UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 52

SCARRED ENDOSPERM AND SIZE INHERITANCE IN KERNELS OF MAIZE

(Publication authorized June 1, 1922.)

COLUMBIA, MISSOURI
JULY, 1922

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

*In service of U. S. Department of Agriculture.

Scarred Endosperm and Size Inheritance in Kernels of Maize

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In the summer of 1920 the writer found in a field of corn in central Pennsylvania a number of plants with striking chlorophyl patterns which are unlike any that have yet been described. These plants were numbered and marked in the field so that they could be identified at harvest time. The matured ears were sent to the writer at the University of Missouri by Mr. Webster Snyder in whose field they were discovered. Plantings were made from each ear in the greenhouse the following winter and the seedlings were found to be entirely green. One plant from each ear was grown to maturity in the greenhouse and self pollinated. In the summer of 1921 field plantings were made from the original ears and also from the self pollinated greenhouse ears. The F_2 progenies segregated plants with the chlorophyl patterns of the original plants together with a number of other characters, including a pistillate plant similar in appearance to tassel ear (Emerson, 1920) and the endosperm character described in this paper, which has been designated *scarred endosperm.*

The field plantings of 1921 were made at the Missouri Agricultural Experiment Station as part of a project in the genetics of maize carried on in the Department of Field Crops.

DESCRIPTION OF SCARRED ENDOSPERM

Maize kernels with scarred endosperm can usually be recognized on the ear, even though the kernels are so closely arranged that only the crowns are visible. The scarred kernels are not so large as the normal kernels on the same ear and are commonly pinched off so that they are somewhat similar in appearance to kernels with "rough identation".

The scarred character can more easily and certainly be recognized upon examination of the abgerminal surface of the kernel. Its external appearance is that of a scar left after the healing up of a deep wound.

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In Fig. 1 are shown camera lucida drawings of a number of kernels with scarred endosperm. In Fig. 2 are similar drawings of two scarred kernels from which the pericarp overlying the abgerminal surface was removed. The nature of this endosperm character can best be seen from the drawings. It is an irregular cavity in the endosperm on the abgerminal side of the kernel. The cavity consists in a crater-like excavation near the crown with divergent and often branched furrows extending towards the base of the kernel.

The pericarp over the crater-like excavation near the crown nearly always collapses and causes the kernels to have a *rough indentation.* Occasionally a kernel is found with the pericarp over the crater of the cavity in the form of a blister.

Scarred Endosperm and Size of Kernel.—Scarred kernels are uniformly smaller than normal kernels. In Fig. 3 is shown a crown view of a series of representative normal kernels (upper row) and scarred kernels (lower row) which were taken from the same ear. In Fig 4 is shown the same series of kernels, as in Fig. 3, but from the side. These figures show in a general way the relative differences in size between normal and scarred kernels of maize.

Scarred Endosperm and Thickness of Kernel.—The most conspicuous size difference between normal and scarred kernels is in the thickness of the kernels. Thickness here refers to the distance between the germinal and abgerminal surfaces of the kernel. The thickness of each kernel of individual ears segregating normal and scarred kernels was measured by using a sliding caliper rule and tabulated as shown in Table 1. Readings were made to the nearest one-half millimeter. The measurements were made by clamping the caliper over the end of the kernel at a uniform distance from the crown.

The distributions given in Table 1 show that for each ear the normal kernels are thicker than those with scarred endosperm. The mean thickness of normal kernels from individual ears varies from 3.856 to 5.722 millimeters. The mean thickness of the scarred kernels from the same ears varies from 3.100 to 5.360 millimeters. The mean difference in thickness of the normal and scarred kernels from the ears studied varied from 0.295 to 0.823 millimeter. The mean thickness of the normal kernels of the eight distributions listed in Table 1 considered collectively is 4.500 ± 0.144 millimeters. The mean thickness of the scarred kernels of these distributions is 3.926±0.258 millimeters. The normal kernels are 0.574 ± 0.295 millimeter thicker than the scarred

kernels. In Fig. 5 are given curves which show graphically the variation in thickness of the normal and scarred kernels. These curves represent the total frequencies of the distributions listed in Table 1.

Scarred Endosperm and Weight of Kernel.—The kernels of each ear studied were weighed individually to the nearest milligram and tabulated as shown in Table 2. In every case the mean weight of the normal kernels is higher than the mean weight of the scarred kernels from the same ear. The mean weights of the normal kernels from the ears studied varied from 251.92 to 341.10 milligrams. The mean weights of the scarred kernels from the same ears varied from 232.70 to 329.60 milligrams. The differences in the means of the individual ears varied from 1.24 milligrams for ear 1243-2 to 19.13 milligrams for ear 1238-16. In order to obtain a general expression of the mean weights of the normal and scarred kernels the distributions in Table 2 are considered collectively. The mean weight of the normal kernels from the eight ears is 274 milligrams and the mean weight of

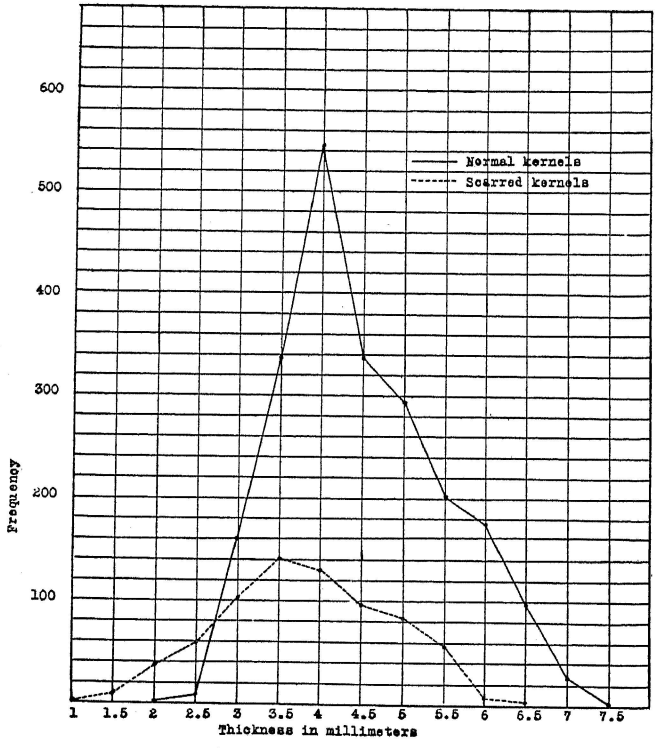

Fig. 5.—Variation in thickness of normal and scarred kernels.

the scarred kernels is 259.57 milligrams. This is a difference of 14.43 ± 1.29 milligrams. In Fig. 6 are curves of variation in weight of normal and scarred kernels when the eight distributions of Table 2 are considered collectively. In many respects these curves are similar to those for thickness of kernel given in Fig. 5.

The normal and scarred kernels respectively of each ear were weighed *en masse* with the results given in Table 3. From these total weights average kernel weights were obtained that do not involve the errors due to the separate weighing of the individual kernels. The average kernel weights are in fairly close agreement with the mean weights as given in Table 2.

The normal and scarred kernels from ear 1243-2 differ only slightly in average thickness and have approximately the same kernel weight. The mean weight of the normal kernels is given in Table 2 as 1.24 milligrams greater than that of the scarred kernels. The average weight, however, of the normals was found to be 1.36 milligrams less than the average weight of the scarred kernels. For the other ears the average weight of the normal kernels varies from 2.17 to 20.63 milligrams heavier than the scarred kernels taken from the same ear. The

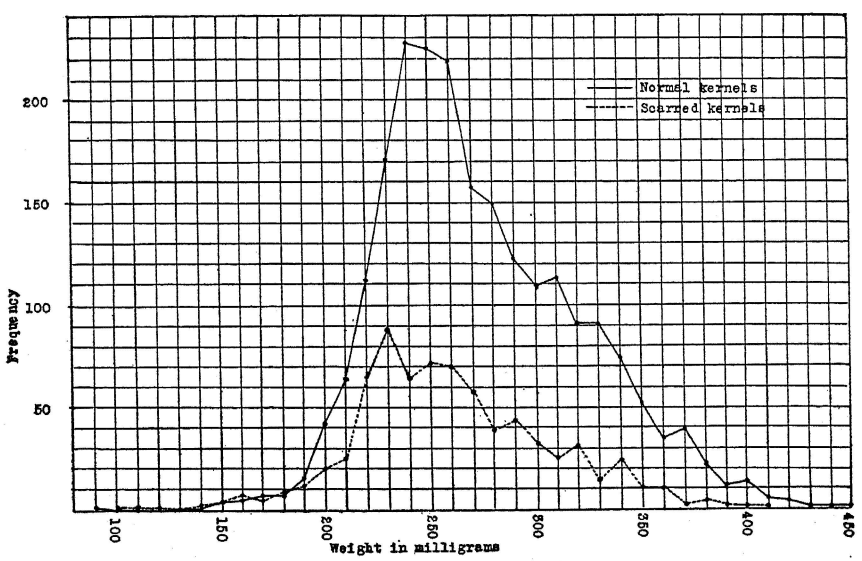

Fig. 6.—Variation in weight of normal and scarred kernels.

ERRATA

Transpose table headings of the two tables opposite page 6.

Page 7, table 3: Strike out "Average Kernel Weight in mgs." in box head of last column.

TABLE 2.—F_2 KERNELS OF THE CROSS NORMAL X SCARRED

Pedigree Number	Description	Thickness of Kernels in Millimeters													Total	Mean	Difference
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5			
1238-16	Normal	--	--	1	4	10	43	93	77	73	32	27	17	10	--	387	4.637	.572
	Scarred	--	1	5	5	11	28	32	25	17	8	5	1	--	--	138	4.065	
	Normal	--	--	--	1	28	95	167	54	37	23	11	3	--	--	419	4.123	.332
	Scarred	--	1	2	5	28	41	39	12	7	6	5	--	--	--	146	3.791	
	Normal	--	--	--	--	3	12	26	30	15	17	29	23	2	--	157	5.070	.815
	Scarred	--	--	--	1	3	9	13	7	10	4	1	1	--	--	49	4.255	
	Normal	--	--	--	--	5	23	69	62	69	62	41	12	3	--	346	4.860	.484
	Scarred	--	--	4	5	5	10	26	26	19	13	9	--	--	--	117	4.376	
	Normal	--	--	--	1	13	43	86	72	49	16	14	9	3	--	306	4.433	.823
	Scarred	--	--	11	13	25	25	15	14	13	6	1	--	--	--	123	3.610	
1245-6	Normal	--	--	--	3	104	118	102	33	22	18	9	6	3	--	418	3.856	.756
	Scarred	1	6	15	29	32	27	5	4	3	2	1	--	--	--	125	3.100	
1245-7	Normal	--	--	--	--	--	3	4	2	15	15	19	8	2	3	71	5.655	.295
	Scarred	--	--	--	--	--	1	1	4	6	7	0	4	2	--	25	5.360	
1245-8	Normal	--	--	--	--	--	1	1	7	14	19	23	18	5	--	88	5.722	.379
	Scarred	--	--	--	--	--	--	1	3	12	11	6	2	--	--	35	5.343	
Total	Normal	--	--	1	9	163	338	548	337	294	202	173	96	28	3	2192	4.500	.574
	Scarred	1	8	37	58	104	141	132	95	87	57	28	8	2	--	758	3.926	

TABLE 1.—THICKNESS OF F_2 KERNELS FROM THE CROSS NORMAL X SCARRED

Number	Description	Weight of Kernels in Milligrams																																							Total	Mean	Difference
		90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450			
1238-16	Normal	1	0	0	0	1	1	3	3	5	1	4	4	7	11	19	18	19	27	20	40	29	27	21	30	24	18	12	11	7	5	5	5	3	2	0	1	--	384	288.07	
	Scarred	--	1	1	1	1	1	1	2	1	3	4	4	4	3	5	10	8	14	8	7	13	9	8	8	8	4	5	3	0	1	1	--	--	--	--	--	--	139	268.94	19.13
1243-2	Normal	--	--	--	--	--	--	1	1	1	4	8	24	37	73	80	67	54	36	22	9	5	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	424	233.94	
	Scarred	--	--	--	--	--	--	1	0	0	1	2	6	12	32	41	11	18	10	7	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	145	232.70	1.24
1243-8	Normal	--	--	--	--	--	--	--	--	--	--	--	1	4	5	2	2	3	8	10	21	40	43	50	34	32	31	22	13	7	9	0	1	1	0	0	0	1	340	312.12	
	Scarred	--	--	--	--	--	--	--	--	--	--	1	2	1	2	4	4	4	1	7	11	15	16	11	12	4	12	3	5	2	1	1	1	--	--	--	--	--	121	300.17	11.95
1243-13	Normal	--	--	--	--	--	--	--	--	--	--	1	4	8	5	20	42	45	47	44	41	18	12	9	3	1	1	--	--	--	--	--	--	--	--	--	--	--	301	260.86	
	Scarred	--	--	--	--	--	2	0	1	2	1	1	2	1	8	15	17	18	22	18	8	5	4	0	3	--	--	--	--	--	--	--	--	--	--	--	--	--	128	249.84	11.02
1243-7	Normal	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	1	3	3	5	10	14	14	29	22	17	11	25	8	6	7	1	2	1	--	--	181	341.10	
	Scarred	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	1	1	4	4	0	5	2	2	1	2	--	--	--	--	--	--	--	24	329.60	11.50
1245-6	Normal	--	--	--	--	--	--	--	--	--	1	0	3	4	11	45	89	91	88	51	24	10	2	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	422	251.92	
	Scarred	--	--	--	--	--	--	2	3	0	2	3	4	5	18	19	17	22	17	9	4	2	0	0	1	--	--	--	--	--	--	--	--	--	--	--	--	--	128	237.03	14.89
1245-7	Normal	--	--	--	--	--	--	--	--	--	--	--	1	0	2	0	0	4	3	3	5	8	6	10	8	4	2	2	--	--	--	--	--	--	--	--	--	--	58	287.93	
	Scarred	--	--	--	--	--	--	--	--	--	1	0	0	0	0	1	1	0	0	4	3	3	3	2	2	2	3	--	--	--	--	--	--	--	--	--	--	--	25	284.82	3.11
1245-8	Normal	--	--	--	--	--	--	--	1	1	1	2	5	5	5	5	8	8	9	4	7	8	7	7	1	1	--	--	--	--	--	--	--	--	--	--	--	--	85	255.65	
	Scarred	--	--	--	--	--	--	--	1	2	0	1	2	2	2	3	4	2	6	3	0	5	0	0	2	0	1	--	--	--	--	--	--	--	--	--	--	--	36	247.22	8.43
Total	Normal	1	0	0	0	1	1	4	5	7	7	15	42	65	112	171	227	225	219	157	150	123	109	113	91	91	74	53	35	39	22	11	13	5	4	1	1	1	2195	274.00	
	Scarred	--	1	1	1	1	3	4	7	5	8	12	20	25	65	88	64	72	70	57	38	44	33	25	32	14	25	10	10	3	4	2	1	--	--	--	--	--	746	259.57	14.43

data in Table 3 show a greater difference in weight of normal and scarred kernels for some ears than the data in Table 2.

TABLE 3.—F_2 KERNELS FROM THE CROSS NORMAL X SCARRED

	Normal Kernels			Scarred Kernels			Difference
Pedigree Number	Number	Total weight in mgs.	Average kernel weight in mgs.	Number	Total weight in mgs.	Average kernel weight in mgs.	Average kernel weight in mgs.
1238-16	387	108880	281.34	138	37700	273.19	8.15
1243-2	442	102325	231.50	124	28875	232.86	—1.36
1243-7	185	52200	337.57	25	8200	328.00	9.57
1243-8	345	107775	312.10	119	36200	304.20	7.90
1243-13	299	80850	270.40	126	32240	255.87	14.53
1245-6	420	89750	213.69	126	24325	193.06	20.63
1245-7	60	17650	294.17	25	7300	292.00	2.17
1245-8	87	21750	250.00	35	8650	247.14	2.86
Total	2225	581180	261.20	718	183490	255.56	5.64

INHERITANCE OF SCARRED ENDOSPERM

The factor pair for scarred endosperm is designated by the symbols S_c s_c.

F_1 Generation.—F_1 kernels from the cross *scarred x normal,* or its reciprocal, have normal endosperm.

F_2 Generation.—When F_1 plants are self pollinated, ears are produced which have normal and scarred kernels in ratios approximating 3 : 1. In Table 4 are recorded the numbers of normal and scarred

TABLE 4.—F_2 KERNELS OF THE CROSS NORMAL X SCARRED

Pedigree Numbers	Normal kernels	Scarred kernels	Total	Ratio per 4
1238-16	390	138	528	2.955 : 1.045
1243-2	442	124	566	3.124 : 0.876
1243-7	185	25	210	3.524 : 0.476
1243-8	345	119	464	2.974 : 1.026
1243-13	299	126	425	2.814 : 1.186
1245-6	424	128	552	3.072 : 0.928
1245-7	60	25	85	2.828 : 1.172
1245-8	87	35	122	2.853 : 1.147
Total observed	2232	720	2952	3.026 : 0.974
Total expected	2214	738	2952	3.000 : 1.000

Deviation 18 ± 15.88

kernels taken from eight ears of F_1 plants that had been self pollinated. The ratios of the individual ears vary from 2.814 : 1.186 to 3.524 : 0.476. The average ratio for all the kernels from the eight ears is 3.026 : 0.974. The total numbers observed were 2232 normal and 720 scarred kernels. This is a deviation from the expected distribution of 18 ± 15.88 kernels.

F_3 Generation.—A field planting under family number 1238 was made from a self pollinated ear that segregated kernels with scarred endosperm. Twenty-one F_2 plants were grown to maturity. Three of these were wholly pistillate plants. The remainder were self pollinated and produced ears with kernels as indicated below:

	Kernels all Normal	Normal and Scarred kernels	All scarred Kernels
Observed	6	9	3
Expected	4.5	9	4.5
Deviation	1.5	0	—1.5

These numbers are small but are in close agreement with expectation.

SUMMARY AND DISCUSSION

Scarred is a new endosperm character in maize which consists in an irregular cavity in the endosperm on the abgerminal side of the kernel. Kernels with scarred endosperm usually have a *rough indentation*. Scarred kernels have been compared in thickness and weight with normal kernels and it is evident both from the general appearance of the kernels and from the data given in this paper that scarred kernels are smaller than the kernels with normal endosperm. Scarred endosperm is inherited as a simple Mendelian recessive character. Correlated with scarred endosperm is a difference in size of kernel that is apparently due to the same factor.

Emerson and East (1913) found in their study of quantitative characters in maize size differences, such as height of plant, length of ear, and size of kernel, to be due to multiple factors. Such quantitative characters, however, are not always due to multiple factors. A difference in size, or in any quantitative character, between certain individuals may be due to multiple factors, but a similar size or quantitative difference between certain other individuals may be due to a single factor. Thus differences in height of plants are commonly due to a number of factors, but a large number of height dif-

ferences in maize plants have already been found that are due to single factors. As examples may be mentioned *dwarf* and *anther ear* (Emerson, R. A., and Emerson, S. H., 1921), *brachytic* (Kempton, 1920) and others from the cultures of the writer and other workers in corn. By inter crossing these different types, progenies can be produced which segregate a number of factors for height of plant, and size inheritance becomes quantitative. The same principle may be applied to other quantitative differences.

Scarred endosperm represents a difference in size of kernel which is quantitative, but due apparently to a single factor. In this respect it is similar to size differences in seeds of beans observed by Johannsen (1913). In one of his pure lines Johannsen found a mutant with a longer seed than the parent stock. Seed length of this mutant bean was found by Leitch (1921) to be inherited as a single Mendelian character. Johannsen (1913) also found in his cultures a broad bean which, when crossed with the type, gives an F_2 progeny of 1 type : 2 intermediate : 1 broad.

It is reasonable to expect that maize plants will be found with other quantitative differences than height of plant and size of kernel that are inherited as simple Mendelian characters.

ACKNOWLEDGMENTS

The writer is indebted to George T. Kline for the drawings in Figs. 1 and 2, and to James F. Barham for the photographs in Figs. 3 and 4.

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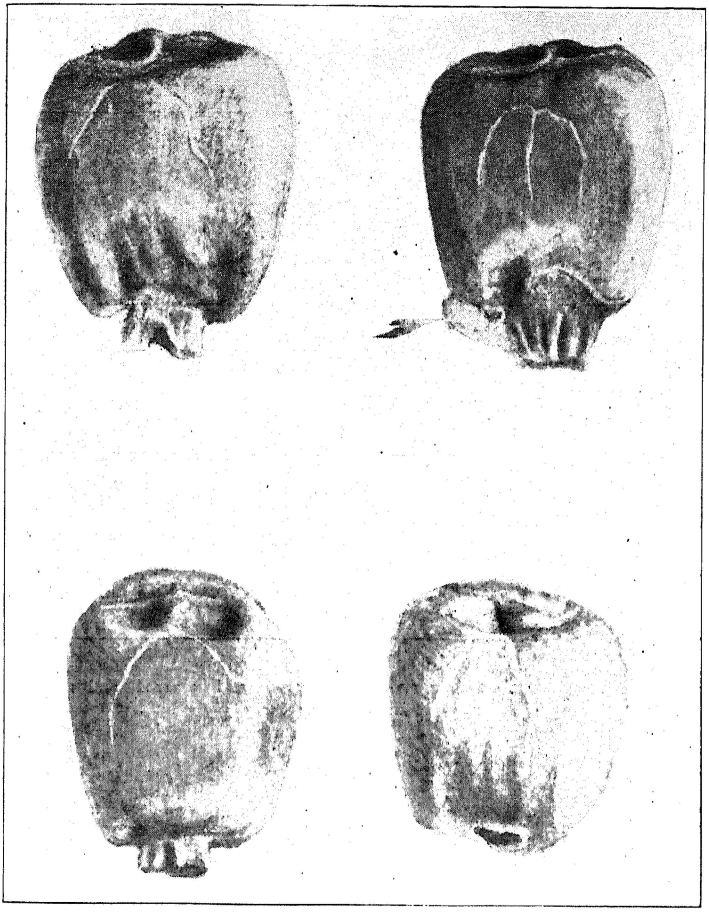

Fig. 1.—Maize kernels with scarred endosperm.

Fig. 2.—Maize kernels with scarred endosperm. The pericarp has been removed from these kernels to show the nature of the scarred endosperm.

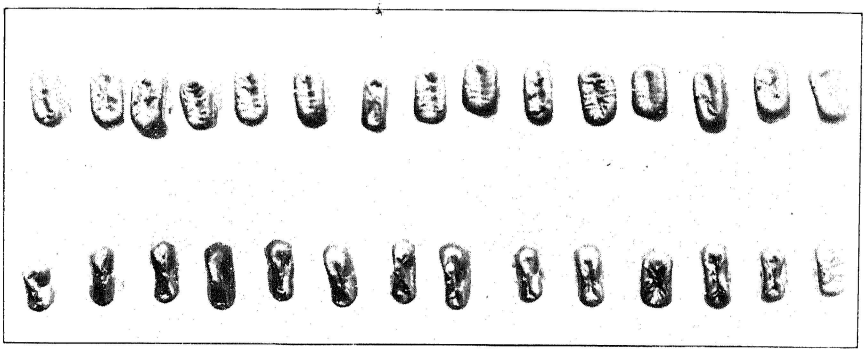

Fig. 3.—Kernels with normal endosperm (upper row) and scarred endosperm (lower row) from the same ear.

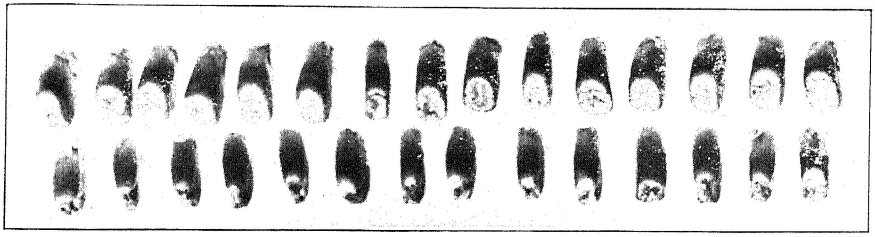

Fig. 4.—Kernels with normal endosperm (upper row) and scarred endosperm (lower row) from the same ear.