with total rainfall during the maturation period for any of the varieties. Grams of oil and gossypol per 100 kernels tended to increase with increasing rainfall and decrease with increasing mean temperature.

The ratio of nitrogen to gossypol is negatively correlated with the oil content of the kernels. The variation attributed to varietal influence decreases as the oil content of the kernel increases. It is postulated that high ratios are desirable for the production of meals containing a low free-gossypol content.

TABLE IX

Multiple Correlation of
(1) Ratio of Nitrogen to Gossypol in Cottonseed Kernels
(2) Mean Temperature, °F., and
(3) Total Rainfall, Inches, During the Maturation Period (No. 3) for Rain-Grown Cottons

Variety of cotton	Multiple correlation coefficient	Partial correlation coefficients	
		With temperature	With rainfall
	$R_{1 \cdot 23}$	$r_{12 \cdot 3}$	$r_{13 \cdot 2}$
Acala 4-42	0.54[a]	0.43[b]	−0.23
Acala 1517W	0.52[b]	0.33	−0.32
Rowden 41B	0.52[b]	0.20	−0.41[b]
Mebane, Watson's	0.57[a]	0.26	−0.44[b]
Stoneville 2B	0.52[b]	0.11	−0.46[b]
Deltapine 15	0.47[b]	0.17	−0.37[b]
Coker 100W	0.44	0.15	−0.35
Coker Wilds	0.75[a]	0.69[a]	−0.19

N = 30.
[a] Highly significant, 1% level.
[b] Significant, 5% level.

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