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Effectiveness of Distance and Border Rows in Preventing Outcrossing in Corn

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The maintenance of strain purity in cross-pollinated grasses is of utmost importance to the breeder and seed producer. Strain purity is dependent on adequate isolation, since the pollen is dispersed by the wind. Once superior germ plasm is obtained, its genetic identity must be maintained with the advance in generation of the material. The isolation requirements used as standards at the present have been primarily based on observation rather than extensive experimentation.

There is evidence that the dispersal of pollen of different grasses follows the same general pattern. Therefore, if information could be obtained with corn, where crosses may be easily detected, it probably would be helpful in establishing the isolation needed for maintaining purity in other cross-pollinated grasses.

Some of the factors which may affect natural outcrossing in cross-pollinated grasses are:

1. Distance of isolation.
2. Height and number of border rows.
3. Direction and velocity of the wind during pollen-shedding season.
4. Quantity of pollen produced by each strain or variety.
5. Time of season and time of day of pollen shedding.
6. Amount of self- or cross-sterility in the variety being contaminated.
7. Climatic conditions which affect the life of the pollen.
8. Variety or hybrid used (1).**
9. Number of bees (3) and birds (8) present during pollen shedding.

The primary objectives of this investigation, which was conducted at Stillwater, Oklahoma, during 1947 to 1949 inclusive, were to obtain information on the effectiveness of spatial isolation and border rows in decreasing outcrossing in corn, *Zea mays* L.

* Respectively: Agronomist, Plant Genetics; and Associate Agronomist, Corn.

** Figures in parentheses refer to "Literature Cited," page 18.

REVIEW OF LITERATURE

Standards of isolation for the production of certified seed have been established by the International Crop Improvement Association from time to time. In its most recent report (4), an isolation of 40 rods from other corn is required as the minimum for open-pollinated corn, inbred lines, and for the ear parent of hybrid corn. This distance may be modified by the size of the certifiable acreage, by adequate natural barriers, by differential maturity dates, and by planting border rows of the pollen parent. For example, in a field of 9 acres or less, the number of border rows required at an isolation of 40 rods is 1, at 25 rods 7, and at 15 rods 11. For certification, not more than 0.5 percent off-type plants in open-pollinated corn nor more than 0.1 percent definitely off-type or 2.0 percent doubtful plants in hybrid parents and inbred lines are permitted.

Varieties of sorghum must be isolated 60 rods from other sorghum for the production of registered seed and 40 rods for certified seed, except sudan grass which must be isolated 60 rods (4). Likewise, rye must be isolated 40 rods for the production of certified seed.

In these same standards, the isolation requirements for the open-pollinated tame grasses is 40 rods for the foundation, 20 rods for registered, and 10 rods for certified seed. For the open-pollinated native grasses, the requirement is 60 rods for foundation and 40 rods for registered and certified seed.

A distance of less than several miles was considered by Tracy (8) as insufficient to prevent outcrossing in corn. He stated that hedge barriers of Osage Orange, Maclura pomifera, (Raf.) Schneider, not over 12 feet in height were effective in preventing outcrossing within 8 to 10 rods of the hedge, while beyond that distance there were many crosses.

Meijers (7) in Wageningen, Holland, studied outcrossing in corn by means of xenia. A small field of Sanjunichi blue corn was located 4 rods to the west of a field of NHM yellow corn. The number of kernels showing xenia (blue color) in a single row of NHM which connected the two fields was used as a measure of the percentage of outcrossing. He stated that approximately 7.0 outcrossing occurred at 1 rod, 0.6 percent at 2 rods, 0.018 percent at 3 rods, and 0.003 percent at 4 rods, and that occasionally outcrossed kernels were found at 10 rods. The fact that both varieties were planted on the same date, even though Sanjunichi was considerably earlier than NHM, may account for the low percentages of outcrossing.

Studies were conducted in the Northern Caucasus of the U.S.S.R. by Salamov (9) to determine the percentage of natural outcrossing in corn. A field of 25 acres of white hybrid corn was located on the windward side of a 5-acre field of yellow corn. The percentage of yellow kernels that occurred at various distances in the white hybrid was used as a measure of outcrossing. The percentage of xenia seed for each distance was calculated on the basis of 30,000 seeds taken from 50 plants. The following percentages of outcrossing were found for various distances:

Dist. (rods) from foreign pollen	Percent of natural crossing	Dist. (rods) from foreign pollen	Percent of natural crossing
2.4	3.30	80.0	0.02
10.0	0.33	100.0	0.08
20.0	0.36	120.0	0.79
30.0	0.25	140.0	0.18
40.0	0.54	160.0	0.21

Salamov recommended an isolation of 40 to 60 rods provided 10 border rows are planted on the side next to the threatening variety. The percentages of crossing are low, probably due to the fact that they were measured in the direction opposite the prevailing winds and that the consecutive rows of corn helped dilute the foreign pollen. No data are given by Meijers (7) nor Salamov (9) relative to the environmental conditions under which they did their research.

The effect of distance of isolation on outcrossing and the influence of contamination on yield in corn were studied in Iowa by Gacitua (1). Thirteen fields of waxy corn were grouped into different exposures to contamination from adjacent fields of starchy corn. Crosses of starchy corn onto waxy corn produce a type of xenia which can be readily identified upon staining with iodine solution. He found that outcrossing in the 100th consecutive row (21 rods) from the contaminating field varied from 2 to 6 percent, depending on the direction of exposure. One field exposed to southwest contamination showed 3.75 percent outcrossing on the 127th row (27 rods) from the south direction alone. Apparently, there was considerable variation in the amount of contamination that occurred in consecutive rows.

Gacitua concluded that 20 rows of corn in fields with north, east or southeast exposure and 40 rows in fields with south exposure seem to be enough to reduce contamination to a reasonable level. From these data, apparently any contamination less than approximately 7 percent is a reasonable level when only milling characteristics and not genetic purity are concerned.

As a mean value for the 5 hybrids used by Gacitua, 5, 10, and 20 percent of contamination with F_2 seed produced a significant reduction in yield of the hybrids.

The amount and distance of pollen dispersal under field conditions in Nebraska were studied by Jones and Newell (5) for 7 species of cross-pollinated forage grasses and cereal crops by means of suitably exposed vaseline-coated microscope slides.

The dispersal of the pollen of all the grasses followed approximately the same general trend. With prevailing southerly winds, most of the pollen was dispersed toward the north from the fields under study. Using the average amount of pollen caught in the center of the field for all of the grasses studied as 100 percent, approximately 31.0 percent was caught per unit area at 5 rods, 10.0 percent at 15 rods, 4.4 percent at 25 rods, 1.2 percent at 40 rods, and 0.8 percent at 60 rods to the north. The amount of pollen caught for corn at these distances was lower than for any of the other grasses. Jones and Newell (5) state that these relatively low percentages of total pollen caught at 60 rods represent considerable numbers of pollen grains, and must be considered omnipresent sources of contamination in the field production of pure seed stocks.

Jones and Newell (5, 6), in other experiments, investigated the viability of grass pollen under field and artificial conditions. Stalks of detasseled corn were isolated 50 rods to the north of a corn field before it started shedding pollen. After two days of pollen dispersal by south winds, it was shown that 7.2 percent of the ovules had set seed. They concluded that on this basis enough cross-fertilization would occur during a corn pollination cycle of 12 to 14 days to cause the loss of genetic identity.

Hodgson (2) in Georgia measured pollen dispersal for Pensacola Bahia grass by collection on microscope slides and by isolating populations which were segregating for albinos at various distances to the north of a homozygous green tester field. He obtained as much as 10 percent outcrossing under an isolaton of 25 rods and indicated this amount was not significantly different from that which occurred at 35 rods. From his studies of approximately 110,000 plants, he concluded that an isolation of 25 rods would be sufficient for the production of seed to be used by farmers for establishing pastures; but isolation in excess of 35 rods should be required if the seed is to be harvested in the next generation. Since only 16 plants were used in the isolation blocks and the albino percent was variable, ranging from 31 to 44 percent with an average of 36.92 percent, certain limitations must be placed on the interpretation of the data.

Two strains of sorghum which differed with regard to a simply inherited mendelian character were used by Hsu (3) to determine the amount of natural outcrossing that occurred at Peiping, China, in a population of 38,469 plants. Seeds of strain S19 carrying recessive green seedling color and strain 493-4-2-1 carrying dominant red seedling color were alternated 1 foot apart in the row, so that each plant of one strain was surrounded by plants of the other strain on all sides. The plot consisted of 20 rows 40 feet long and 2 feet apart. In all directions, seed of S19 were planted in rows which varied from 2 to 50 feet apart, with the farthermost row being 800 feet from the central plot. The number of red seedlings produced from the seed harvested from S19 plants was used as a measure of the percentage of outcrossing. The greatest distance at which outcrossing occurred was 43 rods in the northwest direction.

Hsu concluded that due to the influence of winds and insects, the shortest safe distance at which open-pollination may be avoided varies with different directions as follows: for the south and north, 6 rods; east and west, 15 rods; northeast and southwest, 24 rods; southeast and northwest, 5 rods. According to the field plan, Hsu had a much greater quantity of pollen from the S19 tester strain than from the contaminating pollen strain 493-4-2-1, which may have resulted in the percentage of outcrossing being low.

MATERIALS AND METHODS

The rolling area selected for the study is located 15 miles west of Stillwater in the heart of the Lake Blackwell land-use area. A creek with a heavy tree growth is located one-fourth mile to the west and south of the field. The area was ideal for a study of isolation, since no corn was grown within a radius of approximately five miles.

Cultural methods were those commonly used in producing corn in this region.

Two open-pollinated varieties were used: Yellow Surcropper, a yellow dent field corn; and Honey June, a white sweet corn. Both start shedding pollen approximately 85 days after planting; however, the silks on the Honey June plants appear about two days after pollen shedding starts.

When a pollen grain from Yellow Surcropper effects a cross into a Honey June ovule, the resulting kernel is yellow and plump; whereas a kernel produced by fertilization of a Honey June ovule with Honey June pollen is white and shrunken (Figure 1). This change in the appearance of the kernel (xenia) produced by the Yellow Surcropper pollen made separation of the crossed kernels from the pure Honey June kernels easy.

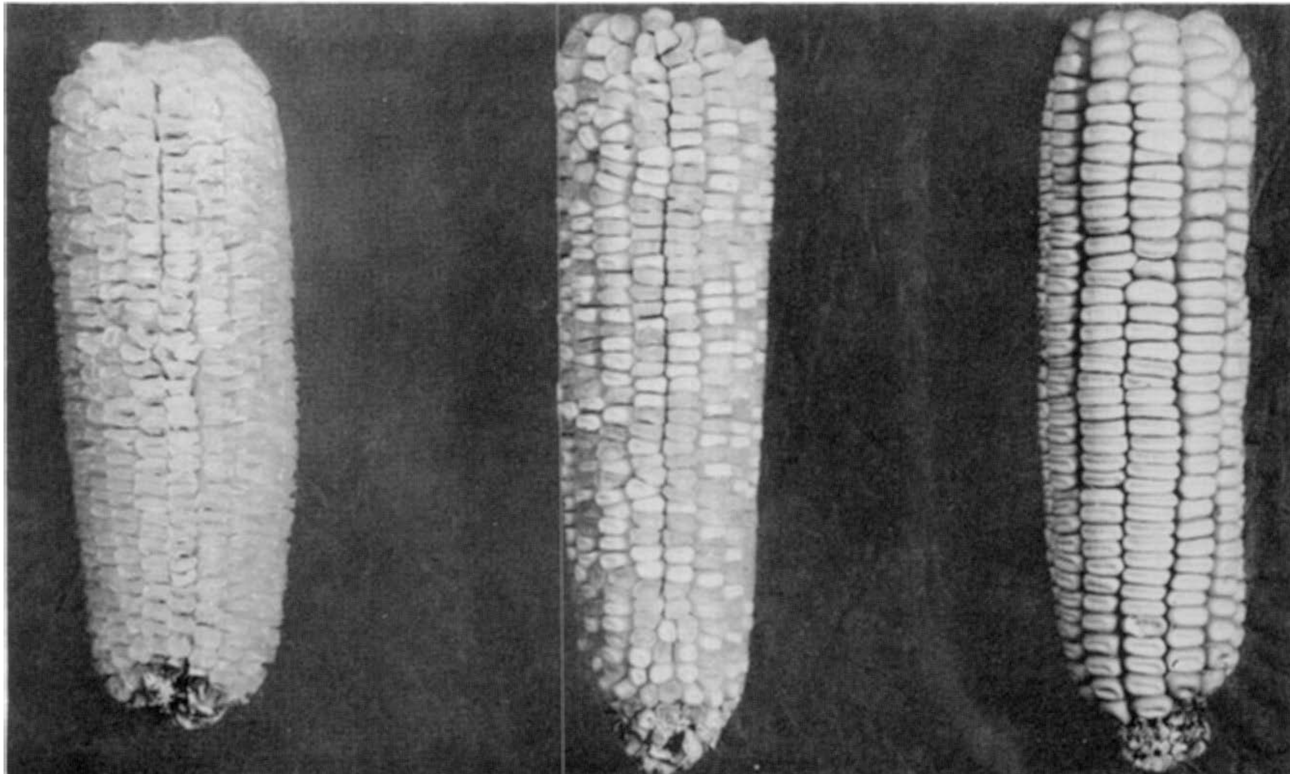


Fig. 1.—Pure Honey June ear on left, Honey June ear in center showing effects of some Yellow Surcropper pollen, and pure Yellow Surcropper on right.

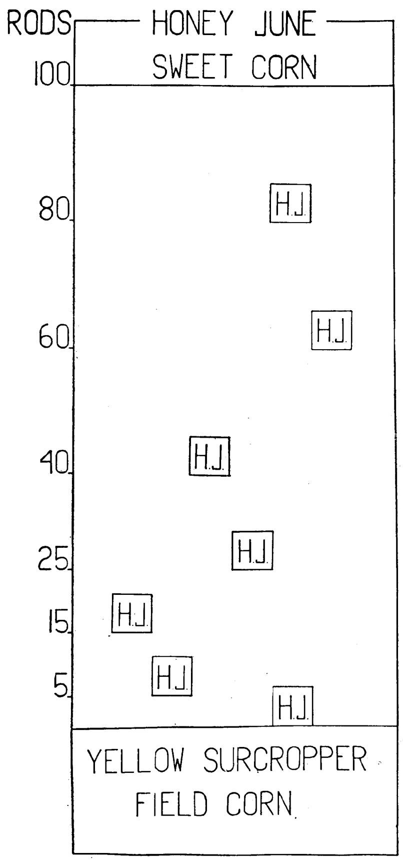


Fig. 2.—Experimental field consisted of a block of Yellow Surcropper corn on the South, with plots of Honey June isolated at various distances to the North.

The field layout consisted of a block of Yellow Surcropper corn 25 rods wide and 50 rods long on the south side. Blocks 100 feet square of Honey June corn were planted to the north of the Yellow Surcropper at distances of 0, 5, 15, 25, 40, 60, 80, 100 rods (Figure 2). The Honey June blocks were located to the north of the Yellow Surcropper because the prevailing winds are from the south and southwest. The blocks were moved to new ground each year to avoid contamination due to volunteer hybrid plants. The rows ran east and west in all blocks, and were spaced 3.5 feet apart. The area between the blocks was planted to small grains which were harvested previous to corn pollination.

At the time of tasseling and silking, 10 plants per row were tagged in each of the eight Honey June blocks. Only plants that showed good tassel and silk development were chosen. All the tagged ears on each row were harvested, and the number of crossed (yellow plump) and non-crossed (white shrunken) kernels on each ear was counted. Preliminary studies showed that the amount of outcrossing in each row in the west 1/3, the center 1/3, and the east 1/3 was approximately the same; therefore, all data are presented on a row basis. The number of kernels and ears studied in each Honey June block during the experiment is given in Table 1.

Since the time of day of pollen shedding of each variety may affect outcrossing, microscope slides coated with a thin film of vaseline were exposed during pollen shedding season according to the method used by Jones and Newell (5) in order to determine when the plants of each variety shed their pollen.

RESULTS AND DISCUSSION

Effect of Isolation Distance on the Percentage of Outcrossed Grain

In this study, the amount of contamination occurring at different distances of isolation was determined by obtaining the percent of the grain on the Honey June ears which developed as a result of fertilization by Yellow Surcropper pollen. The "outcrossed grain" referred to in this discussion is synonymous to contamination.

The percentage of outcrossed grain was determined for each row in each of the isolated blocks. The percentage of outcrossing which occurred in each block was obtained by averaging the values obtained from all rows of each block. The data for block outcrossing are presented in Table 2 for each of the three years. The ears shown in Figure 3 are representative of the 3-year average percent of outcrosses which occurred at the different distances of isolation.

It is apparent from these data that seasonal conditions have influenced the amount of outcrossing which occurred. The outcrossing that occurred in 1948 is low compared to that for 1947 and 1949. Rainy weather and low wind velocity during much of the pollinating season probably contributed to the low percentage of outcrossed grain. In 1947, there were periods of unusually hot and dry weather during the pollinating season which may have contributed to the sharp decrease in outcrossing beyond the 15 rod block. It was found that the time of day of beginning and of maximum pollen shedding was the same for the two varieties used, and therefore did not contribute to the variation in results.

The 40 rods minimum isolation required by the International Crop Improvement Association for pure corn seed production produced relatively pure seed when it is considered that these percentages are based on blocks 25 rows deep. In small fields, such as might be used for inbred seed production, isolation of 40 rods would have resulted in 2.5 percent contamination in the seed from the first 25 rows and 1.0 percent at 60

TABLE 1.—The Number of Kernels and Ears Studied in Each Honey June Block.

Dist. (Rods) from foreign pollen	1947 Number of		1948 Number of		1949 Number of	
	Kernels	Ears	Kernels	Ears	Kernels	Ears
0	14,322	31	104,522	202	98,737	185
5	30,017	60	129,200	226	95,597	181
15	13,297	31	110,540	197	69,286	133
25	55,109	113	124,432	223	79,012	151
40	15,410	26	138,038	243	84,721	169
60	17,793	65	121,982	225	56,419	114
80	9,893	24	93,326	164	44,626	91
100	38,735	79	208,225	385	80,728	147
Total	194,576	429	1,030,265	1,865	609,201	1,171

TABLE 2.—The Percentage of Outcrossed Seed Occurring at Eight Distances of Isolation for Three Years.

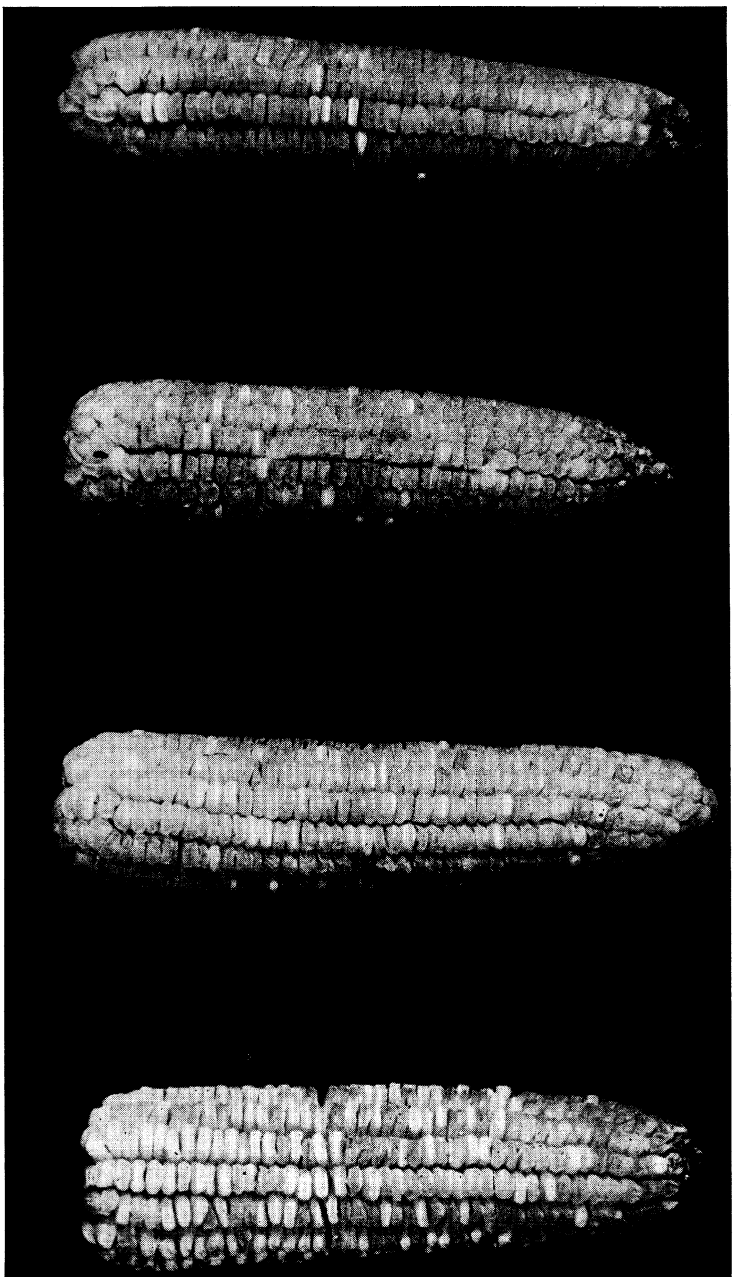
Year	Distance north of contaminating fields (rods):							
	0	5	15	25	40	60	80	100
1947	35.13	16.48	5.13	0.82	0.44	0.15	0.15	0.15
1948	17.88	6.99	3.64	2.48	0.66	0.31	0.21	0.12
1949	32.87	19.17	8.60	3.68	2.47	0.99	0.32	0.32
Av.	28.62	14.21	5.79	2.33	1.19	0.48	0.23	0.20

rods in 1949, the year of maximum outcrossing (Table 2). Both of these amounts are considerably in excess of the percent of "off type" plants permitted by the international standards; however, both inbred and single cross production fields planted to seed of this quality could be rogued to meet these standards. On the other hand, double cross production fields planted with single crossed seed would be extremely difficult to rogue and bring within a satisfactory degree of genetic purity. Additional distance of isolation beyond 60 rods produced comparatively small decreases in the percentage of outcrossed seed.

Possible further application of this data is suggested when the reduction in amount of crossed seed produced at increasing distance of isolation is compared with the distribution of grass pollen described by Jones and Newell (5). A graphic representation of the average percentage of outcrossing occurring at the different distances of isolotion is presented in Figure 4. The amount of pollen occurring at these same distances in percentage of the amount occurring in the contaminating field was taken from Jones and Newell. The pollen data were based on an average of seven different species of grasses, including corn, grown at Lincoln, Nebraska, in 1944 and 1945. The line for corn alone is also shown. The similarity of the three lines is striking in view of the different time and place of the two experiments, and the different species involved in the pollen study.

The similarity between the crossing curve and the pollen distribution lines would suggest that the results of this study of the effectiveness of distance of isolation in pure seed corn production would be directly applicable to cross-pollinated grasses in general. It also suggests the possibility of predicting the effectiveness of particular isolations in different regions by making pollen counts following the method used by Jones and Newell.

In view of the parallel between the percentage of outcrossing of corn and the distribution of other grass pollen at different distances of isolation it appears that in grass species (where contamination is not as easily detected as in inbred lines of corn) 40 rods isolation may be insufficient to produce seed of the degree of purity required by the international standards, i. e., a maximum of 1 percent of other varieties.



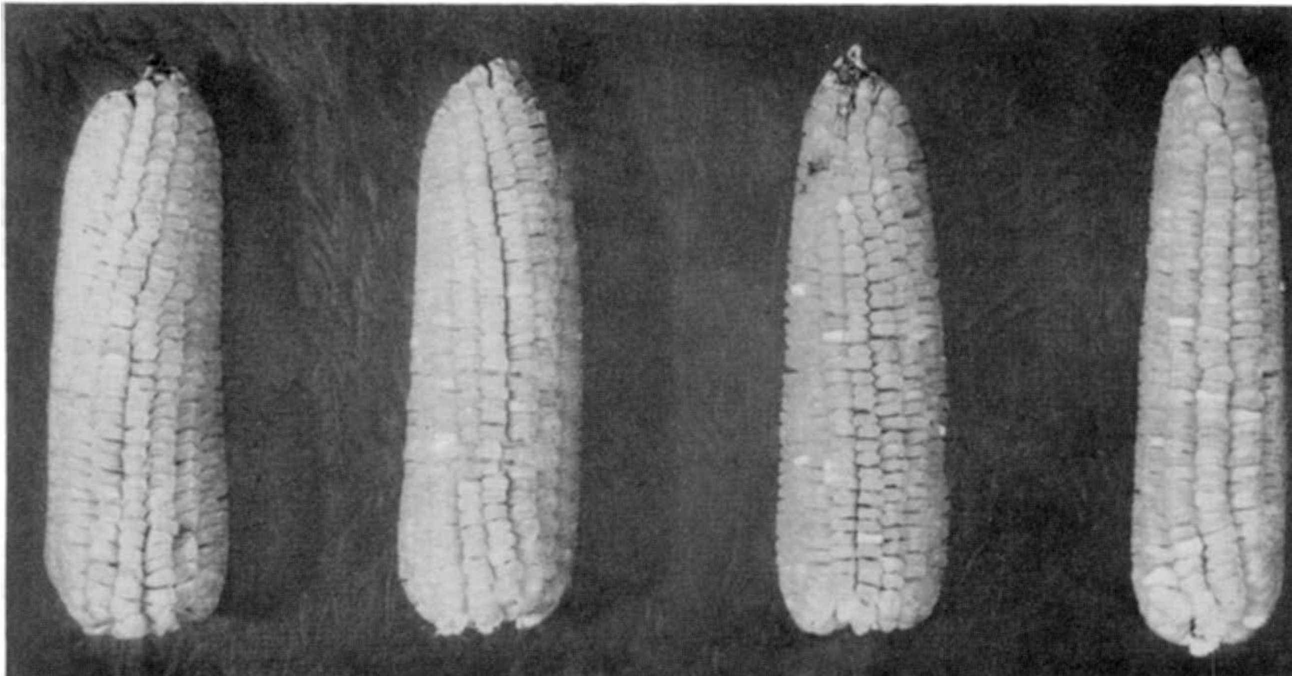


Fig. 3.—Honey June ears representative of the 3-year average percentage of outcrosses which occurred at various distances from Yellow Surcropper. Left to right, top picture, 0, 5, 15, and 25 rods; lower picture, 40, 60, 80, and 100 rods.

right to left,

Effect of Border Rows on the Percentage of Outcrossed Grain

The effectiveness of border rows in increasing the purity of seed produced under various conditions of isolation should be considered, because of the frequent difficulty in obtaining sufficient isolation for the production of pure seed corn, and because experimental results indicate that present isolation requirements may not be adequate. The International Crop Improvement Association (4) has adopted standards of isolation modified by the number of border rows and size of the field.

This experiment lends itself to a study of border row effect, since the percentage of outcrossed seed produced in each row of each block was determined.

The data obtained in 1949 for each row of each isolated block are presented in Table 3. This single year's data is presented as an illustration of the great variation in results from row to row. The 33.5 percent crossing for row 4 of the 15-rod block followed by 1.8 percent and 17.1 percent for rows 5 and 6, respectively, is an example of the type of variation which has been evident throughout the three years of the experiment. In spite of this variation, average figures show a surprisingly consistent picture.

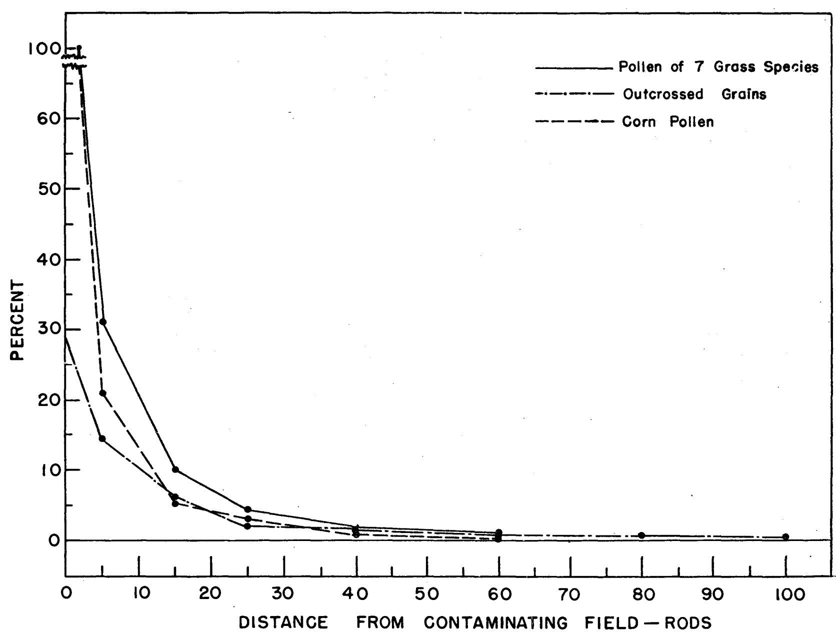


Fig. 4.—The concentration of corn pollen, 7 species of grass and including corn at different distances from the field at Lincoln, Neb., (Jones and Newell, see Literature Cited, page 18), and the percentage of outcrossed corn grains at Stillwater, Okla.

TABLE 3.—Average Percentage of Crossing in 1949 of Yellow Surcropper onto Honey June Corn for 25 Consecutive Rows at Eight Distances North of the Yellow Surcropper Field.

Row	Distance north of contaminating fields (rods):							
	0	5	15	25	40	60	80	100
1	90.62	80.40	28.07	4.33	6.28	2.98	.66	1.42
2	77.62	46.18	13.64	19.22	14.03	3.66	.36	.47
3	39.92	44.07	40.07	8.30	7.91	3.45	.43	.39
4	54.83	36.17	33.54	5.17	6.79	2.34	.00	.27
5	46.11	27.94	1.88	3.62	.68	.71	.08	.90
6	31.89	35.23	17.12	4.89	3.61	2.05	1.31	.33
7	43.37	11.96	9.33	2.35	1.77	1.01	.26	.13
8	45.74	8.36	11.80	1.83	1.56	1.02	.04	.17
9	28.25	16.16	5.81	1.72	.42	.00	.10	.00
10	26.96	20.23	1.72	6.96	.75	.00	.52	.08
11	29.49	14.26	4.55	2.86	1.23	.03	1.42	.00
12	32.88	21.52	3.18	.59	1.15	.65	.04	.63
13	25.05	9.88	2.16	1.72	2.21	1.51	.00	.06
14	26.37	13.40	4.94	1.30	1.07	.54	.30	.65
15	23.20	7.38	7.42	1.90	1.31	.39	.10	.14
16	31.59	12.64	7.12	.88	1.76	.04	.10	.03
17	21.57	4.92	.52	2.94	.99	.00	.00	.08
18	20.53	10.69	3.07	2.79	1.19	.22	.00	.33
19	23.97	15.53	1.37	1.76	.50	.98	.21	.00
20	11.57	7.09	.65	3.36	1.05	2.00	.15	.23
21	18.23	5.13	1.85	1.56	1.30	.14	.00	.30
22	15.13	5.80	3.55	3.06	1.24	.36	.14	.22
23	11.39	6.37	2.21	1.84	.97	.05	.18	.34
24	13.64	11.42	4.30	3.40	1.32	.22	1.17	.07
25	----*	10.40	5.07	----	.79	.33	----	.05
Av.	32.87	19.17	8.60	3.68	2.47	0.987	0.315	0.319

* Blanks indicate data were not obtained.

The 1947 data is omitted from all computations involving rows because of poor stands which resulted in missing values for two or more rows in all but one of the isolation blocks. The average percentage of outcrossing for 1948 and 1949 by 5-row units and distance of isolation are given in Table 4.

Under the conditions of this experiment, more than 1 percent outcrossed grains appeared in the last five rows at an isolation distance of 25 rods and less. Thus, 20 border rows were not effective in reducing crossing in the next five rows to below 1 percent at distances of 25 rods or less. The efficiency of additional border rows is considerably reduced with more than 10 rows at distances of 25 rods or less and with more than five border rows for distances greater than 25 rods. At distances of five rods or greater from an adjacent field, the first five rows appear to have half of the total number of outcrossed grains occurring in the first 25 rows. This condition appears to be the result of the first few rows acting as a barrier. The pollen from the adjacent field is screened out by these border rows or falls out due to reduced wind velocity. Pollen which rises above the level of the plants may fall out in any part of the field; and, therefore, beyond the first few rows the out-

TABLE 4.—Average Percentage of Outcrossed Grain Occurring in Groups of Five Rows During 1948 and 1949 at Eight Distance of Isolation.

Rows*	Distance north of contaminating fields (rods):							
	0	5	15	25	40	60	80	100
1-5	51.67	31.91	16.00	7.32	4.40	1.78	0.54	0.46
6-10	28.12	12.49	5.60	3.13	1.10	.55	.26	.15
11-15	19.02	8.73	3.54	1.48	.99	.32	.23	.21
16-20	16.82	6.41	2.53	1.77	.74	.46	.07	.12
21-25	9.53	5.64	2.95	1.60	.67	.23	.19	.12
Av.	25.38	13.08	6.12	3.08	1.57	0.65	0.27	0.22

*Row 1 is the row in each block nearest the contaminating field, and row 25 the most distant.

crossing appears to be in proportion to the diluting effect of the pollen produced by the rows nearer the edge of the field.

The outcrossing was progressively less from the margin of the field nearest the contaminating field toward the most distant side (Table 4). It would seem that depth of the field measured in the above direction is of greater importance than total acreage. A 10-acre field extending for 20 rods along a contaminating field and 80 rods deep should have the same average contamination as a 40-acre field extending 80 rods along a contaminating field and 80 rods deep.

The number of border rows which in this experiment reduced crossing in the next five rows to the 0.5 percent mixture permitted by the international standards is given in Table 5, together with the number of border rows required by these standards for this same distance. Also shown are the amounts of outcrossing obtained in the five rows adjacent to the number of border rows required by the international standards.

If it is assumed that the conditions of this experiment were comparable to conditions generally existing in fields where commercial corn seed is produced (and they are believed to be), it appears that it would be impratical for certification standards to require that the distance of isolation and number of border rows be such as to bring all sections of the field within the 0.5 percent mixture permitted. Mixing the seed from the rows adjacent to the border with that from rows deeper in the field must be depended upon to reduce the mixture to the acceptable amount. It should be noted, however, that mixing the first five rows with an equal number of rows with no contamination would not reduce the mixture to an allowable amount. To insure equal quality of all bags of seed, fields should be harvested in such a way as to mix each row near the contaminating field with several more distance rows.

Since winds in the plains area are generally more frequent and of higher velocity than in the central Corn Belt, the outcrossing obtained in this experiment is probably greater than that occurring in the Corn Belt. However, this experiment was conducted under the conditions of open pollinated seed production—that is, without detasseling. Reducing the pollen produced in the seed field by detasseling three of each four rows presumably would increase contamination considerably above the percentages obtained in this experiment. Further experiments are in progress to obtain data under conditions of hybrid seed production.

SUMMARY AND CONCLUSIONS

Investigations were conducted at Stillwater, Oklahoma, during 1947 to 1949, inclusive, to obtain information on the effectiveness of spatial isolation and border rows in decreasing outcrossing in corn, *Zea mays* L. Two open pollinated varieties were used: Yellow Surcropper, a yellow dent field corn; and Honey June, a white sweet corn. The percent of yellow plump kernels (xenia) on the Honey June ears was used as a measure of the amount of outcrossing that occurred in each row of every Honey June block. The amount of outcrossing that occurred in the Honey June blocks located at distances of 0, 5, 15, 25, 40, 60, 80, and 100 rods north of the contaminating yellow surcropper field was determined.

The percentage of outcrossed seed was greater than the maximum mixture permitted by the international standards at distances of 40 rods isolation or less. In one of three years, the outcrossing exceeded this maximum at 60 rods isolation.

The percentage of outcrossing within a field was related to the depth of the field in the direction of the source of contamination. It would seem that "depth of the field" is of greater importance than total acreage in reducing contamination.

The percentage of outcrosses occurring in successive rows at different distances of isolation indicates that the first five rows adjacent to the source of contamination function as a barrier to the dispersal of contaminating pollen. Additional border rows serve only to dilute the contaminating pollen.

TABLE 5.—Average Percentage of Outcrossing in the Five Rows Next to the Number of Border Rows Required by the International Standards, and the Number Required According to Experimental Results to Reduce Crossing to 0.5% for Various Distances of Isolation.

Distance from contaminating field (rods)	Av. percent outcrossing**	Number border rows required by International standards*	Number border rows required by Experimental results
15	3.88	11	More than 20
25	2.66	7	More than 20
40	3.94	1	More than 20
60	1.65	1	5
80	0.42	1	1
100	0.32	1	0

* For fields of less than 10 acres.
** Average percentage of outcrossing in the five rows next to the number of border rows required by the International Standards.

At least under the conditions of this experiment it is not considered practicable to obtain the isolation or number of border rows necessary to bring all sections of a field within the purity requirements of the International Crop Improvement Association standards. It is suggested that, instead, seed from the most heavily contaminated portion of the field be carefully mixed with seed from less contaminated portions to maintain the standards of purity. Seed which is to be increased through several generations should be carefully isolated at maximum possible distances and with five or more border rows.

Possible application of these results to other cross-pollinated grasses is suggested.

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