Symbol	Chromosomes	Chromosomal Designation	
8997	5-8	5L. 16	8L. 08
9002	2-6	2L. 57	6L. 58
9020	8-10	8L. 13	10S. 50
9021	1-9	1L. 26	9L. 83

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1. Yield, stand and lodging of restored and of male sterile single crosses of maize compared to their regular counterpart single crosses.

Tests were conducted in the summer of 1959 to compare thirteen restorer single crosses and thirty-one male sterile single crosses on T cytoplasm with their regular counterpart single crosses on normal cytoplasm for yield, stand and lodging. All the single crosses in these tests were samples from lots produced by open pollination in isolated fields and represent material available for the production of commercial hybrid seed corn.

All the lines were regular corn belt dents and none of them originally were on T cytoplasm or carried the dominant allele of the full restoring gene designated as the "Rf" gene. However, some of the lines used, namely, M14, Oh41 and K166, carried a gene or genes for heavy partial restoring which made it impossible to follow the "Rf" gene in the conversion process and are therefore designated with the suffix "TRp" or "NRp", depending on whether the line had been converted to T cytoplasm or not. All other lines were non-restorers, unless the dominant allele of the Rf gene had been introduced in the conversion process. All converted lines were on T cytoplasm, whether they carried the full restorer gene, the partial gene or genes or were cytoplasmic male sterile. The suffixes TRf, TRp and Tms were used with the regular line designations to give the pertinent added information concerning the hereditary make-up of these converted counterpart lines.

Four donors for the Rf gene were used in the pollen restorer conversion matings. These had all been tested to determine that the restorer gene which they carried was allelic with the full restorer gene carried by the I153 inbred line. All the converted lines (TRf, TRp and Tms) had been back-crossed five generations or more after the initial outcross to introduce the T cytoplasm and the Rf gene, if also introduced. In addition, the restorer line L317TRf had been selfed twice before the production of the restorer singles in which it was used. The line K166 had not been converted onto T cytoplasm but was known to carry a gene or genes for heavy partial restoring. This line was used as the pollinator in the production of one of the restorer single crosses. All the other restorer (TRf) lines used were in the last backcross generation and the plants shedding pollen in the single-crossing field were therefore heterozygous for the Rf rf alleles. As seed parents in making up several of the restorer single crosses, some inbred lines on T cytoplasm but without restorer genes, (Tms lines), were used.

All comparisons of these counterpart single crosses on the two cytoplasms were made between paired plots which were adjacent to each other in all locations. The restorer single crosses versus their regular counterparts were grown in three locations: Ames, Iowa, Frankfort, Indiana, and Hillsboro, Ohio, in the summer of 1959. In all locations the test plots were planted by hand and the intended rate of planting was 16,000 seeds per acre. The plantings were made in hills with 40-inch spacings, each having four kernels. The stands were not thinned. The total number of plants in all plots were counted at harvest, as were the number of lodged plants. There were five hills planted in each of two replications at Ames and a full stand would have been forty plants. Eight hills were planted in each of two replications at Frankfort, Indiana, and a full stand would have been sixty-four plants. At Hillsboro, Ohio, ten hills were planted in one series and a full stand would have been forty plants. The plots were harvested by hand at maturity and yields were calculated as bushels per acre of shelled corn corrected to 15.5% moisture.

The male sterile singles versus their regular counterparts were tested at one location, Ames, Iowa, in 1959. The tests for these comparisons were conducted the same as were the restorer comparisons at the same location.

The yields for all the samples in the test of the restorer singles are given in Table 1, and Table 2 shows the differences for the paired comparison when the yield of the regular single cross was subtracted from the yield of the restorer single cross.

TABLE 1

Yield of 13 Restorer Single Crosses on T Cytoplasm Compared with their Counterpart Regular Single Crosses on Normal Cytoplasm.

Pedigrees of restorer single crosses	Yield in b.p.a. 15.5% H_2O Ames Iowa	Frankfort Ind.	Hillsboro Ohio	Pedigrees of regular single crosses	Yield in b.p.a. 15.5% H_2O Ames Iowa	Frankfort Ind.	Hillsboro Ohio
M14TRpxB103TRf	108	86	77	M14xB103	82	81	67
M14TRpxOh51ATRf	101	112	83	M14xOh51A	124	113	86
M14TRpxOh43TRf	113	79	93	M14xOh43	121	105	93
M14TRpxB14TRf	131	116	84	M14xB14	124	115	74
M14TRpxC103TRf	139	134	100	M14xC103	114	101	102
M14TRpx187-2TRf	106	108	76	M14x187-2	100	97	88
Oh41TRpxHyTRf	126	115	100	Oh41xHy	121	123	90
Oh43TmsxC103TRf	140	125	X	Oh43xC103	133	108	X
C103TmsxB14TRf	117	141	116	C103xB14	116	119	120
420TmsxHyTRf	114	110	X	420xHy	109	98	X
HyTmsxL317TRf	130	132	122	HyxL317	133	130	96
HyTmsxB14TRf	129	96	107	HyxB14	115	116	74
L317TRfxK166NRp	127	X	98	L317xK166	106	X	96

TABLE 2

Differences in Yield Between Restorer Single Crosses on T Cytoplasm Minus Yield of Counterpart Regular Single Crosses on Normal Cytoplasm. Data from Table 1.

	Yield in bushels per acre			
Basic Pedigree	Ames Iowa	Frank-fort Ind.	Hills-boro Ohio	Av. dif.
M14xB103	26	5	10	14
M14xOh51A	-23	- 1	- 3	- 9
M14xOh43	- 8	-26	- 0	-11
M14xB14	7	1	10	6
M14xC103	25	33	- 2	19
M14x187-2	6	11	-12	2
Oh41xHy	5	- 8	10	2
Oh43xC103	7	17	X	12*
C103xB14	1	22	- 4	6
420xHy	5	12	X	8*
HyxL317	- 3	2	26	8
HyxB14	14	-20	33	9
L317xK166	21	X	2	8*
	Total	201		

* Yields from 2 locations only

Mean difference: Plus 5.6 bushels per acre

σ s. dif. = 14.3 b. p. a.

σ mean dif. = 2.4 b. p. a.

The yields for the pollen restorer single crosses on T cytoplasm averaged 5.6 bushels per acre higher than the values for the regular single crosses on normal cytoplasm and the standard deviation for this mean difference was 2.4 bushels per acre. From these values it can be assumed that these pollen restorer single crosses on T cytoplasm yielded significantly higher than their counterpart regular single crosses on normal cytoplasm.

The values for the stands of all the cultures in the thirty-six paired comparisons are given in Table 3.

TABLE 3

Stands of 13 Restored Single Crosses on T Cytoplasm Compared with their Counterpart Regular Single Crosses on Normal Cytoplasm.

	Number of Plants per Comparison							
	Pollen restorer single crosses on T cytoplasm			:	Regular counterpart single crosses on normal cytoplasm			
Basic Pedigree	Ames Iowa	Frank-fort Ind.	Hills-boro Ohio	Total	: Ames Iowa	Frank-fort Ind.	Hills-boro Ohio	Total
M14xB103	39	58	31	128	: 30	55	30	115
M14xOh51A	32	62	34	128	: 39	60	32	131
M14xOh43	35	49	34	118	: 40	61	32	133
M14xB14	39	63	36	138	: 40	58	33	131
M14xC103	36	64	31	131	: 33	51	37	121
M14x187-2	31	63	36	130	: 36	59	35	130
Oh41xHy	38	57	36	131	: 39	61	31	131
Oh43xC103	36	56	X	92*	: 37	55	X	92*
C103xB14	37	63	37	137	: 36	56	33	125
420xHy	36	59	X	95*	: 35	55	X	90*
HyxL317	39	62	28	129	: 35	55	35	125
HyxB14	38	51	33	122	: 39	57	30	126
L317xK166	38	X	37	75*	: 33	X	32	65*
Total				1554				1515

* Stands from 2 locations only.

Average difference 36 paired comparisons equals 1.1 plant per test more for the restorer single crosses. This difference is not significant in these data.

Table 4 gives the number of lodged plants in each plot of the thirty-six paired comparisons.

TABLE 4

Paired Comparisons for Lodged Plants of Restorer Single Crosses on T Cytoplasm with their Counterpart Regular Single Crosses on Normal Cytoplasm.

	Number of Lodged Plants per Comparison							
	Pollen restorer single crosses on T cytoplasm			:	Regular counterpart single crosses on normal cytoplasm			
Basic Pedigree	Ames Iowa	Frank-fort Ind.	Hills-boro Ohio	Total :	Ames Iowa	Frank-fort Ind.	Hills-boro Ohio	Total
M14xB103	0	6	1	7 :	1	3	5	9
M14xOh51A	0	2	2	4 :	0	10	1	11
M14xOh43	0	10	0	10 :	0	0	1	1
M14xB14	0	0	0	0 :	0	3	1	4
M14xC103	1	16	4	21 :	4	23	6	33
M14x187-2	0	35	3	38 :	6	34	2	42
Oh41xHy	1	7	24	32 :	2	29	7	38
Oh43xC103	0	3	X	3* :	1	5	X	6*
C103xB14	0	1	0	1 :	0	1	0	1
420xHy	3	44	X	47* :	4	29	X	33*
HyxL317	12	28	15	55 :	12	45	25	82
HyxB14	0	1	0	1 :	0	0	0	0
L317xK166	8	X	18	26* :	8	X	19	27*
Total				245				287

* Lodged plants from 2 locations only.

Average differences 36 paired comparisons equals 1.0 plant per paired comparisons more for the regular single crosses on normal cytoplasm. This value is not significant in these data. Significant differences very evidently exist between the values for the varieties and the values for the locations. A study of these differences was not, however, the purpose of this investigation.

The percentages of restored plants were determined in two tests, one at Lantana, Florida, season of 58-59 and one at Hillsboro, Ohio, in the season of 1959 for the 13 pollen restorer lots of seed in these experiments. In the Hillsboro test the percent restoring was determined for the plants in the same plots on which the other determinations were made. At Lantana, Florida, the plants were in a special planting for the determination of the percent restoring. The results are shown in Table 5.

TABLE 5

Percent of Restored Plants for the Restorer Single Crosses on T Cytoplasm in Two Tests.

	Florida 58-59			: Hillsboro 59		
Pedigree	Total Plants	Restored Plants	% Restored	: Total Plants	Restored Plants	% Restored
M14TRpxB103TRf	164	145	88%	: 38	37	97%
M14TRpxOh51ATRf	153	133	87%	: 36	18	50%
M14TRpxOh43TRf	160	132	82%	: 35	22	63%
M14TRpxB14TRf	162	142	88%	: 38	38	100%
M14TRpxC103TRf	105	78	74%	: 35	20	57%
M14TRpx187-2TRf	174	168	96%	: 37	32	86%
Oh41TRpxHyTRf	173	128	74%	: 38	27	71%
Oh43TmsxC103TRf	183	105	57%	: 39	20	51%
C103TmsxB14TRf	173	104	60%	: 40	19	48%
Os420TmsxHyTRf	147	122	83%	: 40	21	52%
HyTmsxL317TRf	X	X	X	: 29	25	86%*
HyTmsxB14TRf	176	84	48%	: 35	23	66%
L317TRfxK166NRp	177	177	100%	: 37	29	78%
Weighted average:		78% restored			68% restored	

* Not included in weighted average percent restored.

All the TRf inbred lines except L317TRf were heterozygous for the Rf rf alleles. The M14TRp, Oh41TRp, and the K166NRp theoretically should be homozygous or nearly so for the gene or genes for heavy partial restoring. Therefore, in all the single crosses except those with L317TRf 50% of the plants would have been restored by the dominant Rf gene. Any significant increase of restoring in excess of 50% in these single crosses would be assumed to be the result of the dominant gene or genes for partial restoring carried by the M14TRp, Oh41TRp, or the K166NRp as influenced by environmental conditions or by modifying genes carried in either or both inbred lines or random variations of sampling.

The data from the paired comparisons of the 31 cytoplasmic male sterile singles with their regular counterpart singles are given in Table 6.

The yields for the cytoplasmic male sterile single crosses averaged 2.2 b. p. a. less than the values for the regular counterpart singles on normal cytoplasm. The standard deviation for this mean difference was 2.2 b. p. a. This difference is not large and in these data is not statistically significant. The total stands differed by only one plant between the totals for these two groups of single crosses. There was very little lodging in this test as a whole but no significant differences in lodging between the cytoplasmic male sterile cultures and the normal cultures were noted.

The T type of cytoplasm seems destined to replace the original type or types of cytoplasm in more and more of the commercial corn in the United States in the near future, with seed production following the "restored-sterile" method on this cytoplasm. Any, even minor, beneficial or detrimental effects of these two changes in the hereditary make-up of the corn plants becomes of great economic importance, as well as of basic scientific interest.

The results from these tests indicate that the cytoplasmic male sterile cultures tended to yield practically the same or slightly less than their pollen-fertile counterparts on normal cytoplasm, while the cultures with 50% or more restored pollen-fertile plants on T cytoplasm yielded appreciably more than their pollen-fertile counterpart cultures on normal cytoplasm. It would seem, therefore, that the yield of hybrids produced by the "restored-sterile" method on T cytoplasm would tend to yield sub-

stantially higher than their sterile counterparts on T cytoplasm. This agrees with the results reported by Stringfield, G. H. "Fertility Restoration and Yields in Maize," Agronomy Journal, Vol. 50:215-218. 1958. This would indicate that as high a percentage of restored plants as possible should be obtained in seed produced by the "restored-sterile" method when T cytoplasm is involved.

TABLE 6

Yields, Stands and Lodged Plants of 31 Male Sterile Single Crosses Compared with their Counterpart Regular Single Crosses on Normal Cytoplasm. Tested at Ames, Iowa, in 1959.

Pedigree		Yield			Stand		Lodged	
Cytoplasmic male sterile		Cytoplasmic male sterile	Regular	Tms minus reg- ular	Cytoplasmic male sterile	Regular	Cytoplasmic male sterile	Regular
Oh51ATmsxB8	Oh51AxB8	91	101	-10	33	37	0	0
Oh51ATmsxW64A	Oh51AxW64A	116	101	15	39	29	1	0
RLTmsx182B	RLx182B	111	110	1	38	35	0	2
RLTmsx162	RLx162	94	103	- 9	38	40	0	2
RLTmsxOh43	RLxOh43	116	124	- 8	39	39	0	0
RLTmsx751	RLx751	100	130	-30	34	39	1	0
RLTmsxOh51A	RLxOh51A	110	112	- 2	40	38	2	0
W64ATmsxWF9	W64AxWF9	102	82	20	37	31	0	0
WF9TmsxOh56A	WF9xOh56A	107	115	- 8	37	36	6	1
WF9TmsxRL-4	WF9xRL-4	102	92	10	36	38	0	3
WF9TmsxB8	WF9xB8	118	118	0	37	33	0	0
WF9TmsxOh51A	WF9xOh51A	130	100	30	38	35	0	1
WF9TmsxOh43	WF9xOh43	112	133	-21	33	37	0	0
WF9TmsxB21	WF9xB21	134	130	4	36	39	5	2
WF9TmsxOs420	WF9xOs420	129	132	- 3	35	37	0	2
WF9TmsxI205	WF9xI205	122	124	- 2	37	37	0	1
WF9TmsxB6	WF9xB6	134	127	7	38	37	0	0
WF9TmsxW22	WF9xW22	132	128	4	39	33	0	0
WF9TmsxB14	WF9xB14	119	122	- 3	34	37	0	0
WF9TmsxHy	WF9xHy	114	126	-12	29	37	0	0
WF9TmsxC103	WF9xC103	152	136	16	39	35	0	1
WF9TmsxN6	WF9xN6	132	125	7	39	38	0	1
WF9Tmsx751	WF9x751	122	124	- 2	38	38	0	1
WF9Tmsx187-2	WF9x187-2	118	120	- 2	38	37	0	2
WF9Tmsx38-11	WF9x38-11	127	134	- 7	35	36	2	0
WF9Tmsx07	WF9x07	122	134	-12	36	39	1	1
WF9Tmsx07A	WF9x07A	118	129	-11	35	39	0	0
WF9TmsxB7	WF9xB7	104	110	- 6	40	34	2	0
WF9TmsxR61	WF9xR61	112	118	- 6	31	34	2	2
WF9Tmsx317	WF9x317	108	116	- 8	38	35	9	5
07Tmsx187-2	07x187-2	110	131	-21	28	36	0	0
n = 31		3618	3687	-69	1124	1125	31	27

Mean difference in yield = -2.2 b. p. a.
σ s. dif. = 12.4 b. p. a.
σ mean dif. = 2.2 b. p. a.

In trying to explain the differences between cultures such as those reported here, at least four main variables must be considered. They are:

1. Differences due to the effects of the cytoplasms themselves
2. Possible pleiotropic effects of the restorer genes on other functions of the plant in addition to the restoration of pollen fertility
3. Changes in the genotypic make-up of the counterpart inbred lines remaining after the conversion processes have been carried out
4. The effect of pollen shedding as such on the other functions of the plants.

The results reported above may be explained as being due to two or more of the factors listed above. One very important problem will be to devise matings and experimental methods which will determine, as far as possible, the effects of each of these variables with the others held constant. Such matings are being made in the Florida 1959-1960 nursery for testing in experiments in the Corn Belt in 1960.

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1. Characterization of sterile cytoplasms.

In addition to the original S and T sources of sterile cytoplasm, we are currently maintaining 12 other sources, each in process of being combined with the genotypes of inbreds WF9 and A158. The detailed origins of 8 of these sources are given in Bulletin 610 of The Connecticut Agricultural Experiment Station, but for convenient reference the origins of the 12 new sources are presented in the table below. It will be noted that three sources, C, D and E, stem from various Vg stocks. Source E was listed in Bull. 610 as having originated from a cross between two Pennsylvania lines, but records kindly furnished by J. E. Wright show clearly that the source of this sterile cytoplasm was Coop stock 49-10, which was segregating Vg. The records also state that earlier Coop notes made by Emerson mention the presence of male sterile plants in this Vg stock (some progenies consisted of all male sterile plants). It is entirely possible that the Vg material originally maintained by the Coop carried sterile cytoplasm and restorer genes. Since the anthers of Vg plants often blast, it is probable that such plants would be used as seed parents in crosses, and in this way the cytoplasm of the Vg stock would be transmitted along with the Vg gene. Continued backcrossing would eliminate the restorer genes. This could account for the origin of cytoplasmic male steriles from Vg stocks.

A preliminary genetic test has been conducted on nine of the sources to determine whether each is S, T or a different type. The A158 and WF9 series of steriles, with from two to seven generations of backcrosses, were crossed by the inbreds NY16 and Ky21, both of which restore S and T. However, Buchert's findings (MNL, 1959) on the behavior of S restorer genes makes it possible to distinguish between S and T type restored steriles, provided the restorer genes are in heterozygous condition. In heterozygous restored S steriles, pollen grains with the non-restoring allele abort; thus, restoration is only 50 per cent. Heterozygous restored T steriles, on the other hand, approach 100 per cent restoration, since T restorers behave as though sporophytic in action.