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Cotton Dust Concentrations and Particle Size Distributions Associated with Genotypes

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The problem of byssinosis has plagued cotton textile mills for hundreds of years, and it is still a problem today. With the regulations on airborne raw cotton dust set by OSHA and the ACGIH, research regarding the measurement of cotton dust in lint fiber is a necessity. A procedure known as the mass concentration particle size distribution (MCPSD) technique, developed at Texas A&M University, was used to measure the characteristics of cotton dust as affected by harvesting method and genotype. Cotton genotypes from three harvest seasons were analyzed by using a Coulter Counter, Model TAII, to obtain the mass concentrations and particle size distributions of dust present in the lint fiber. The genotypes were subjected to both hand harvesting and conventional spindle harvesting for comparison purposes. Results from the dust concentration analyses of particles less than 100 μm, 16 μm, and 8 μm in diameter, respectively, are presented. Also, a proposed procedure to obtain large quantities of "cotton dust" from gin trash material is discussed.

Introduction

Cotton dust is undoubtedly the most serious problem facing the cotton and textile industries today. Incidences of byssinosis, both acute and chronic, have been cited in textile processing environments as far back as the eighteenth century (*1*). Both the Occupational Safety and Health Administration (OSHA) (*2*) and the American Conference of Governmental Industrial Hygienists (ACGIH) (*3*) have set their respective criteria, the permissible exposure limit (PEL) and threshold limit value (TLV), at 200 $\mu m/m^3$. However, OSHA has proposed changes that would alter the list of processes to which this standard would apply.

Regardless of these changes, the byssinotic hazard of cotton dust remains. Since it appears that the lint fiber is not the causitive agent of byssinosis, it is logical to assume that the nonlint fraction of inhalable dust (<15 μm) entrained in the working environment is responsible (*4*).

It was with this idea in mind that research was conducted at Texas A&M University to measure respirable dust content in cotton lint. A procedure was developed to provide a measure of the mass concentration of dust per unit weight of lint. It consisted of a lithium chloride/methanol liquid wash to remove dust from a lint sample and a subsequent particle size distribution using a Coulter Counter Model TAII. The entire process became known as the mass concentration-particle size distribution (MCPSD) technique, and it proved to be a simple and repeatable dust analysis procedure (*5*).

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Test Description

With the development of the MCPSD technique at Texas A&M, research was initiated to apply the process in an analysis of various cotton genotypes. While the idea of breeding cotton to obtain more desirable trash/dust characteristics was not new (*6*), the opportunity to incorporate a new analytical method into the investigation of a variety of genotypes led to high expectations.

The MCPSD procedure was performed on various genotypes of cotton from three harvesting seasons: 1980, 1982, and 1983. The genotypes and abbreviations are given in Table 1.

Pilose cotton is characterized by a dense covering of short trichomes (plant hairs) on leaves, stems, bracts, and bolls. In normally pubescent cottons, the covering of trichomes is less dense and trichomes are somewhat longer. In glabrous cottons, trichomes are absent (or nearly so) on above-ground parts of the plant. In frego bract cottons, the bracts subtending the fruit form (square, bloom, or boll) are elongated and narrow, with a prominently twisted appearance. Presence of the okra

gene produces a leaf that is palmately lobe, or divided, into five sections.

Prior to normal harvesting each year, mature bolls that had opened completely (slightly, but nonetheless completely), designated "clean cotton," were hand-picked from each plot. These samples were removed from the boll, dried, and then subjected to normal ginning and cleaning. After the clean cotton was harvested, the plots were spindle harvested and ginned in conventional fashion. This cotton was termed "ginned cotton."

Table 1. Cotton genotypes and abbreviations.

	Genotype	Abbreviation
1980	Normal leaf and pubescence	NLP
	Okra–frego–smooth	OFS
	Okra–frego–pubescent	OFP
	Pilose	PIL
	Pilose–frego	PFR
	Pilose–okra	POK
	Frego–smooth	FRS
	Smooth–okra	SMO
	Okra–pubsecent	OKP
	Heavy pubescence	HPB
1982	Normal leaf and pubescence	NLP
	Pilose 1	PL1
	Pilose 2	PL2
	Glabrous 1	GL1
	Glabrous 2	GL2
	Glabrous–frego 1	GF1
	Glabrous–frego 2	GF2
	Okra–glabrous	OKG
	Okra	OKR
1983	Normal leaf and pubescence	NLP
	Pilose	PIL
	Pilose–okra	POK
	Glabrous	GLA
	Glabrous–frego	GFR
	Okra–glabrous	OGL
	Okra–frego	OFR
	Okra	OKR

Results and Discussion

Figures 1 through 6 are graphical representations of the mass concentration results for all samples in the

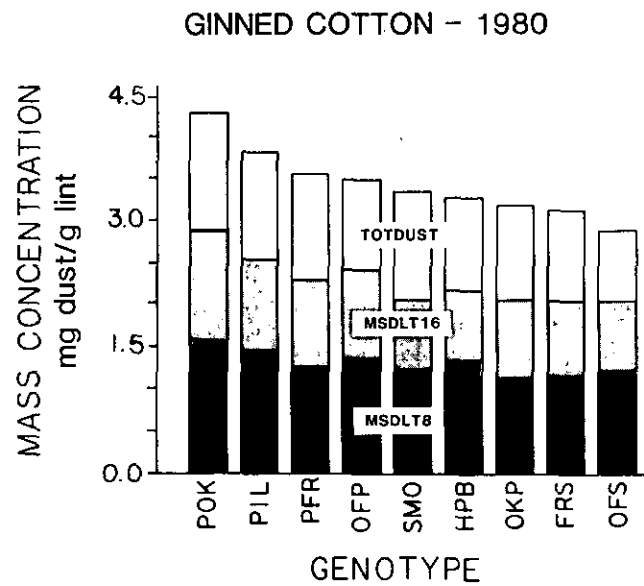

FIGURE 2. Mass concentrations of total mass of dust less than 100 μm (TOTDUST), mass of dust less than 16 μm (MSDLT16), and mass of dust less than 8 μm (MSDLT8) for 1980 "ginned cotton" genotype samples.

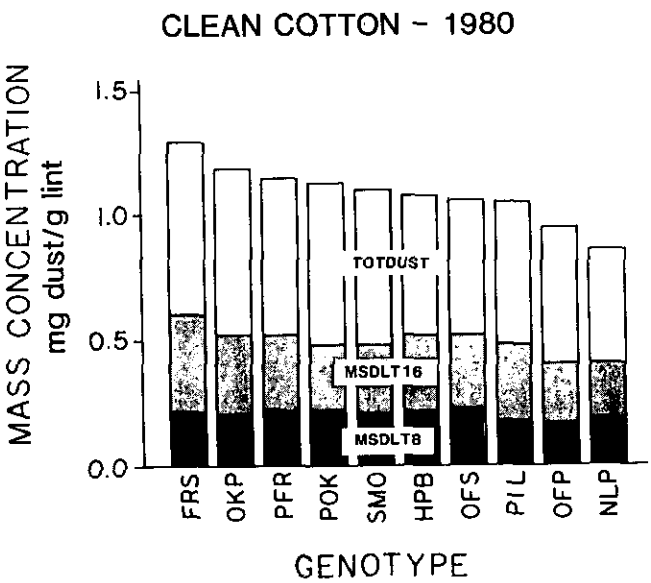

FIGURE 1. Mass concentrations of total mass of dust less than 100 μm (TOTDUST), mass of dust less than 16 μm (MSDLT16), and mass of dust less than 8 μm (MSDLT8) for 1980 "clean cotton" genotype samples.

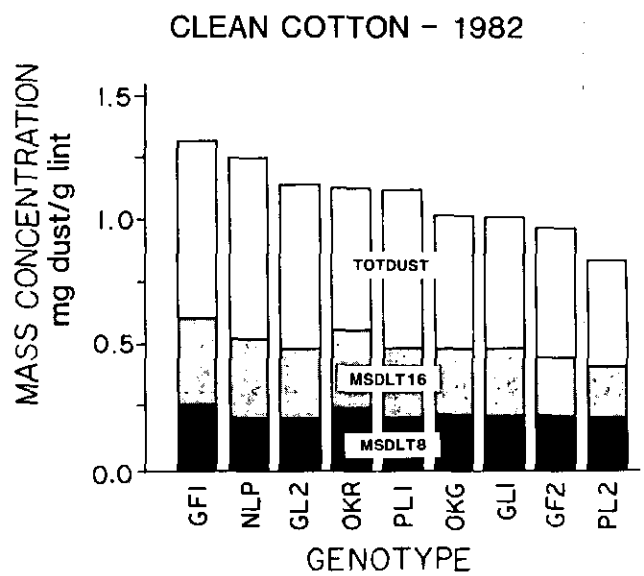

FIGURE 3. Mass concentrations of total mass of dust less than 100 μm (TOTDUST), mass of dust less than 16 μm (MSDLT16), and mass of dust less than 8 μm (MSDLT8) for 1982 "clean cotton" genotype samples.

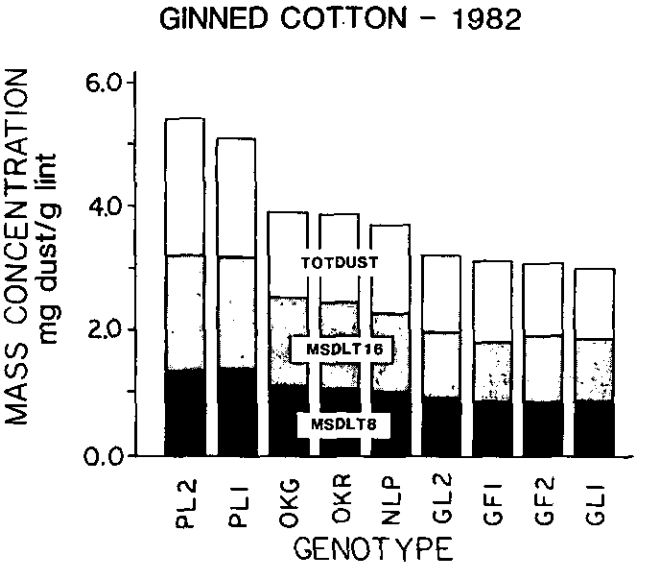

FIGURE 4. Mass concentrations of total mass of dust less than 100 μm (TOTDUST), mass of dust less than 16 μm (MSDLT16), and mass of dust less than 8 μm (MSDLT8) for 1982 "ginned cotton" genotype samples.

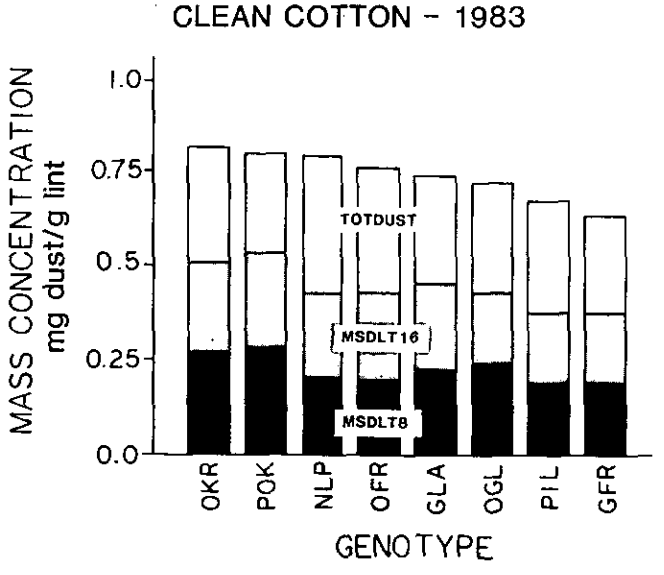

FIGURE 5. Mass concentrations of total mass of dust less than 100 μm (TOTDUST), mass of dust less than 16 μm (MSDLT16), and mass of dust less than 8 μm (MSDLT8) for 1983 "clean cotton" genotype samples.

study. Each graph is divided into three dust categories: (1) the total mass of dust per gram of lint less than 100 μm (TOTDUST); (2) the mass of dust less than 16 μm (MSDLT16), which represents the inhalable fraction of dust in the samples; (3) the mass of dust less than 8 μm (MSDLT8), which represents the respirable dust in the samples. While these figures do provide a representation of the relative differences in genotype dust contents, it

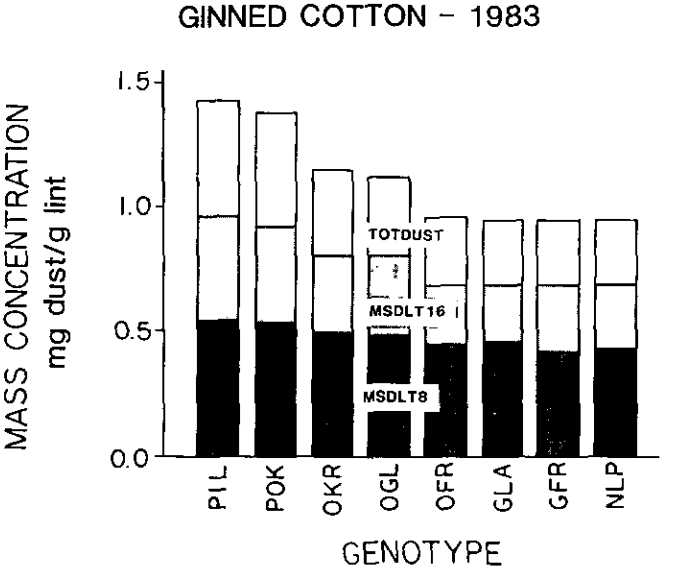

FIGURE 6. Mass concentrations of total mass of dust less than 100 μm (TOTDUST), mass of dust less than 16 μm (MSDLT16), and mass of dust less than 8 μm (MSDLT8) for 1983 "ginned cotton" genotype samples.

Table 2. Duncan's Multiple Range Test for 1980 clean cotton samples.[a]

Dust category	Genotype	Number of repetitions	Mean mass concentration, mg dust/g lint	
TOTDUST	FRS	3	1.2882	A
	OKP	3	1.1786	A
	PFR	3	1.1417	A
	POK	3	1.1223	A
	SMO	3	1.0884	A
	HPB	3	1.0734	A
	OFS	3	1.0455	A
	PIL	3	1.0446	A
	OFP	3	0.9403	A
	NLP	3	0.8531	A
MSDLT16	FRS	3	0.6239	A
	PFR	3	0.5492	A
	HPB	3	0.5428	A
	OKP	3	0.5396	A
	OFS	3	0.5385	A
	POK	3	0.5134	A
	PIL	3	0.5058	A
	SMO	3	0.4970	A
	OFP	3	0.4315	A
	NLP	3	0.4310	A
MSDLT8	PFR	3	0.2209	A
	OFS	3	0.2185	A
	POK	3	0.2177	A
	FRS	3	0.2139	A
	HPB	3	0.2123	A
	SMO	3	0.2063	A
	OKP	3	0.2032	A
	NLP	3	0.1808	A
	PIL	3	0.1782	A
	OFP	3	0.1460	A

[a] Means followed by the same letter within each dust category are not significantly different at the 5% level of significance.

is not easy to draw any scientific conclusions from them. Therefore, a statistical analysis was performed on the mass concentration data.

The statistical test used to draw conclusions about the data was Duncan's Multiple Range Test at a 5% level of significance. This test was performed to determine if there were any mean mass concentrations among the various genotypes that were significantly different from the other means. The results of these tests can be found in Tables 2 through 7. Each of the three dust categories (TOTDUST, MSDLT16, MSDLT8) was tested. In examining the test results on clean cotton (Tables 2, 4, and 6), there appears to be concurrence of results between the 1980 and 1983 data, in that no means are significantly different. However, in the TOTDUST and MSDLT16 data for clean cotton, three and two significant groups are observed respectively. Upon closer examination of the genotypes, though, there are no specific trends toward a certain genotype being responsible for a significantly different dust content.

The same conclusion cannot be drawn when interpreting the results of the ginned cotton tests (Tables 3, 5, and 7). In all three years of data, the pilose genotypes consistently contain the highest amounts of dust per gram of fiber. This is especially prevalent in the 1982 TOTDUST and MSDLT16 data, where both of the pilose genotypes are significantly different from all the others in the study (see Table 5). It also appears that a combination of pilose pubescence with an okra-type leaf causes high dust content levels (see Tables 3 and 7). On the other hand, in all ginned cotton samples, the glabrous characteristic consistently yielded lower dust content levels. The incorporation of the frego bract characteristic into a variety caused no discernable increase or decrease in dust content.

The MCPSD analyses of cotton dust samples from the 1980 and 1982 tests yielded comparable lint dust content results for both the clean and ginned cottons. However, the 1983 MCPSD results (Tables 6 and 7) suggested that the lint fiber from the 1983 test contained significantly less cotton dust per unit mass than the previous two years. In examining the test plot histories of the three years, an explanation was obtained. In both 1980 and 1982 a rain occurred during the harvesting season. In 1983, the cotton was late, and in mid-September, prior to boll opening, heavy rains occurred (the result of a hurricane). Following these rains, bolls opened and were harvested during a near perfect harvest (no rainfall).

While the 1983 ginned lint samples had lower dust content values when compared to 1980 and 1982, they were not free of dust. In fact, the so-called "clean cotton" exhibited dust contents of approximately 1 mg of dust

Table 3. Duncan's Multiple Range Test for 1980 ginned cotton samples.[a]

Dust category	Genotype	Number of repetitions	Mean mass concentration, mg dust/g lint	
TOTDUST	POK	3	4.285	A
	PIL	3	3.791	AB
	PFR	3	3.519	AB
	OFP	3	3.475	AB
	SMO	2	3.320	AB
	HPB	3	3.249	AB
	OKP	3	3.160	B
	FRS	3	3.110	B
	OFS	3	2.891	B
MSDLT16	POK	3	2.970	A
	PIL	3	2.552	AB
	OFP	3	2.443	AB
	PFR	3	2.343	AB
	HPB	3	2.294	AB
	OKP	3	2.165	AB
	FRS	3	2.130	B
	SMO	2	2.126	B
	OFS	3	2.110	B
MSDLT8	POK	3	1.571	A
	PIL	3	1.407	A
	OFP	3	1.361	A
	HPB	3	1.305	A
	PFR	3	1.230	A
	OFS	3	1.197	A
	SMO	2	1.188	A
	FRS	3	1.161	A
	OKP	3	1.106	A

[a] Means followed by the same letter within each dust category are not significantly different at the 5% level of significance.

Table 4. Duncan's Multiple Range Test for 1982 clean cotton samples.[a]

Dust category	Genotype	Number of repetitions	Mean mass concentration, mg dust/g lint	
TOTDUST	GF1	4	1.311	A
	NLP	4	1.241	AB
	GL2	4	1.126	AB
	OKR	4	1.120	AB
	PL1	4	1.111	ABC
	OKG	4	1.012	BC
	GL1	4	0.9978	BC
	GF2	4	0.9613	BC
	PL2	4	0.8336	C
MSDLT16	GF1	4	0.6130	A
	OKR	4	0.5669	AB
	NLP	4	0.4478	AB
	PL1	4	0.5191	AB
	GL2	4	0.5133	AB
	OKG	4	0.4974	AB
	GL1	4	0.4953	AB
	GF2	4	0.4576	AB
	PL2	4	0.4401	B
MSDLT8	GF1	4	0.2478	A
	OKR	4	0.2400	A
	GL1	4	0.2169	A
	OKG	4	0.2132	A
	NLP	4	0.2058	A
	GF2	4	0.2049	A
	GL2	4	0.1994	A
	PL2	4	0.1955	A
	PL1	4	0.1925	A

[a] Means followed by the same letter within each dust category are not significantly different at the 5% level of significance.

Table 5. Duncan's Multiple Range Test for 1982 ginned cotton samples.[a]

Dust category	Genotype	Number of repetitions	Mean mass concentration, mg dust/g lint	
TOTDUST	PL2	4	5.256	A
	PL1	4	5.018	A
	OKG	4	3.867	B
	OKR	4	3.841	B
	NLP	4	3.659	B
	GL2	4	3.190	B
	GF1	4	3.102	B
	GF2	4	3.056	B
	GL1	4	2.976	B
MSDLT16	PL1	4	3.183	A
	PL2	4	3.168	A
	OKG	4	2.439	B
	OKR	4	2.462	BC
	NLP	4	2.289	BC
	GL2	4	1.987	BC
	GF2	4	1.919	BC
	GL1	4	1.866	C
	GF1	4	1.826	C
MSDLT8	PL1	4	1.390	A
	PL2	4	1.361	AB
	OKG	4	1.152	ABC
	OKR	4	1.104	BC
	NLP	4	1.070	C
	GL2	4	0.9263	C
	GF1	4	0.8911	C
	GL1	4	0.854	C
	GF2	4	9.8837	C

[a] Means followed by the same letter within each dust category are not significantly different at the 5% level of significance.

per gram of lint. Herein lies the cotton dust problem.

Suppose that there exists a carding room in a mill that measures 12 m high, 10 m wide, and 17 m long and contains ten cards. Each card can process 18,160 g lint/hr. Thus, the total capacity for the room is

$$(18{,}160)(10) = 181{,}600 \text{ g lint/hr}$$

Now suppose that each gram of lint contains 1.0 mg of inhalable dust (a conservative amount). Assuming that a mere 10% of this dust is entrained in the room air. The concentration of dust in the air is then

$$\frac{\left(181.6 \frac{\text{kg lint}}{\text{hr}}\right)\left(1.0 \frac{\text{mg dust}}{\text{g lint}}\right)\left(1000 \frac{\text{g}}{\text{kg}}\right)\left(0.10\right)}{(12 \text{ m})(10 \text{ m})(17 \text{ m})} = 8.9 \frac{\text{mg}}{\text{m}^3\text{-hr}}$$

which greatly exceeds the recommended OSHA exposure limit of 0.2 mg/m^3! Therefore, even "clean" lint can result in relatively high dust levels in working environments.

Topics for Future Research

With the development of the MCPSD technique, it has become practical and relatively simple to analyze lint samples for dust that represents a byssinotic hazard. However, a major problem in performing research with these extremely small particles is the inability of researchers to obtain sizable quantities of cotton dust.

Since the mass concentrations and particle size distributions of cotton dust have been determined in numerous lint samples, it may be possible to develop procedures whereby large quantities of cotton dust can be extracted from a gin trash parent material.

Several pounds of dust were obtained from the U.S. Cotton Ginning Research Laboratory in Stoneville, Mississippi. This dust was the result of sifting cotton gin trash through a 200 μm screen to remove unwanted larger particles. With the recent acquisition of a Donaldson Air Classifier in the Department of Agricultural Engineering, it is hoped that large amounts of the small diameter dust fractions can be isolated in order to facilitate the creation of a "mixture" of "cotton dust" that is representative of the type of dust presently being extracted from lint fiber. This process will yield much larger amounts of "cotton dust" than are presently available on which to carry out byssinosis research.

Table 6. Duncan's Multiple Range Test for 1983 clean cotton samples.[a]

Dust category	Genotype	Number of repetitions	Mean mass concentration, mg dust/g lint	
TOTDUST	OKR	4	0.8080	A
	POK	4	0.7970	A
	NLP	4	0.7904	A
	OFR	4	0.7615	A
	GLA	4	0.7409	A
	OGL	4	0.7158	A
	PIL	4	0.6744	A
	GFR	4	0.6308	A
MSDLT16	POK	4	0.5446	A
	OKR	4	0.5216	A
	GLA	4	0.4704	A
	OGL	4	0.4547	A
	NLP	4	0.4545	A
	OFR	4	0.4353	A
	PIL	4	0.3973	A
	GFR	4	0.3784	A
MSDLT8	POK	4	0.2798	A
	OKR	4	0.2651	A
	OGL	4	0.2345	A
	GLA	4	0.2229	A
	NLP	4	0.2013	A
	OFR	4	0.1935	A
	GFR	4	0.1879	A
	PIL	4	0.1849	A

[a] Means followed by the same letter within each dust category are not significantly different at the 5% level of significance.

Table 7. Duncan's Multiple Range Test for 1983 ginned cotton samples.[a]

Dust category	Genotype	Number of repetitions	Mean mass concentration, mg dust/g lint	
TOTDUST	PIL	4	1.423	A
	POK	4	1.373	A
	OKR	4	1.145	AB
	OGL	4	1.113	AB
	OFR	4	0.9506	B
	GLA	4	0.9355	B
	GFR	4	0.9345	B
	NLP	4	0.9345	B
MSDLT16	PIL	4	0.9794	A
	POK	4	0.9322	A
	OKR	4	0.8372	A
	OGL	4	0.8308	A
	OFR	4	0.7136	A
	GLA	4	0.6995	A
	NLP	4	0.6900	A
	GFR	4	0.6886	A
MSDLT8	PIL	4	0.5375	A
	POK	4	0.5267	A
	0KR	4	0.4871	A
	OGL	4	0.4871	A
	GLA	4	0.4512	A
	OFR	4	0.4437	A
	NLP	4	0.4221	A
	GFR	4	0.4108	A

[a] Means followed by the same letter within each dust category are not significantly different at the 5% level of significance.

Summary

Three harvest seasons of cotton of various genotypes were subjected to hand picking immediately after the bolls opened, and then to spindle harvesting. The mass concentrations of the hand-harvested (clean cotton) showed no significant dust retention characteristics based on genotype. However, the pubescent genotypes of cotton subjected to spindle harvesting (ginned cotton), especially heavily pubescent pilose varieties, showed significant increases in lint fiber dust concentrations. At the same time, varieties containing the glabrous characteristic consistently had the lower dust concentrations when subjected to the same treatment.

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