The Effect of Cotton Grade, Variety, and Growing Location on the Dust Generated in a Model Card Room[1]

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ABSTRACT

The influence of cotton grade, growing location, and genetic variety on the amount of cotton dust generated while processing cotton in a model card room has been examined. Even though data collected from 140 bales were considered, an analysis of variance based on a standard linear additive model could not be made because the samples available were unbalanced with respect to the independent variables. The data were therefore evaluated by determining whether any deviations in the amount of dust emitted by individual bales from that of the average measured on all bales of the same grade of cotton could be attributed to growing location and/or variety. In general, the results suggest that cottons grown in the eastern U. S. A. produce somewhat less dust in the card room for a given grade of cotton than the U. S. A. average; and cottons grown in the arid areas of the west, somewhat more than average. Quantitatively, deviations from the U. S. A. average ranged from -146 to $+145$ $\mu g/m^3$, a spread that is almost inconsequential when compared with the 3.5 times greater range observed among bales of a single grade of cotton grown in a single state. Variety effects were even smaller than state effects. Many factors other than growing location and variety were observed to have large effects on the measured dust concentrations.

Introduction

A model card room, designed to measure airborne dust concentrations while processing individual bales of cotton, began operating at the School of Textiles, North Carolina State University, late in 1973 [6]. Results of several studies conducted in the card room, involving experimental groups of bales with well-defined and controlled experimental variables, have already been reported [5–9]. No general analysis of the data, however, has heretofore been attempted. It was thought worthwhile, therefore, to determine whether cotton grade, variety, and growing location in themselves have any identifiable effect on the measured dust levels. During the time interval considered (February 27, 1974, through December 31, 1976) 178 bales of cotton were processed. Of these, 38 involving experimental or unknown varieties of cotton were deleted from the analysis.

As described earlier [6], the normal procedure for evaluating cotton in the model card room is to examine at least two bales of each item by processing one bale on two consecutive days, a half bale each day. Some large bales are run in three parts on three consecutive working days. The replicate bale is then processed in a similar fashion sometime later. By following this procedure, it is possible to determine the variability within and between replicate bales. In the data analysis utilized here, no effort was made to assess the variability between bales, because previous studies have led to the conclusion that the variability between bale parts is greater than that between bales [6, 7]. The error variance for testing significant effects was therefore the variance between bale parts (*i.e.*, the within-bale variance). A total of 140 bales were processed in 305 runs, an average of 2.2 runs per bale. The results reported herein are based on run averages rather than bale averages; as a result a bale run in three parts exerts 50% greater weight in the reported average than a bale run in two parts.

Data Analysis

Independent variables considered were the state S in which the cotton was grown, its variety V, and its classer's grade G, omitting the color index. In this system, for example, grade "4" includes all the strict low middling grades from "white" to "tinged"—*i.e.*, grades 41–44. The cottons included in the analysis were

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grown in 13 states and consisted of ten varieties and five grades (3–6 and 8). Under ideal conditions the most direct approach to analyzing the influence of the independent variables would be to carry out an analysis of variance using a linear additive model with interactions. Since the data at hand were not part of a comprehensively-planned experiment, however, they represented a very unbalanced design, as may be seen from the display in Tables I, II, and III. Thus this approach could not be used.

In order for a linear additive model to be employed to determine simultaneously the influence of state, variety, and grade, data must be available for all the cross-classification cells. In other words, the experimental design must be complete and balanced. For example, referring to Table I, it would not be appropriate to compare the mean value of the dust concentrations measured for the bales grown in Arkansas (329 $\mu g/m^3$) with the mean value for the bales grown in Georgia (371 $\mu g/m^3$), because the former includes measurements made on one bale of grade 3 cotton and three bales of grade 4 cotton, while the latter includes results from lower quality cottons: one bale of grade 4, three bales of grade 5, and four bales of grade 6. In addition, the influence of variety, if any, will further complicate the analysis, since all four bales of AR cotton were Deltapine, while the GA cotton consisted of four bales each of Coker and McNair (Table III). Thus it is evident that a direct comparison of category means by states, varieties, or grades cannot be made unless: 1) the experimental design is balanced—*i.e.*, all cells are filled (making a complete factorial design); 2) certain cells, selected in a carefully chosen way, are left open (making a fractional factorial design); or 3) means are "adjusted" to common levels of the other two categories (which for all practical purposes cannot be done for qualitative variables unless the design is balanced). Another complication is that no adjustment was made for such factors as steaming, time of harvest, harvesting method, use of defolients, etc.

TABLE I. Number of bales processed and average dust concentrations measured with the Vertical Elutriator Cotton Dust Sampler (VE) arranged by growing location and cotton classer's grade.

State grown	Number of bales of Classer's grade (and VE Dust Concentration, $\mu g/m^3$)						State average VE, $\mu g/m^3$
	Unknown	3 (M)	4 (SLM)	5 (LM)	6 (SGO)	8 (BG)	
OK	5 (174)	2 (184)	0	6 (309)	0	0	243
TN	0	0	2 (269)	0	0	0	269
SC	0	0	9 (282)	1 (329)	0	0	286
NC	0	0	0	2 (297)	0	0	297
LA	0	0	3 (321)	0	0	0	321
AL	0	2 (354)	4 (403)	6 (266)	0	0	322
AR	0	1 (250)	3 (351)	0	0	0	329
MS	0	0	4 (308)	2 (360)	0	0	329
GA	0	0	1 (335)	3 (466)	4 (275)	0	371
CA	0	4 (425)	9 (328)	3 (505)	0	0	386
AZ	0	1 (400)	5 (449)	0	0	0	439
TX	0	4 (270)	24 (344)	20 (554)	0	8 (756)	468
NM	0	1 (421)	1 (519)	0	0	0	480
VE grade average, $\mu g/m^3$	174	329	342	430	275	756	392

TABLE II. Number of bales processed and average dust concentrations measured with the Vertical Elutriator Cotton Dust Sampler (VE) arranged by variety and cotton classer's grade.

Variety	Number of bales of Classer's grade (and VE Dust Concentration, $\mu g/m^3$) Unknown	3 (M)	4 (SLM)	5 (LM)	6 (SGO)	8 (BG)	Variety average VE, $\mu g/m^3$
Westburn	5 (174)	0	0	4 (183)	0	0	179
Stoneville	0	0	5 (269)	2 (360)	0	0	301
Coker	0	2 (354)	15 (314)	11 (299)	2 (176)	2 (818)	331
Paymaster	0	3 (255)	17 (310)	3 (627)	0	2 (734)	343
Deltapine	0	4 (271)	14 (395)	0	0	0	367
Acala	0	6 (407)	9 (341)	3 (505)	0	0	389
Tamcot	0	0	3 (425)	1 (353)	0	0	409
McNair	0	0	0	2 (525)	2 (373)	0	464
Lockett	0	0	0	2 (499)	0	0	499
Stripper	0	0	2 (484)	15 (569)	0	4 (734)	595
VE grade average, $\mu g/m^3$	174	329	342	430	275	756	392

For informational pruposes, dust concentration means for categories—*i.e.*, by state, by variety, and by grade—and for two-factor cross categories are given in Tables I, II, and III. It is re-emphasized, however, that no significance can be attached to the ranking of the means listed in these tables without qualifications such as those cited above.

Deviation of Responses from Those Based on Cotton Grade

Even though a direct factorial analysis of the data was not possible, some useful results of sufficient generality, though somewhat limited in scope, can be derived by employing alternative techniques of analysis. In the alternative approach used here, it is assumed that dust levels are determined by the cotton grade, and that any deviation from the dust concentration expected on the basis of grade can be ascribed to growing location or variety. This concept is similar to that utilized in interlaboratory testing, in which one purpose of the test is to determine whether measurements made in any of the laboratories deviates significantly from the average made in all laboratories [1]. In the present application, the expected dust concentration for any bale of cotton is assumed to be the average measured for that grade regardless of growing location or variety. An analysis is made to establish whether any deviations from the average can be ascribed to growing location and/or variety. The procedure for making such an analysis is as follows:

Let y_{svgi} represent each observed response, with indices s, v, and g representing the state of origin, variety, and grade, respectively. Index i refers to the individual observations made on each bale. Since responses were always averaged over i, this index will henceforth be dropped. In this notation, a missing location, variety, or grade index indicates that the response is averaged over that index. The average dust concentration measured on all bales of each grade of cotton y_g is indicated in Tables I, and II. With the exception of grade 6, y_g increases with increasing grade number, as has been observed earlier [3, 4]. Grade 6 is an exception, because it is based on measurements made on only four bales, all grown in one state (Georgia), and therefore cannot be expected to be truly representative of the dust concentration generated by grade 6 cottons grown in all states. A plot is then made for each state (or variety) of the average dust concentration measured for that state y_{sg} (or variety y_{vg}) for grade g versus the average x_g ($\equiv y_g$) measured on all bales of grade g. Such a plot

TABLE III. Number of bales processed and average dust concentrations measured with the Vertical Elutriator Cotton Dust Sampler (VE) arranged by growing location and variety.

State grown	Number of bales of Variety (and VE Dust Concentrations, $\mu g/m^3$, in parentheses)										State avg. VE, μ/m^3
	Westburn	Stoneville	Coker	Paymaster	Deltapine	Acala	Tamcot	McNair	Lockett	Stripper	
OK	9 (179)	0	0	0	2 (185)	0	0	0	2 (499)	0	243
TN	0	0	2 (269)	0	0	0	0	0	0	0	269
SC	0	0	8 (290)	0	2 (265)	0	0	0	0	0	286
NC	0	0	2 (297)	0	0	0	0	0	0	0	297
LA	0	3 (321)	0	0	0	0	0	0	0	0	321
AL	0	0	12 (322)	0	0	0	0	0	0	0	322
AR	0	0	0	0	4 (329)	0	0	0	0	0	329
MS	0	4 (290)	0	0	2 (436)	0	0	0	0	0	329
GA	0	0	4 (269)	0	0	0	0	4 (464)	0	0	371
CA	0	0	0	0	2 (400)	14 (384)	0	0	0	0	386
AZ	0	0	0	0	6 (439)	0	0	0	0	0	439
TX	0	0	4 (602)	25 (343)	0	2 (313)	4 (409)	0	0	21 (595)	468
NM	0	0	0	0	0	2 (480)	0	0	0	0	480
VE variety average, $\mu g/m^3$	179	301	331	343	367	389	409	464	499	595	392

for the cotton grown in Texas is shown in Figure 1. A least squares regression line of the following form is then fit to these data:

$$\hat{y}_j = a_j + b_j(x_g - 392) \quad , \qquad (1)$$

where 392 is the grand average $\bar{y}$ ($\bar{x}$) of all dust concentrations ($\mu g/m^3$) measured with the Vertical Elutriator Cotton Dust Sampler (VE), and j refers to a particular state s or variety v index. By including the grand mean $\bar{x} = 392$ in the equation, a_j becomes the expected value of y_j adjusted to a common dust concentration of 392 $\mu g/m^3$.

If the data for a given state or variety do not deviate from the grade averages, the slope b_j would be 1.00, and a_j would be 392. Thus, to determine whether the dust measurements for a specific state or variety deviate significantly from the average dust concentration generated by all bales of the same grade of cotton grown in the U. S. A., it is only necessary to place confidence intervals on a and b utilizing conventional regression analysis techniques.

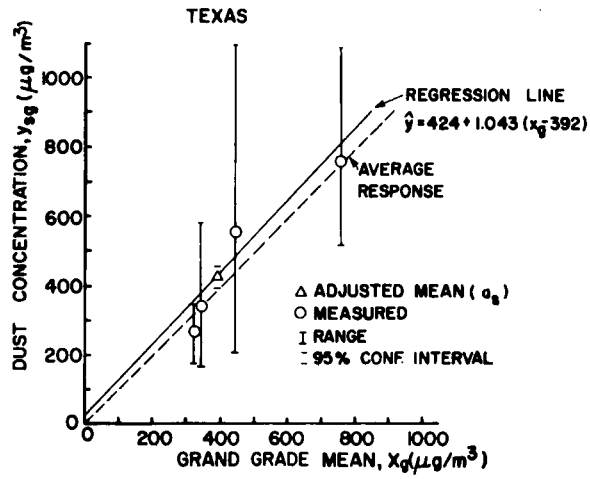

FIG. 1. Plot of the average dust concentration y_{sg} measured on all cottons grown in Texas for each grade g versus the average dust concentration x_g measured on all bales of classer's grade g. (Note: Adjusted mean a_s or a_v is calculated value expected, while processing cotton grown in a specific state (or of a given variety) of a grade which would generate a U. S. A. average of 392 $\mu g/m^3$.)

Results and Discussion

DEVIATIONS OF MEASURED FROM EXPECTED DUST CONCENTRATIONS

Results of this analysis are shown in Tables IV and V and Figures 2 through 5. Values of a_j and b_j and their confidence intervals are plotted, respectively, in Figures 2 and 3 for individual states and in Figures 4 and 5 for individual varieties. The average deviation Δy of the measured dust concentrations from the grade means x_g is listed in the last column in Tables IV and V. This value is generally given by

$$\Delta y_j = a_j - 392 \quad . \tag{2}$$

As shown later, Equation 2 is inappropriate for calculating Δy_j if the slope of the regression equation is significantly different from 1.00. In these situations the deviations Δy_j were calculated as the weighted average of the deviations from the grade means x_g—*i.e.*:

$$\Delta y_j = \sum_g n_{jg}(y_{jg} - x_g)/\sum_g n_{jg} \quad , \tag{3}$$

where n_{jg} is the number of observations in the state or

TABLE IV. Deviations of measured cotton dust concentrations from grade means by states.

State grown	Number of grades	VE cotton dust concentration, μg/m³ Single grade: Mean ± 2σ	Single grade: Grade mean	Multiple grades: Adjusted mean a ± 2σ	Multiple grades: Slope[a] b ± 2σ	Deviation Δy,[b]
NC	1	297 ± 15	430	—	—	−146[c]
OK	2	—	—	255 ± 80	1.05 ± 1.45	−137[c]
TN	1	269 ± 26	342	—	—	−123[c]
SC	2	—	—	305 ± 45	0.47 ± 0.93	− 87[c]
AL	3	—	—	324 ± 26	−1.09 ± 0.50	− 72[c]
MS	2	—	—	333 ± 55	0.51 ± 1.11	− 59[c]
LA	1	321 ± 50	342	—	—	− 22
AR	2	—	—	608 ± 193	5.33 ± 3.64	− 10
GA	3	—	—	406 ± 49	1.14 ± 0.57	+ 14
TX	4	—	—	424 ± 31	1.04 ± 0.21	+ 32[c]
CA	3	—	—	426 ± 51	1.17 ± 0.94	+ 34
AZ	2	—	—	575 ± 418	2.60 ± 7.96	+100[c]
NM	2	—	—	768 ± 119	5.15 ± 1.10	+145[c]

[a] Dimensionless.
[b] If confidence interval on slope b does not include 1.00, Δy is calculated from Equation 3. This calculation was made for AL ($2\sigma = \pm 27$), AR ($2\sigma = \pm 4$), and NM ($2\sigma = \pm 27$). Because of the large confidence intervals, Δy for AZ was also calculated in this way ($2\sigma = \pm 63$).
[c] Significant at 95% confidence level.

TABLE V. Deviation of measured cotton dust concentrations from grade means by variety.

Variety	Number of grades	VE Cotton Dust Concentration, μg/m³ Single grade: Mean ± 2σ	Single grade: Grade mean	Multiple grades: Adjusted mean a ± 2σ	Multiple grades: Slope[a] b ± 2σ	Deviation Δy[b]
Westburn	1	183 ± 30	443	—	—	−260[c]
Stoneville	2	—	—	313 ± 34	0.91 ± 0.69	− 79[c]
Coker	5	—	—	327 ± 24	1.01 ± 0.24	− 65[c]
Paymaster	4	—	—	373 ± 35	1.20 ± 0.37	− 19
Deltapine	2	—	—	711 ± 224	6.55 ± 4.23	+ 28
Acala	3	—	—	431 ± 51	1.09 ± 9.82	+ 39
Tamcot	2	—	—	390 ± 81	−0.72 ± 1.66	+ 44
Lockett	1	499 ± 55	433	—	—	+ 56[c]
McNair	2	—	—	478 ± 29	0.90 ± 0.34	+ 86[c]
Stripper	3	—	—	536 ± 66	0.55 ± 0.38	+ 96[c]

[a] Dimensionless.
[b] If confidence interval on slope b does not include 1.00, Δy is calculated from Equation 3. This calculation was made for Deltapine ($2\sigma = \pm 34$), Tamcot ($2\sigma = \pm 74$), and Stripper ($2\sigma = \pm 53$).
[c] Significant at 95% confidence level.

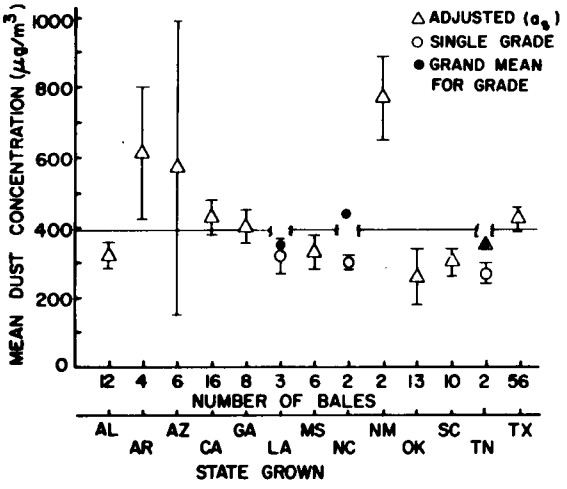

FIG. 2. Adjusted mean dust concentration (constant term "a" of regression Equation 1) and number of bales of cotton processed from each state. Regression equations could not be calculated for LA, NC, and TN, since only one grade of cotton was processed from these states. For these states actual results are shown. Confidence intervals are at the 95% level. (See Note, Fig. 1)

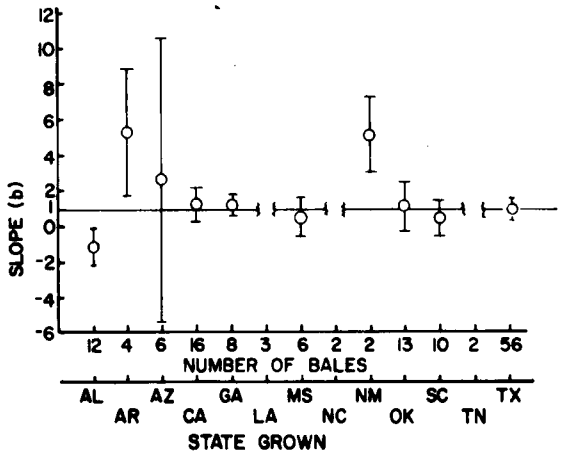

FIG. 3. Slope "b" of regression Equation 1 and number of bales of cotton processed from each state. Confidence intervals are at the 95% level. Regression equations could not be calculated for LA, NC, and TN, since only one grade of cotton was processed in these states.

variety category j of grade g. Confidence intervals (CI) on Δy were calculated from the relationship

$$\text{CI} = \Delta y \pm 2\sigma_p/\sqrt{n} \qquad (4)$$

where σ_p is the pooled within-grade standard deviation of the bales involved, and n is the total number of dust concentrations measured—*i.e.*, Σn_{jg} summed over g. States and varieties for which b_j was significantly different from 1.00, thus requiring Δy_j to be calculated from Equation 3, were Alabama, Arkansas, New Mexico, Deltapine, Tamcot, and Stripper.

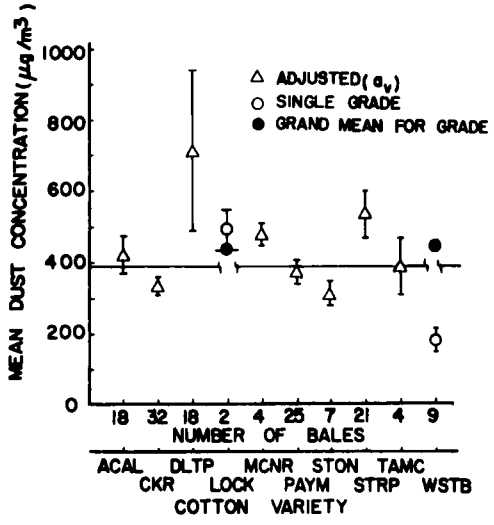

FIG. 4. Adjusted mean dust concentration (constant term "a" of regression Equation 1) and number of bales of cotton processed of each variety. Regression equations could not be calculated for Lockett and Westburn cottons, since only one grade of cotton was processed of these varieties. Confidence intervals are at the 95% level. (See Note, Fig. 1).

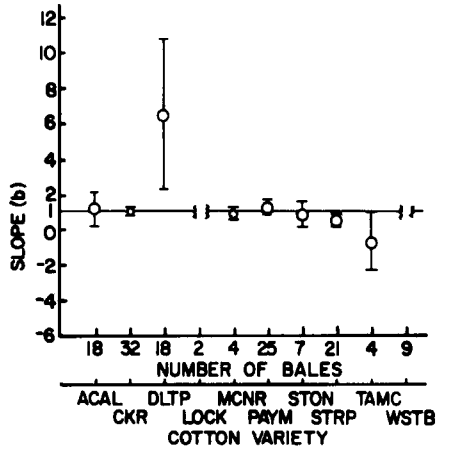

FIG. 5. Slope "b" of regression Equation 1 and number of bales of cotton processed of each variety. Confidence intervals are at the 95% level. Regression equations could not be calculated for Lockett and Westburn cottons, since only one grade of cotton was processed of these varieties.

Regression equations could not be calculated, of course, for those states and varieties represented by only a single grade of cotton. For these categories the deviation from the expected means was calculated from Equation 3 based on the single cotton grade involved.

INFLUENCE OF GROWING LOCATION

As shown in Table IV and Figure 2, cottons grown in NC, OK, TN, SC, AL, and MS generated dust concentrations slightly lower than the average produced by the same grade of cotton grown in all states. Although the differences were small, ranging from 59 to 146 $\mu g/m^3$, they were significant. Dust concentrations of cottons grown in LA, AR, GA, and CA did not differ significantly from the average concentration of cottons of similar grades grown in all states, while dust concentrations of cotton grown in the arid, dusty western states of TX, AZ, and NM were slightly higher. Mittal *et al.* [8] have noted that trash samples from cottons grown under arid conditions tend to have relatively high inorganic contents—an observation that suggests that the higher dust concentrations generated by such cottons may be due to a relatively higher content of mineral matter from the soil. High mineral contents would probably not reduce the cotton grade but would show up as "cotton dust" measured by the VE. Such behavior could explain the observations reported herein that cottons grown in western states tend to generate higher dust concentrations than would be expected on the basis of cotton grade. It is perhaps of some interest to note that the "raw" unadjusted means by states y_s shown in Table I follow the same pattern as do the adjusted means reported in Table IV.

Even though a rather elaborate scheme has been utilized to compare results on the basis of a common grade of cotton, pitfalls abound which make some inferences very suspect. For example, the state showing the lowest raw and next-to-lowest adjusted dust concentrations is Oklahoma. From Table III it can be noted that 9 of the 13 bales from OK were Westburn variety. Of these, three were steamed. No other steamed bales were included in the bales evaluated here. Hence, the low dust concentrations associated with the processing of OK cotton could be indicative of the fact that steaming reduces the dust-generating potential of cotton more than it upgrades the classer's grade.

Another misleading conclusion is illustrated by the collection of bales grown in Alabama. Eight of these 12 bales were processed as part of an investigation designed to study the influence of time of harvesting. The four bales picked late (Nov 25, 1974) were downgraded from 4 to 5 because of grass content; these generated an average dust concentration of 280 $\mu g/m^3$ (instead of the grade average x_5 of 430 $\mu g/m^3$). The four bales picked early (Oct 11, 1974) consisted of two bales of grade 3 and two bales of grade 4. Dust concentrations measured for these bales averaged 330 $\mu g/m^3$ (close to the expected values of 336 $\mu g/m^3$ based on $x_3 = 329$ and $x_4 = 342$ $\mu g/m^3$). To further confuse the situation, two bales of Coker cotton of grade 4 grown in 1974 produced a dust concentration averaging 495 $\mu g/m^3$ (much higher than the average for grade 4 of 342 $\mu g/m^3$). Two bales of the same variety of cotton grown in the same field the following year were one grade lower in quality (grade 5) yet generated only about half as much dust (258 $\mu g/m^3$). As a consequence of these anomalies, the plot of observed versus expected dust concentrations based on grade for AL has a negative slope, as shown in Figure 6.

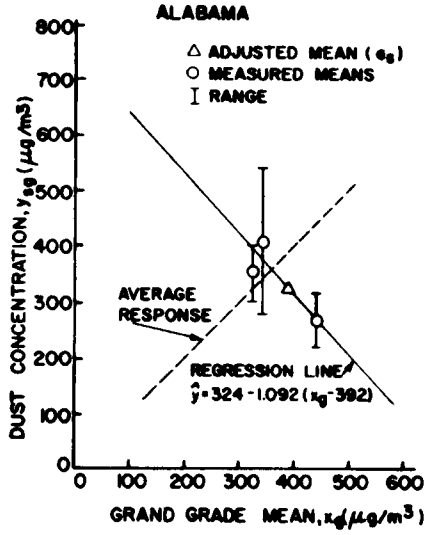

FIG. 6. Plot of the average dust concentration y_{sg} measured on all cottons grown in Alabama for each grade g versus the average dust concentration x_g measured on all bales of classer's grade g. (See Note, Fig. 1).

Although cottons from no other state have such extreme anomalies as those from AL, these data, as well as the OK data cited above, should serve to caution the reader that it is difficult, if not impossible, to predict and associate any deviations in dust concentrations observed from that expected on the basis of cotton grade directly with growing location or variety. Many other uncontrolled factors may also be exerting overriding influences. Indeed, the range in dust levels measured on a single grade of cotton grown in a single state can far exceed the differences observed between grades and between states. As shown in Figure 1, dust concentrations measured on grade 5 cotton grown in Texas ranged from 207 to 1094 $\mu g/m^3$—six times greater than any state effect.

Table IV and Figure 3 show that the confidence intervals for b do not include 1.00 for AR, AL, and NM, and that the interval for AZ is extremely large. The observed/expected dust-concentration relationships for cottons from these states were therefore examined in more detail. The reasons for the inverse correlation (*i.e.* negative b) for the cottons grown in AL have already been discussed. As shown in Figure 7, the high value of b for AR (5.33) is obtained because only grades

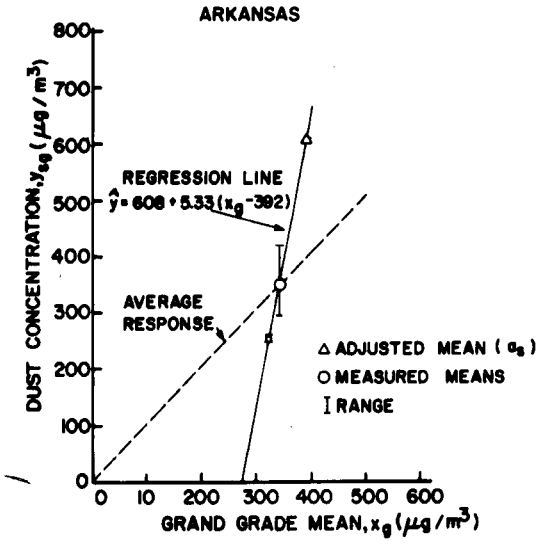

FIG. 7. Plot of the average dust concentrations y_{sg} measured on all cottons grown in Arkansas for each grade g versus the average dust concentration x_g measured on all bales of classer's grade g. (See Note, Fig. 1).

3 and 4 cottons are represented. The means of these two grades are very closely spaced, and both are below the grand average of 392 $\mu g/m^3$. The resulting regression line is very steep and leads to a misleading value for a. The situation for NM is similar. For this reason, the adjusted means Δy for these states were calculated from Equation 3. Although the confidence interval for b for AZ includes 1.00, its range is extremely large because a wide range in dust concentrations was observed for the grade 4 bales (from 290 to 701 $\mu g/m^3$).

Included in the bales analyzed were a group of 10 bales of Deltapine 16 cotton from five states (two each) all grown in the same crop year. All bales were grade 4 except for the two bales grown in Oklahoma, which were grade 3. A separate analysis of variance of the dust concentration data obtained from these 10 bales showed that there was a significant difference in the dust generated from bales grown in different locations.

These results are summarized in Table VI and show the ranking of the dust measurements to be in the same order as that given in Tables I and IV except for the CA-MS inversion. This difference is not significant in the 10-bale analysis. Since the cotton grown in OK is a better grade than the other cottons in this group, it is not surprising that the smallest quantity of dust was generated by this cotton. Although the remaining bales were all the same grade and variety of cotton, the amount of dust emitted varied by a factor of 2 to 1. Still, as pointed out above, cottons grown in the same field in AL in two consecutive years also varied by a factor of 2 to 1, again demonstrating that it would be futile to generalize about the effect of growing location on the dust-emitting characteristics of cotton, even if the grade and variety are the same.

TABLE VI. Vertical Elutriator cotton dust concentrations of Deltapine 16 cotton grown in five locations (all grade 4 except bales grown in OK which were grade 3).

State grown	VE dust concentration, $\mu g/m^3$		
	Bale A	Bale B	Average[a]
OK	194	176	185
SC	234	296	265
CA	448	351	400
MS	484	389	436
AZ	434	682	558

[a] All significantly different at 95% confidence level except for bracketed results, which were not significant at 90%.

INFLUENCE OF VARIETY

The most striking varietal effect shown in Tables II and V and Figure 4 is the reduction of 260 $\mu g/m^3$ in dust concentration measured on four bales of Westburn cotton of grade 5 (expected value 430 $\mu g/m^3$; observed value 183 $\mu g/m^3$.) This reduction is associated with the steaming of these bales, as discussed earlier.

Other statistically-significant changes are decreases in dust concentrations compounded with those expected for the Stoneville and Coker varieties, and increases for the Lockett, NcNair, and Stripper varieties. All of these changes are less than 100 $\mu g/m^3$. The Stripper cotton yielded a value significantly higher than the grand average of 392 $\mu g/m^3$, but the corresponding slope was less than 1.00. A closer look at this type of cotton, as illustrated in Figure 8, shows that the dust generated by this variety of cotton for grades 4 and 5 is consider-

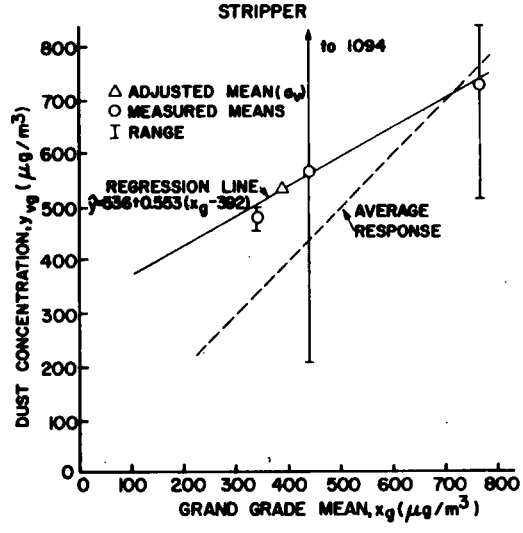

FIG. 8. Plot of the average dust concentration y_{vg} measured on all Stripper variety cottons for each grade g versus the average dust concentration x_g measured on all bales of classer's grade g. (See Note, Fig. 1).

ably greater than the corresponding averages of all cottons of these grades. For below-grade cotton (*i.e.*, grade 8) the measured dust concentration is slightly less than the grand average. Since the confidence interval on b does not include 1.00, Δy for the Stripper cottons was calculated from Equation 3.

It is interesting to note that the order of the adjusted means Δy listed on Table V is identical (except for one inversion) with the raw means y_v listed in Table II. The range in deviations from grade averages, Δy, associated with the varieties included in the study (excluding the Western samples, some of which were steamed) is 175 $\mu g/m^3$ (from -79 to $+96$ $\mu g/m^3$). The range in deviations associated with growing location is 291 $\mu g/m^3$ (from -146 to $+145$ $\mu g/m^3$). Thus in the bales examined, growing location introduced greater variations in the amount of dust generated for bales of given grade than did variations in variety. Brown *et al.* [2] have concluded that the composition of electrically-precipitated cotton dusts were affected more by growing location than by variety. Mittal *et al.* [8] point out, on the other hand, that variety may play an important role in the chemical composition of cotton dust.

Trash Content and Dust Concentrations Measured on Other Samplers

The inferences discussed above are borne out equally well, in principle but not in detail, by measurements made with other samplers. It would be redundant, therefore, to tabulate these additional data. To illustrate the similarity, however, correlation coefficients between measurements made on the VE and those on the other samplers are indicated below.

Area sampler	$r^2 = 0.91$
High-volume sampler	$r^2 = 0.67$
Cyclone sampler (total)	$r^2 = 0.73$
Andersen sampler (total)	$r^2 = 0.76$

One of the other functions of the model card room is to provide wastes and trash from each bale processed for use in other studies [5-8]. Shirley Analyzer measurements are also made on each bale in order to determine whether such measurements can be used to predict either its dust-generating potential or its trash content. Although detailed analyses of the relationships between dust emission, trash contents, growing location, variety, and grade have not been made, there are many similarities in the observed data, as indicated by the correlation coefficients listed below:

VE dust concentration *vs.* total wastes	$r^2 = 0.35$
VE dust concentration *vs.* Shirley trash	$r^2 = 0.32$
VE dust concentration *vs.* Shirley invisible	$r^2 = 0.20$
VE dust concentration *vs.* Shirley total	$r^2 = 0.34$
Total wastes *vs.* Shirley trash	$r^2 = 0.74$
Total wastes *vs.* Shirley invisible	$r^2 = 0.27$
Total wastes *vs.* Shirley total	$r^2 = 0.71$

A most striking observation concerning trash measurements was an almost complete reversal in the dust-trash relationship between OK and NM cottons. While the dust emitted from cottons grown in Oklahoma is the lowest of any state, the total wastes and Shirley trash and nonlint content of the OK cottons are exceeded by only two other states. New Mexico cottons, which have the highest dust emissions, have the lowest total wastes, Shirley trash, and Shirley nonlint content. The significance of these observations remains to be examined.

Summary and Conclusions

An attempt has been made to determine whether growing location, variety, and classer's grade influence the amount of dust emitted while processing cotton in a model card room. To answer this often-asked question, it was considered worthwhile to analyze the results collected from the processing of 140 bales of cotton over a period of 3 years. As commonly experienced when data are collected randomly over a long time period, a coherent analysis can be difficult because the data are unbalanced with respect to the set of independent variables of interest. In the present study the data available do not include all varieties from all states, each with a complete range of grades. Thus it is not possible to determine the independent effects of the three independent variables examined, and measurements averaged over individual growing locations, varieties, and grades cannot be compared directly.

An analysis was therefore made based on the assumption that the dust concentrations are completely determined by the classer's grade. Any deviation of the dust concentration measured on a specific sample from that of the average of all bales of the same grade was therefore ascribed to some other factor, such as the state in which the cotton was grown and/or the variety. As expected, the dust concentration measured in the card room was found to increase as the quality of the cotton processed went down (from 329 $\mu g/m^3$ for middling cotton, grade 3, to 756 $\mu g/m^3$ for below grade cotton, grade 8). The exception noted for grade 6 cotton should be excluded, because the four bales examined were grown in only one state and were too few to provide a representative average.

This analysis indicates that the dust concentrations generated while processing cottons grown in several states and of certain varieties deviated significantly from those expected on the basis of grade alone. In general the results suggest that cottons grown in the eastern U. S. A. produce less dust in the card room for a given

grade of cotton than the overall U. S. A. average, and cottons grown in the arid areas of the west generate more dust than the average. Quantitatively, the range of state average deviations from the U. S. A. average was from -146 to $+145$ $\mu g/m^3$, a spread that is quite small when compared with, for example, the range of 207 to 1094 $\mu g/m^3$ observed among bales of cotton of grade 5 grown in a single state (Texas). Some deviations from grade averages were associated with cotton varieties, but the range was even smaller than the effects associated with growing location. Neglecting the extreme effect of steaming, deviations for varieties ranged from -79 to $+96$ $\mu g/m^3$.

Although the trends cited above hold true in general, there were many anomalies and exceptions. For example, it was observed that the harvesting time might completely change the dust-grade relationship. Harvesting method might also have the same effect. The relationship could also be reversed when one variety of cotton was grown in the same field in two successive years. The steaming of cotton could also change this relationship. Thus many factors other than growing location and variety can influence the results, and extreme caution must be exercised in their interpretation.

Finally, although one might expect that the examination of data from a group of 140 bales would be a large enough collection to assess the influence of growing location, variety, and grade on the dust concentrations generated during processing, it was found that many of these effects were obscured by other overriding, uncontrolled factors.

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