SEED CORN PRODUCTION AS AFFECTED BY SOIL FERTILITY AND PLANT POPULATION

Thesis for the Degree of M. S.

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George E. Carter

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SEED CORN PRODUCTION AS AFFECTED BY SOIL FERTILITY

AND PLANT POPULATION

By

GEORGE E. CARTER

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State University
of Agriculture and Applied Science in partial fulfillment
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MASTER OF SCIENCE

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1960

Approved E. C. Rossman

ABSTRACT

Several fertilizer and plant population treatments were evaluated for effects on seed production with inbred lines and single-cross hybrids in 1957 and 1958 on a Conover loam soil, testing high in residual fertility, in Ingham County, Michigan. Corn did not reach full maturity in any of the experiments.

Average increases in yields from fertilizer were not significant for inbreds in either year, nor significant for single-cross hybrids in 1957, but were significant for single-cross hybrids in 1958.

Plant population was the most important factor affecting seed yields.

Inbred lines

Seed yields on WF9 and Oh51 inbreds in 1957 were not affected significantly by complete fertilizer treatments of either 200 or 850 pounds 12-12-12 per acre. Sidedressed nitrogen applications of 29 and 40 pounds per acre did increase yields significantly but there was no difference between the 20 and 40 pound rates. Average yields increased significantly from 17.8 to 38.4 bushels per acre as population was increased from 5,500 to 16,000. The highest seed yields were 43.1 and 46.9 bushels per acre for these two inbreds.

Fertilizer effects on seed yields of 25 inbreds in 1958 were not significant. Average yields increased significantly from 26.8 to 50.3 bushels per acre as population increased from 7,500 to 18,300. Good

agreement was obtained between actual yields and predicted yields using Duncan's method (2). Predicted yields continued to increase up to 30,000 plants per acre for most inbreds and a few predicted yields increased to 40,000 population.

As population was increased from 14,600 to 18,300: (1) yields of Oh51, Oh51A, W64A, Oh43, W22, WF9, MS116, MS211, and MS1334 increased significantly 9.2 to 12.1 bushels, (2) 38-11, W10, W70, B8, MS132, A73, MS24A, MS131, and MS206 increased 4.7 to 8.2 bushels which were not significant at the 5% level, and (3) W23, WR3, Hy2, MS130, M14, R53, and C103 showed little or no increase in yield.

Single-cross hybrids

In 1957 (Experiment 2), average yield and grading of seed from WF9 x Oh51A were not significantly affected by complete fertilizer and nitrogen sidedressing treatments. Yields averaged 43.2, 60.6, 69.4, 88.8, and 91.6 bushels at populations of 6,100, 9,200, 11,200, 15,100, and 17,200 plants per acre, respectively. Each increase except the last was significant.

In 1958 (Experiments 11 and 12), five single-cross hybrids averaged 11.6 and 9.6 bushels more when fertilized with 550 pounds of 15-15-15 and 40 pounds sidedressed nitrogen per acre at the highest plant populations.

As population increased from 7,300 to 17,100 in Experiment 11, average yields increased significantly from 58.1 to 89.1 bushels. When population increased from 7,000 to 14,000 in Experiment 12, average yields increased from 46.9 to 74.7 bushels.

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In both years, kernel width and length were reduced as population increased. Percent large flats decreased and small flats increased about the same amount while medium flats remained unchanged as population increased. Production per acre of medium flats, small flats, and rounds increased and production of large flats remained unchanged as population increased.

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INTRODUCTION

An estimated 400,000 acres of double-cross hybrid seed corn are produced each year to plant the 85 million acres of commercial corn in the United States. Extensive production research has been conducted with double-cross plants on the effects of soil fertility and plant population. Relatively little cultural and production information is available for the inbreds and single crosses used in seed production. The relatively low vigor and yielding ability of corn inbred lines makes production of inbred and single-cross seed much more costly than that of double-cross seed on the more vigorous and productive single-cross plants. One purpose of this research was to investigate the effects of soil fertility and plant population on seed production of inbreds and single crosses.

In the development and evaluation of most corn hybrids, yield trials are conducted at several locations for a number of years under various soil, cultural, and climatic conditions. Hybrids with the best average performance under these conditions are selected for production. All hybrids do not respond alike to increases in fertilizer and plant population. By conducting all phases of inbreeding, selection, and evaluation of inbred lines and yield testing of hybrids under conditions of high soil fertility and plant population, it may be possible to develop hybrids better adapted to take full advantage of these conditions.

In planning an effective and efficient breeding program it would be helpful if existing inbred lines could be classified for response to high level production practices and a similar evaluation made of the hybrids composed of various combinations of these lines. The second objective of this research attempted to classify a group of 25 inbred lines preliminary to evaluation in single- and double-cross hybrids.

LITERATURE REVIEW

Many studies of effects of fertilizer and plant population on grain production have been conducted with double-cross hybrids, but no published information was found relating to effects of fertilizer and population on single-cross and double-cross seed production.

Airy (1) suggests that because of drouth hazards, 12,000 to 14,000 plants per acre in double-cross seed production fields should be adequate, with 16,000 plants recommended only at highest fertility levels. No seed yields were presented.

A method for predicting yield at any plant population from yield at any two actual populations was described by Duncan (2). He proposed that the logarithm of yield per plant bears a linear relationship to plant population. He suggests using reasonable limits between 5,000 and 25,000 plants per acre to predict double-cross yields. However, yields of some drawf and semi-dwarf corn maintained a linear relationship with plant populations up to 78,000 plants per acre.

As ear corn moisture reduced in the field from 50% to 40%, Rather and Marsten (3) observed yield increases of five to twelve bushels per acre in twelve to sixteen days. Results were consistent between early and late maturing hybrids.

MATERIALS AND METHODS

Field experiments were conducted on Conover Clay loam in 1957 and 1958 to study the effects of soil fertility and plant population on seed production of several inbred lines and single-cross hybrids. Prior to plowing and fitting, soil samples were taken and plow-down fertilizer for the high fertility treatment in Experiments 1 and 2 (Table 1) was broadcast on predetermined areas. The plots, each one row 32 feet long, were planted with a regular corn planter equipped with special cone seeders for small plots. Row fertilizer was placed one inch below and three inches to the side of the seed. Simazin was band-sprayed over the rows at planting in 1958. Weeds were further controlled by cultivation and hoeing. Additional nitrogen treatments were applied by sidedressing with ammonium nitrate at the last cultivation. The same field was used in 1957 and 1958.

Experiment 1 was planted in 1957 in a split-plot design with four replications to determine the effects of various levels of complete fertilizer, nitrogen sidedressing, and plant population on seed production of two inbred lines. Oh51, a midseason line, and WF9, a late maturing line for Michigan, were used. Since the amount of pollen produced and the timing of flowering are important factors in seed production and must be considered when producing a particular hybrid, it was decided to attempt to reduce or eliminate these pollination difficulties by providing extra pollen to assure full pollination if possible. Therefore, two rows of

WF9 x Oh51A single cross were planted between every six rows of inbred plots on two later dates to provide more adequate pollen for inbred plants. The first single-cross planting was made when inbred seedlings emerged, and the second when the first planting started to emerge. A border row of inbreds was planted on each side of the single-cross rows to reduce competition from the more vigorous single-cross plants.

Experiment 2 was planted in the same field in 1957 as a split-plot design with two replications. The effect of various levels of complete fertilizer, nitrogen sidedressing, and plant population on the production of various grades of seed of single-cross WF9 x Oh51A plants was studied.

In 1958, 25 inbred lines were classified for response to two fertility and four population treatments. All lines were planted in eight separate triple-lattice experiments--Nos. 3, 4, 5, 6, 7, 8, 9, and 10--with a different fertilizer and plant population treatment for each experiment. The experiments were arranged so that when combined, they could be analyzed as a 2 x 4 x 25 split-plot experiment with three replications.

Five single-cross hybrids were planted June 2 and June 10, 1958, in two separate split-plot experiments, 11 and 12 respectively, and replicated three times with the same treatments for each. In addition to providing data on the effect of fertilizer and plant population on double-cross seed production, the two rows of these five single crosses between every five rows of inbred plots also provided additional pollen for the 1958 inbred experiments.

Fertilizer treatments, plant population, pedigrees, experimental designs, and cultural agronomic information are presented in Table 1.

TABLE 1. FERTILIZER TREATMENTS, PLANT POPULATIONS, PEDIGREES, EXPERIMENTAL DESIGNS, AND CULTURAL AGRONOMIC INFORMATION FOR EXPERIMENTS 1, 2, 3-10, 11, AND 12 IN 1957 AND 1958

Plow-down and row fertilizer per acre	Plant population per acre	Nitrogen sidedressing per acre	Entry numbers and inbreds or single crosses	Experimental design
		Experiment 1, 1957		
None	5,500	None	1. Oh51	3x5x3x2 split-plot
200 pounds 12-12-12 in row	8,700	20 pounds	2. WF9	4 replications
650 pounds 12-12-12 plow-down, 200 pounds 12-12-12 in row	11,700	40 pounds		
	13,800			
	16,000			
		Experiment 2, 1957		
None	6,100	None	WF9 x Oh51A	3x5x4 split-plot
200 pounds 12-12-12 in row	9,200	20 pounds		2 replications
650 pounds 12-12-12 plow-down, 200 pounds 12-12-12 in row	11,200	40 pounds		
	15,100	60 pounds		
	17,200			
		Experiments 3, 4, 5, 6, 7, 8, 9, 10, 1958		
None (Exps. 7-10)	7,500 (Exps.3,7)		1. B8 14. W10	Each experiment was 5x5 triple-lattice, 3 replications. All eight experiments combined for 2x4x25 split-plot analysis, 3 replications.
	11,400 (Exps.4,8)		2. Oh51A 15. Oh51	
550 pounds 15-15-15 in row plus 40 pounds nitrogen sidedressed later (Exps. 3-6)	14,600 (Exps.5,9)		3. Hy2 16. A73	
	18,300 (Exps.6,10)		4. W70 17. WF9	
			5. Oh43 18. MS206	
			6. MS132 19. R53	
			7. W23 20. M14	
			8. MS116 21. MS130	
			9. MS24A 22. W64A	
			10. C103 23. W22	
			11. 38-11 24. WR3	
			12. MS1334 25. MS131	
			13. MS211	

TABLE 1 (CONTINUED).

Plow-down and row fertilizer per acre	Plant population per acre		Nitrogen sidedressing per acre	Entry numbers and inbreds or single crosses	Experimental design
Experiments 11 and 12, 1958					
None	11	12		1. WF9 x Oh51A	Each experiment was 2x4x5 split-plot, 3 replications.
	7,300	7,000		2. Oh51 x R53	
550 pounds 15-15-15 in row plus 40 pounds nitrogen sidedressed later	10,400	9,400		3. W23 x MS24	
	12,800	11,200		4. MS116 x MS211	
	17,100	14,000		5. WF9 x M14	

Cultural agronomic information

Experiment number	Year	Date planted	Date harvested	Previous crop	Soil test			Soil type	Killing frost
					pH	P_2O_5	K_2O		
1	1957	June 2	October 10	Alfalfa	7.1	63	237	Conover clay loam	Sept. 27
2	1957	June 2	October 10	Alfalfa	7.1	63	237	Conover clay loam	Sept. 27
3-10	1958	May 24	October 15	Corn	6.6	61	161	Conover clay loam	October 6
11	1958	June 2	October 15	Corn	6.6	61	161	Conover clay loam	October 6
12	1958	June 10	October 15	Corn	6.6	61	161	Conover clay loam	October 6

Stand, moisture, field weight, and lodging data were taken at harvest on all plots. The relatively small amount of lodging in these experiments was not reported. All corn for each plot was harvested by hand and weighed in the field. Moisture content was reported as ear corn moisture. Yields were calculated as shelled corn at 15.5% moisture.

Seed from each plot of Experiments 2, 11, and 12 was separated into commercial seed corn grades with hand screens mounted on a small Clipper cleaner. Two 500-gram samples from each plot of Experiment 2 and one 500-gram sample from each plot of Experiments 11 and 12 were graded for width and thickness of kernels. Two 100-kernel samples of medium flats from each plot of all three experiments were measured with a length gauge. Kernels 28/64 to 34/64 of an inch long were classified as long medium flats. Length specifications were kept constant for all treatments and single crosses to determine the effect of treatment on kernel length. In practice, a seedsman might adjust the length specifications for each lot to yield the most bushels of uniform, long medium flats. The various grades of rounds were not separated. Grading specifications are given in Table 2. Although "grade" (1) often denotes quality, in the hybrid seed corn trade it is more commonly used when referring to kernel size. Therefore, "grade" denotes kernel size classification rather than seed quality in this report.

Yields were adjusted to average stands for each population by covariance analysis. Analyses of variance were computed for all observations.

TABLE 2. GRADES AND KERNEL DIMENSIONS
FOR EXPERIMENTS 2, 11 AND 12

Grade	Symbol	Sizes in 64ths of an inch					
		Round hole		Rectangular hole		Length	
		Through	Over	Through	Over	Through	Over
Large flats	LF	26	22	14			
Medium flats	MF	22	18	13			
Long medium flats	LMF	22	18	13		34	28
Short medium flats	SMF	22	18	13		28	
Small flats	SF	18	17	13			
Rounds	R	26	22		14		
		22	17		13		

Duncan's (2) proposal that the logarithm of yield in pounds per plant bears a linear relationship to plant population was applied to Experiments 3 through 10. Thus, bushels per acre for any variety at any population can be predicted from yield at any two known populations. Predictions from the most widely separated populations are considered most accurate. To apply this method to Experiments 3 through 10, pounds of shelled grain per plant for each of the four actual populations for each inbred were plotted on semi-logarithmic paper. The straight predicting line was drawn through points for the lowest and highest populations regardless of where points for the other two populations fell in relation to the line. From this line, yields of shelled corn per acre were determined for any desired population.

A summary of temperature and rainfall is presented in Table 3. The longest dry period occurred between July 22 and August 23, 1957. There were no prolonged dry periods in 1958.

TABLE 3. WEATHER DATA FOR 1957 AND 1958, INGHAM COUNTY, MICHIGAN*

Month	Average rainfall			Average temperature			Days with rain		Dry periods 15 days or more	
	1957	1958	Normal	1957	1958	Normal	1957	1958	1957	1958
May	6.12	.38	3.75	54.8	55.6	56.5	10	2		May 1 to May 22
June	2.42	3.28	3.37	67.0	60.8	67.4	6	7		
July	7.22	4.31	2.28	70.4	69.0	71.1	5	7	July 22 to Aug. 23	
August	1.55	3.24	2.68	67.1	68.3	69.0	4	5		
September	1.28	2.26	3.05	58.9	60.7	61.8	7	7	Sept.24 to Oct. 15	
October	3.84	2.13	2.45	48.2	52.2	50.5	5	5		

*From Climatological Data, U.S.D. Commerce, Volumes LXXII and LXXIII, Numbers 5-10.

RESULTS

Inbred Lines

Experiment 1

Analysis of variance and average yields of inbreds Oh51 and WF9 are presented in Tables 4 and 5. Plow-down and starter fertilizer treatments increased seed yields slightly but these differences were not statistically significant. Average yields were 28.8, 31.0, and 31.3 bushels per acre for 0, 200, and 850 pounds of 12-12-12 per acre, respectively.

Yields for each plant population were 17.8, 26.6, 32.4, 36.6, and 38.4 bushels per acre for average populations of 5,500, 8,700, 11,700, 13,800, and 16,000 plants per acre. All yield differences were highly significant except that from 13,800 to 16,000 plants per acre. Components of variance (Table 4) show that plant population was by far the most important factor determining seed yield.

Nitrogen sidedressings of 20 and 40 pounds per acre averaged 2.0 and 1.6 bushels more than no nitrogen. Both increases were significant but 40 pounds of nitrogen was no better than 20 pounds. Interactions involving fertility levels, nitrogen, and population were not significant, showing that these treatment effects were generally consistent.

The highest seed yield for Oh51 was 46.9 bushels per acre with no plow-down or starter fertilizer, 20 pounds nitrogen sidedressing and 16,000 plants per acre. For WF9, the highest yield was 43.1 bushels with

TABLE 4. ANALYSIS OF VARIANCE FOR YIELDS OF TWO INBRED LINES AT THREE FERTILIZER LEVELS, FIVE PLANT POPULATIONS, AND THREE NITROGEN SIDEDRESSING LEVELS - EXPERIMENT 1, 1957

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	Components of variance
Total	359	35492.5			
Replication	3	4260.0	1420.0		14.8
Fertilizer (F)	2	490.5	245.2	2.7	0.4
Error a	6	551.3	91.9		3.0
Population (P)	4	20092.3	5023.1	89.0**	68.1
F x P	8	974.0	121.8	2.2	1.2
Error b	36	2031.0	56.4		5.3
Nitrogen (N)	2	222.7	111.4	4.6*	0.9
F x N	4	210.4	52.6	2.2	0.3
P x N	8	209.7	26.2	1.1	0.2
F x P x N	16	353.4	22.1	0.9	-1.3
Error c	90	2204.5	24.5		4.3
Inbred (I)	1	34.9	34.9	1.8	-0.4
F x I	2	186.6	93.3	4.7*	0.2
P x I	4	237.1	59.5	3.0*	-0.1
N x I	2	33.8	16.9	0.9	-0.4
F x P x I	8	504.0	63.0	3.8**	3.3
F x N x I	4	171.9	43.0	2.6*	1.0
P x N x I	8	196.0	24.5	1.5	0.1
F x P x N x I	16	383.8	24.0	1.5	2.0
Error d	135	2144.6	15.9		
Error d plus fourth order interaction	151	2528.4	16.7		
Error d plus all third and fourth order interactions	171	3400.3	19.9		

* Significant at the 5% level of probability
** Significant at the 1% level of probability

TABLE 5. AVERAGE YIELDS FOR THREE FERTILITY LEVELS, FIVE PLANT POPULATIONS, AND THREE NITROGEN SIDEDRESSINGS WITH TWO INBREDS, Oh51 AND WF9 - EXPERIMENT 1, 1957

Nitrogen sidedressing - pounds per acre	Inbred	Plant population - plants per acre 5,500	8,700	11,700	13,800	16,000	Average
		No plow-down or starter fertilizer					
0	Oh51	19.1	25.3	21.6	33.8	36.9	27.3
	WF9	12.6	27.8	25.9	29.4	32.7	25.7
	Average	15.9	26.6	23.8	31.6	34.8	26.5
20	Oh51	20.0	27.3	26.8	37.9	46.9	31.8
	WF9	18.3	28.2	33.1	33.0	31.3	28.8
	Average	19.2	27.8	30.0	35.5	39.1	30.3
40	Oh51	16.8	25.9	27.3	35.4	44.2	30.0
	WF9	17.8	25.0	31.6	34.2	37.0	29.1
	Average	17.3	25.5	29.5	34.8	40.6	29.6
F x P	Average	17.5	26.6	27.8	34.0	38.2	28.8
		200 pounds starter fertilizer					
0	Oh51	17.0	30.3	36.4	40.2	37.2	32.2
	WF9	19.0	21.4	34.1	38.9	34.9	29.7
	Average	18.0	25.9	35.3	39.6	36.1	31.0
20	Oh51	20.9	28.4	37.1	37.1	42.4	33.2
	WF9	18.9	28.0	29.7	35.6	34.5	29.3
	Average	19.9	28.2	33.4	36.4	38.5	31.3
40	Oh51	18.8	29.3	33.7	37.1	31.4	30.1
	WF9	20.2	27.2	34.7	38.3	35.9	31.3
	Average	19.5	28.3	34.2	37.7	33.7	30.7
F x P	Average	19.1	27.5	34.3	37.9	36.1	31.0
		650 pounds plow-down and 200 pounds starter fertilizer					
0	Oh51	13.1	25.3	32.2	38.0	36.3	29.0
	WF9	15.2	23.3	32.4	41.6	41.8	30.9
	Average	14.2	24.3	32.3	39.8	39.1	30.0
20	Oh51	17.8	26.1	32.0	35.8	41.0	30.5
	WF9	18.7	28.5	36.6	39.1	43.1	33.2
	Average	18.3	27.3	34.3	37.5	42.1	31.9
40	Oh51	17.7	24.8	35.4	40.4	42.9	32.2
	WF9	17.9	27.0	41.4	32.5	40.6	31.9
	Average	17.8	25.9	38.4	36.5	41.8	32.1
F x P	Average	16.8	25.8	35.0	37.9	41.0	31.3
Population	Average	17.8	26.6	32.4	36.6	38.4	30.4
0	Nitrogen	16.0	25.6	30.5	37.0	36.7	29.2
20	x	19.1	27.8	32.6	36.5	39.9	31.2
40	Population	18.2	26.6	34.0	36.3	38.7	30.8
Inbred x	Oh51	17.9	27.0	31.4	37.3	39.9	30.7
population	WF9	17.6	26.3	33.3	35.8	36.9	30.0

Least significant differences:
- Fertility means = 3.0 bu. @ 5%, 4.6 bu. @ 1%
- Population means = 2.5 bu. @ 5%, 3.4 bu. @ 1%
- Nitrogen means = 1.3 bu. @ 5%, 1.7 bu. @ 1%
- Any two fertility x population x nitrogen x inbred means = 7.1 bu. @ 5%, 9.3 bu. @ 1%

650 pounds plow-down and 200 pounds starter fertilizer, 20 pounds nitrogen sidedressing, and 16,000 plants per acre. With no plow-down or starter fertilizer, the best yield for WF9 was 37.0 bushels for 40 pounds nitrogen sidedressing, and 16,000 population.

There was no significant difference in average effects between the two inbreds. In general, Oh51 yielded more at low fertility and WF9 yielded more at high fertility. The inbred x fertility, inbred x population, and inbred x fertility x population interactions were significant. At low population, the two inbreds yielded about the same but Oh51 yielded more than WF9 at the high populations. At the highest fertility level, however, WF9 outyielded Oh51.

Average ear moisture contents at harvest were 43.2 percent and 53.2 percent for Oh51 and WF9, respectively. Neither inbred was fully mature, using 40 percent ear moisture to indicate maturity. Killing frost occurred September 27 and the plots were harvested October 10. Maturity as measured by ear corn moisture was not affected by soil fertility, nitrogen sidedressings, or plant population.

Experiments 3-10

Tables 6 through 10 present average yield, average percent moisture, and analyses of variance for 25 inbred lines. The average increase of only nine-tenths bushel per acre when fertilizer was applied was not statistically significant. Average yields were 39.3 and 40.2 bushels per acre for 0 and 550 pounds per acre of 15-15-15, respectively.

Yield increased significantly with each plant population increase. Averages were 26.8, 37.5, 44.3, and 50.3 bushels per acre for plant

TABLE 6. ANALYSIS OF VARIANCE FOR YIELD OF 25 INBRED LINES WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS EXPERIMENTS 3-10 COMBINED, 1958

Source of variance	Degrees of freedom	Sum of squares	Mean square	F	Components of variance
Total	599	105879.5			
Replication	2	80.3	40.1		-0.1
Fertilizer (F)	1	112.2	112.2	1.0	-0.1
Error a	2	228.3	114.2		0.7
Population (P)	3	45750.5	15250.2	354.4**	101.5
F x P	3	374.4	124.8	2.9	-1.3
Error b	12	516.3	43.0		1.1
Inbred (I)	24	29320.4	1221.7	27.9**	47.6
F x I	24	2590.1	107.9	2.4**	1.4
P x I	72	6958.3	96.6	2.2**	-16.6
F x P x I	72	14118.9	196.1	12.9**	60.3
Error c	384	5829.8	15.2		15.2
Error c + F x P x I	456	19948.7	43.7		

**Significant at the 1% level of probability

TABLE 7. AVERAGE PERCENT MOISTURE AND YIELD RANKED FOR 25 INBREDS, EXPERIMENTS 3-10, 1958

	Experiments 3-10 All fertilizer and populations			Experiments 3-6 Fertilizer-550 lbs/a. All populations			Experiments 7-10 No fertilizer All populations		
Yield rank	Inbred	Bu. per acre	Percent moisture	Inbred	Bu. per acre	Percent moisture	Inbred	Bu. per acre	Percent moisture
1	W23	50.7	36.8	W23	53.2	36.3	W70	51.2	52.6
2	W64A	49.1	47.0	Oh51	48.8	46.0	W64A	49.6	47.7
3	W70	48.4	53.1	W64A	48.5	45.2	Oh43	48.5	52.6
4	Oh51A	47.6	47.0	Oh51A	47.9	48.0	W23	48.3	37.4
5	Oh51	46.5	44.9	W70	45.5	53.7	Oh51A	47.4	46.0
6	Oh43	45.0	53.4	WR3	44.0	46.0	WR3	45.6	48.2
7	WR3	44.8	48.1	B8	43.7	41.0	Oh51	44.2	43.9
8	B8	43.2	40.8	Hy2	42.8	52.3	W22	43.7	53.6
9	W22	42.6	53.6	MS132	42.1	47.9	M14	43.2	50.1
10	MS132	42.4	46.7	A73	42.0	50.5	B8	42.7	40.6
11	M14	40.8	50.0	W10	41.8	50.2	MS132	42.7	45.5
12	W10	40.6	51.0	Oh43	41.4	54.1	MS116	40.4	47.3
13	WF9	40.3	56.3	W22	41.4	53.6	WF9	40.1	56.4
14	MS116	39.8	52.5	MS130	41.1	45.9	MS211	39.9	47.0
15	A73	39.8	51.6	WF9	40.4	56.1	W10	39.3	51.8
16	Hy2	39.4	53.4	MS116	39.1	46.4	A73	37.6	52.6
17	MS130	39.3	45.3	M14	38.4	50.0	MS130	37.5	44.6
18	MS211	38.0	48.2	MS24A	36.4	43.1	MS24A	36.8	41.3
19	MS24A	36.6	42.2	MS211	36.1	49.5	MS1334	36.4	38.5
20	MS1334	35.8	40.2	R53	35.3	38.4	Hy2	35.9	54.6
21	R53	34.0	37.7	MS1334	35.2	41.8	R53	32.8	37.0
22	MS206	32.7	33.3	MS206	32.6	32.7	MS206	32.7	34.0
23	MS131	30.6	57.8	MS131	31.5	59.5	MS131	29.7	56.0
24	38-11	23.5	59.9	38-11	28.1	55.9	38-11	18.8	64.0
25	C103	22.7	58.3	C103	27.5	53.0	C103	17.9	63.6
Averages		39.8	48.1		40.2	47.9		39.3	48.3

Least significant differences(LSD) for average yields:

(a) over all fertilizer and plant population treatments
LSD = 2.2 bu. @ 5%, 2.9 bu. @ 1%

(b) within fertilizer treatments
LSD = 3.1 bu. @ 5%, 4.1 bu. @ 1%

(c) between fertilizer treatments for the same inbred
LSD = 8.9 bu. @ 5%, 11.7 bu. @ 1%

TABLE 8. AVERAGE YIELD RANKED FOR 25 INBREDS AT FOUR PLANT POPULATIONS - EXPERIMENTS 3-10, 1958

Rank	Experiments 3 and 7, 7,500 plants per acre		Experiments 4 and 8, 11,400 plants per acre		Experiments 5 and 9, 14,600 plants per acre		Experiments 6 and 10, 18,300 plants per acre	
	Inbred	Bu. per acre	Inbred	Bu. per acre	Inbred	Bu. per acre	Inbred	Bu. per acre
1	W64A	34.2	W23	50.1	W23	59.6	Oh51	61.7
2	W70	33.2	W64A	49.0	Oh51	52.9	Oh51A	61.3
3	M14	32.7	WR3	46.1	Oh51A	52.0	W64A	61.2
4	W23	32.3	Oh51A	45.3	W64A	51.9	W23	60.9
5	W22	32.2	W70	44.6	WR3	50.9	W10	60.5
6	Oh51A	31.9	Oh43	43.1	B8	50.8	W70	60.3
7	WR3	30.9	M14	42.7	Hy2	48.6	Oh43	59.3
8	Oh43	30.1	Oh51	41.6	MS132	48.4	B8	56.7
9	Oh51	29.6	MS132	40.2	Oh43	47.2	W22	56.2
10	WF9	27.7	B8	37.9	MS130	47.2	MS132	54.3
11	B8	27.4	MS116	37.7	W22	46.4	WF9	53.0
12	MS132	26.6	A73	37.6	W70	45.4	MS116	52.5
13	MS130	25.9	WF9	37.2	M14	44.9	A73	52.2
14	MS24A	25.8	MS211	35.7	A73	44.4	MS211	51.5
15	MS116	25.4	MS130	35.7	MS116	43.4	WR3	51.2
16	Hy2	25.3	W22	35.5	WF9	43.2	Hy2	49.4
17	W10	25.1	R53	35.2	W10	41.7	MS1334	48.5
18	A73	25.0	W10	35.0	MS24A	41.0	MS130	48.4
19	MS211	24.2	Hy2	34.1	MS206	40.9	MS24A	45.7
20	MS1334	22.2	MS24A	34.0	MS211	40.6	M14	43.1
21	C103	21.9	MS1334	33.3	R53	40.3	R53	39.6
22	38-11	21.5	MS206	31.1	MS1334	39.3	MS131	39.6
23	R53	21.0	MS131	30.7	MS131	34.0	MS206	37.9
24	MS206	20.6	C103	22.9	C103	22.0	38-11	29.5
25	MS131	18.0	38-11	21.6	38-11	21.3	C103	23.9
Averages		26.8		37.5		44.3		50.3

Least significant differences (LSD) for average yields:

(a) within populations

LSD = 4.4 bu. @ 5%, 5.8 bu. @ 1%

(b) between populations, any inbred

LSD = 8.5 bu. @ 5%, 11.1 bu. @ 1%

TABLE 9. AVERAGE YIELD RANKED FOR 25 INBREDS WITH AND WITHOUT FERTILIZER AT 7,500 AND 11,400 PLANTS PER ACRE

	7,500 plants per acre				11,400 plants per acre			
	Experiment 3 Fertilized		Experiment 7 Unfertilized		Experiment 4 Fertilized		Experiment 8 Unfertilized	
Yield rank	Inbred	Bushels per acre	Inbred	Bushels per acre	Inbred	Bushels per acre	Inbred	Bushels per acre
1	W64A	35.6	W22	35.0	W23	48.4	W64A	53.7
2	Oh51A	34.7	W70	34.0	W64A	44.3	W23	51.9
3	M14	33.3	W64A	32.8	Oh51	43.7	W70	51.6
4	W23	32.9	M14	32.1	WR3	42.2	Oh51A	50.1
5	W70	32.5	Oh43	32.1	Oh43	41.6	WR3	50.0
6	WR3	32.2	W23	31.7	MS130	39.1	M14	46.9
7	A73	31.3	WR3	29.7	WF9	38.6	Oh43	44.7
8	Oh51	31.0	WF9	29.1	M14	38.5	MS132	43.1
9	Hy2	30.1	Oh51A	29.1	W70	37.6	MS116	43.0
10	W22	29.4	Oh51	28.2	MS132	37.3	Oh51	39.5
11	Oh43	28.2	MS24A	27.9	A73	37.2	B8	39.5
12	B8	27.8	B8	27.0	C103	36.6	MS211	39.3
13	MS132	27.2	MS130	26.3	MS24A	35.5	A73	38.0
14	MS116	26.3	MS132	26.1	W22	34.8	R53	37.3
15	WF9	26.2	MS211	25.5	W10	34.7	W22	36.2
16	W10	25.8	MS116	24.5	Oh51A	34.7	MS1334	36.1
17	MS130	25.4	W10	24.3	R53	33.0	Hy2	35.9
18	MS206	24.1	38-11	23.3	38-11	32.6	WF9	35.8
19	MS24A	23.7	C103	22.0	MS116	32.3	MS206	35.6
20	MS1334	23.6	MS1334	20.9	Hy2	32.3	W10	35.3
21	R53	23.4	Hy2	20.6	MS211	32.2	MS24A	32.6
22	MS211	22.9	MS131	19.8	MS131	30.9	MS130	32.4
23	C103	21.8	R53	18.7	MS1334	30.5	MS131	30.5
24	38-11	19.8	A73	18.6	B8	27.8	38-11	10.6
25	MS131	16.1	MS206	17.2	MS206	26.7	C103	9.3
Averages		27.4		26.3		36.7		38.4

Analyses of variance

Source	Degrees of freedom	Mean squares			
Replication	2	101.8	22.0	269.6	2.5
Inbreds	24	71.8**	80.7**	74.4**	352.4**
Error	48	26.0	18.1	21.1	32.9

Least significant differences

LSD 5%	8.4	7.0	7.5	9.4
LSD 1%	11.1	9.3	10.0	12.5

**Significant at 1% level of probability

TABLE 10. AVERAGE YIELD RANKED FOR 25 INBREDS WITH AND WITHOUT FERTILIZER AT 14,600 AND 18,300 PLANTS PER ACRE

	14,600 plants per acre				18,300 plants per acre			
	Experiment 5 Fertilized		Experiment 9 Unfertilized		Experiment 6 Fertilized		Experiment 10 Unfertilized	
Yield rank	Inbred	Bushels per acre	Inbred	Bushels per acre	Inbred	Bushels per acre	Inbred	Bushels per acre
1	W23	61.8	W70	60.7	W23	69.6	Oh43	63.7
2	Oh51	57.3	W23	57.4	Oh51	63.0	W64A	61.4
3	Hy2	54.1	Oh43	53.5	Oh51A	62.9	Oh51	60.4
4	Oh51A	53.5	B8	52.2	W70	62.0	Oh51A	59.7
5	W64A	53.3	WR3	51.3	W10	61.5	W10	59.5
6	WR3	50.6	Oh51A	50.6	B8	61.1	W70	58.6
7	W70	50.0	W64A	50.4	W64A	60.9	WF9	55.7
8	MS130	49.8	W22	49.4	W22	58.1	W22	54.3
9	B8	49.4	Oh51	48.6	MS132	55.1	MS132	53.5
10	MS132	48.8	MS132	48.1	Oh43	55.0	A73	53.3
11	A73	48.4	M14	47.8	Hy2	54.7	MS116	53.2
12	WF9	46.5	MS211	45.5	MS211	53.5	B8	52.3
13	MS116	45.9	MS130	44.5	MS116	51.9	W23	52.1
14	W10	45.2	Hy2	43.2	A73	51.1	WR3	51.4
15	W22	43.4	MS24A	41.8	WR3	51.0	MS1334	50.0
16	MS206	42.7	MS116	40.9	WF9	50.3	MS211	49.7
17	R53	42.0	A73	40.5	MS130	50.1	MS130	46.7
18	M14	42.0	WF9	39.9	MS1334	47.1	M14	46.2
19	Oh43	40.9	MS206	39.1	MS24A	46.4	MS24A	45.0
20	MS24A	40.2	MS1334	38.8	R53	42.7	Hy2	44.2
21	MS1334	39.9	R53	38.5	MS131	42.7	MS206	39.1
22	MS131	36.2	W10	38.3	M14	39.9	R53	36.6
23	MS211	35.7	MS131	31.8	38-11	38.7	MS131	36.5
24	C103	25.5	38-11	21.2	MS206	36.8	C103	21.8
25	38-11	21.3	C103	18.6	C103	26.0	38-11	20.3
Averages		45.0		43.7		51.7		49.0

Analyses of variance

Source	Degrees of freedom	Mean squares			
Replication	2	255.0	1.0	54.6	13.0
Inbreds	24	261.9**	288.5**	304.2**	374.6**
Error	48	57.1	45.6	73.4	34.3

Least significant differences

LSD 5%	12.4	10.8	14.1	9.6
LSD 1%	16.5	14.4	18.8	12.8

**Significant at 1% level of probability

populations of 7,500, 11,400, 14,600, and 18,300 plants per acre, respectively.

Differences among inbred yields were highly significant in each experiment and in the combined analysis. Average yields ranged from 22.7 bushels for C103 to 50.7 bushels for W23. Highly significant interactions--fertilizer x inbred and population x inbred--indicated that some of the inbreds did not respond alike to fertilizer and plant population. These interactions are illustrated in Figure I. However, when the error effects were removed from these interaction terms, the components of variance were either very small or negative (Table 6). Thus relatively little importance can be attached to these interactions.

Moisture content was not affected by fertilizer or population. The averages are presented in Table 7 to indicate relative maturity of the inbreds. Correlations of yield and moisture content (Table 11) were low, indicating that only a small portion of the difference in yield was associated with maturity of the inbreds. The significant negative correlations in Experiments 5, 8, 9, and 10 indicate that early maturing inbreds tended to be higher yielding than late inbreds in these cases.

Table 12 gives r values for yield for all possible combinations of Experiments 3-10. Correlations were nearly all highly significant, indicating the inbreds tended to respond alike to fertilizer and population. Low and negative components of variance for inbred x fertilizer and inbred x population interactions (Table 6) and similarity of ranking (Tables 7, 8, 9, and 10) further substantiate the tendency for the inbreds to respond in a similar manner.

FIGURE I. YIELDS OF 25 INBREDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS

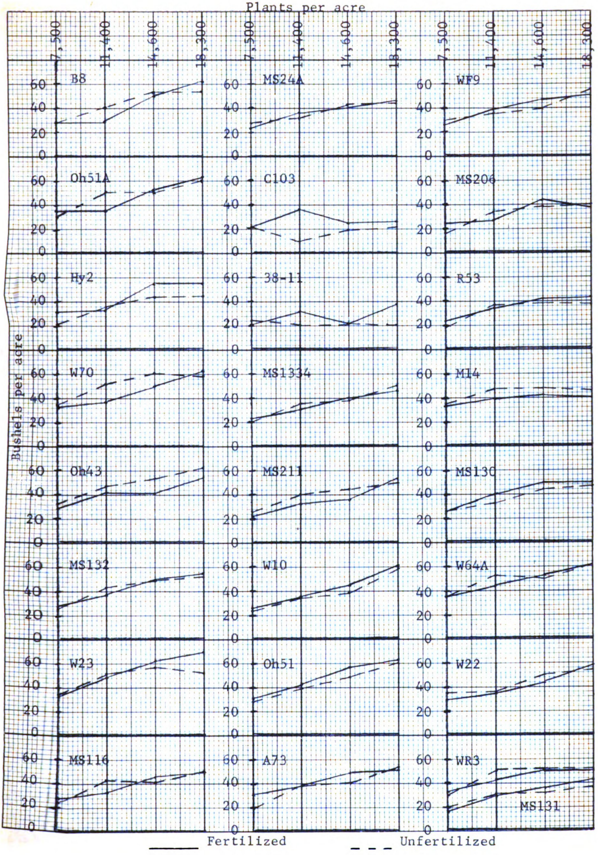

TABLE 11. CORRELATION OF PER CENT MOISTURE WITH YIELD FOR EXPERIMENTS 3-10

Experiment no.	r	Plants per acre	Fertilizer
3	-.0905	7,500	Fertilized
4	-.1105	11,400	Fertilized
5	-.5669*	14,600	Fertilized
6	-.2033	18,300	Fertilized
7	-.0491	7,500	Unfertilized
8	-.4671*	11,400	Unfertilized
9	-.4964*	14,600	Unfertilized
10	-.4088*	18,300	Unfertilized

* Significant at 5% level of probability

TABLE 12. CORRELATION OF YIELD FOR ALL POSSIBLE COMBINATIONS OF EXPERIMENTS 3, 4, 5, 6, 7, 8, 9, AND 10

	Plants per acre						
	Fertilized			Unfertilized			
Experiment	11,400	14,600	18,300	7,500	11,400	14,600	18,300
number	4	5	6	7	8	9	10
3	.6898**	.7569**	.6328**	.6079**	.7630**	.7523**	.6750**
4		.5762**	.5502**	.6849**	.4965*	.5472**	.4910*
5			.7851**	.3530	.7864**	.7826**	.7327**
6				.5431**	.7030**	.7901**	.8225**
7					.5257**	.6740**	.5609**
8						.9041**	.8089**
9							.8095**

* Significant at 5% level of probability
** Significant at 1% level of probability

Duncan's (2) proposal that the logarithm of yield in pounds per plant bears a linear relationship to plant population was applied to 23 of the inbred lines tested. Inbreds C103 and 38-11 have been omitted from these predictions because stands were poor and pollination was not complete. Yields for the four actual populations fell close to a straight line for some inbreds, but not for others. In general, yields predicted by this method for the four populations agreed closely with yields adjusted by covariance analysis (Table 13).

Yields predicted by Duncan's method for 23 inbreds at 5,000, 10,000, 15,000, 20,000, 25,000 and 30,000 plants per acre are given in Table 14. Predicted yields for most of the inbreds continued to increase up to 30,000 plants per acre. Some inbreds--B8, Hy2, W70, Oh43, MS132, MS116, MS1334, MS211, W10, Oh51, A73, MS130, W64A--continued to increase up to 40,000 plants per acre before yields leveled off. Predicted yields for MS24A, MS206, R53, M14, W22, and WR3 reached a peak at about 25,000 plants. These predictions for 20,000 to 40,000 plants were not evaluated by actual field experiments.

Figure II illustrates the relationship of pounds per plant, logarithms of pounds per plant, and predicted yields for four of the inbreds. Pounds per plant and logarithms of pounds per plant were plotted for the four actual populations. Actual values for W70 and Oh51 fit a straight line very closely. Highest predicted yields were for about 35,000 plants per acre. Logarithms of yield per plant for MS206 and M14 did not fit as closely the predicting line drawn through the highest and lowest points. Since yield per plant decreased more rapidly

FIGURE II. POUNDS PER PLANT AND LOGARITHMS FOR FOUR ACTUAL PLANT POPULATIONS, AND YIELDS PER ACRE PREDICTED FROM LOGARITHMS FOR POPULATIONS OF 5,000 TO 40,000 FOR FOUR INBREDS

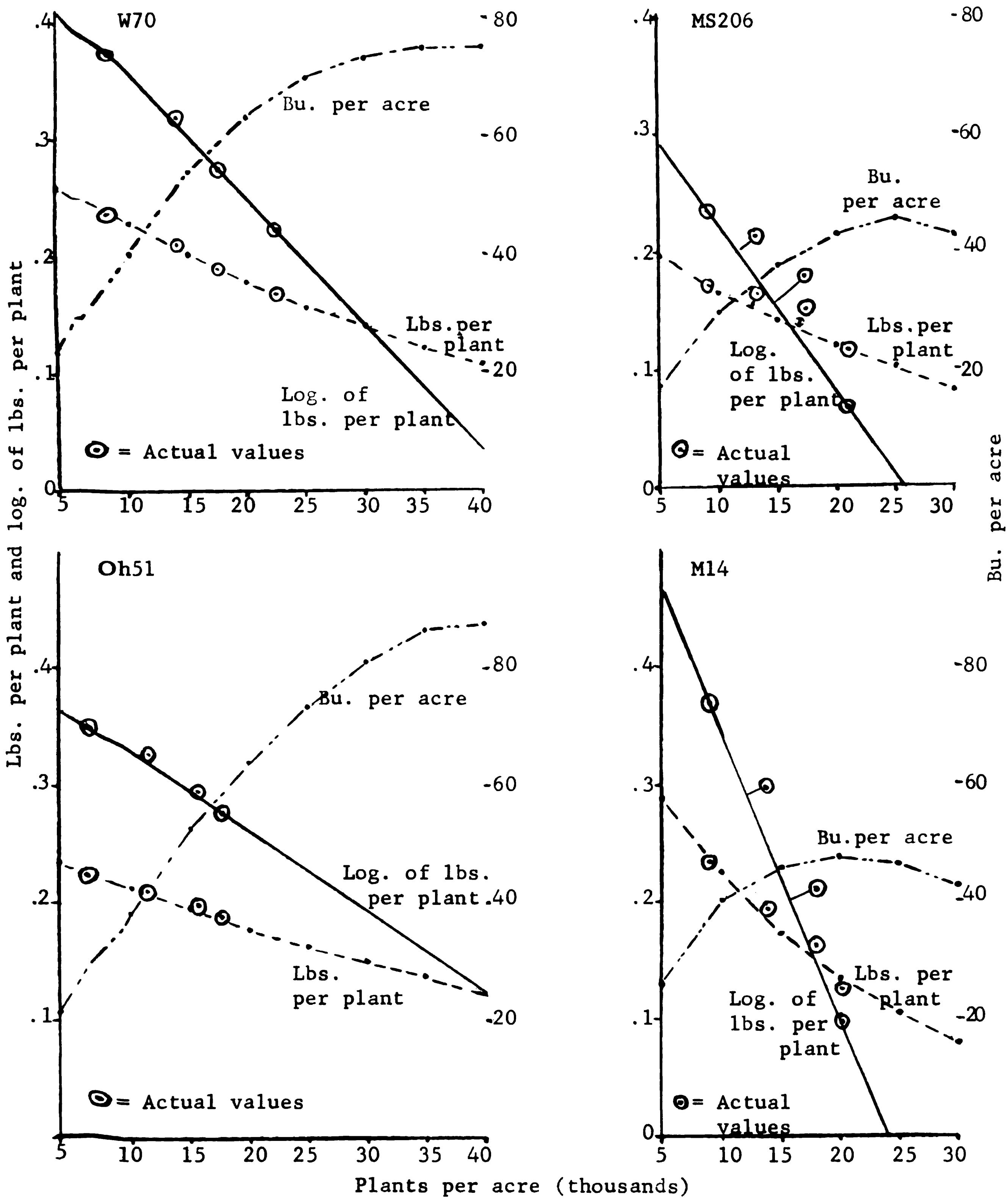

TABLE 13. BUSHELS PER ACRE FOR 23 INBRED LINES ADJUSTED TO FOUR AVERAGE PLANT POPULATIONS BY COVARIANCE ANALYSIS AND BY DUNCAN'S (2) LOGARITHM METHOD - EXPERIMENTS 3-10

	Plants per acre							
	7,500		11,400		14,600		18,300	
Inbred	Covari-ance	Duncan's log.	Covari-ance	Duncan's log.	Covari-ance	Duncan's log.	Covari-ance	Duncan's log.
B8	27.4	28.9	39.7	40.5	50.8	48.8	56.7	56.5
Oh51A	31.9	34.4	45.3	46.6	52.0	54.0	61.3	60.1
Hy2	25.3	26.4	34.1	36.6	48.6	43.5	49.4	50.0
W70	33.2	32.4	44.6	44.6	55.4	52.9	60.3	60.1
Oh43	30.1	31.1	43.1	42.7	47.2	50.6	59.3	57.8
MS132	26.6	28.1	40.2	39.1	48.4	46.4	54.3	52.9
W23	32.3	35.4	50.1	47.2	59.6	54.7	60.9	61.1
MS116	25.4	22.9	37.7	32.2	43.4	38.6	52.5	45.1
MS24A	25.8	24.1	34.0	31.8	41.0	36.2	45.7	39.9
MS1334	22.2	24.0	33.3	34.0	39.3	41.2	48.5	48.4
MS211	24.2	24.2	35.7	34.8	40.6	42.5	51.5	50.3
W10	25.1	26.2	35.0	37.5	41.7	45.4	60.5	53.9
Oh51	29.6	29.7	41.6	42.5	52.9	51.4	61.7	60.8
A73	25.0	26.0	37.6	36.2	44.4	43.5	52.2	50.7
WF9	27.7	28.1	37.2	38.9	43.2	45.9	53.0	52.6
MS206	20.6	24.1	31.1	32.2	40.9	37.3	37.9	41.5
R53	21.0	22.1	35.2	30.5	40.3	36.0	39.6	41.5
M14	32.7	34.0	42.7	42.3	44.9	45.9	43.1	47.4
MS130	25.9	25.2	35.7	35.8	47.2	43.0	48.4	50.3
W64A	34.2	34.6	49.0	47.2	51.9	55.3	61.2	62.7
W22	32.2	32.4	35.5	43.2	46.4	49.8	56.2	54.9
WR3	30.9	31.1	46.1	40.9	50.9	46.4	51.2	51.3
MS131	18.0	20.1	30.7	28.3	34.0	34.4	39.6	40.2

TABLE 14. YIELDS FOR 23 INBREDS PREDICTED FOR SIX PLANT POPULATIONS BY DUNCAN'S (2) LOGARITHM METHOD

Inbred	Plants per acre 5,000	10,000	15,000	20,000	25,000	30,000
	Bushels per acre					
B8	22.1	36.6	49.8	60.0	68.3	73.9
Oh51A	25.0	42.5	54.4	61.8	66.1	67.5
Hy2	18.6	33.2	44.5	52.9	59.4	63.2
W70	23.4	40.7	54.1	63.2	69.6	73.4
Oh43	22.1	42.5	49.0	60.7	66.9	71.2
MS132	19.9	35.2	46.9	55.7	61.6	65.9
W23	25.4	43.4	55.4	62.9	67.0	68.6
MS116	16.1	29.1	39.6	47.5	54.5	58.9
MS24A	17.5	29.3	36.7	40.4	42.4	41.8
MS1334	16.7	30.7	42.1	51.1	58.9	64.3
MS211	16.7	31.1	43.4	53.6	62.5	69.6
W10	18.1	33.4	46.6	57.9	66.1	73.4
Oh51	20.8	38.2	52.5	63.9	73.2	80.9
A73	18.2	32.7	43.7	52.1	58.5	62.7
WF9	19.8	35.4	47.4	56.4	62.5	67.0
MS206	17.4	29.6	37.8	42.9	45.5	42.9
R53	14.8	28.2	37.0	43.6	48.2	48.2
M14	25.5	43.0	45.8	47.5	46.0	42.9
MS130	17.7	32.1	44.2	53.6	61.2	67.5
W64A	24.8	43.0	56.3	65.4	70.5	73.9
W22	23.4	43.2	50.4	56.8	60.3	61.1
WR3	22.6	37.7	47.1	52.5	54.5	54.6
MS131	14.0	25.5	34.8	42.1	48.2	52.0

as population increased for these two inbreds, predicted yields reached a peak at 25,000 and 20,000 plants per acre and then declined.

The 25 inbreds could be classified into three groups based on their response to increasing population from 14,600 to 18,300. (1) Oh51, Oh51A, W64A, Oh43, W22, WF9, MS116, MS211, and MS1334 increased yields significantly, 9.2 to 12.1 bushels per acre. (2) 38-11, W10, W70, B8, MS132, A73, MS24A, MS131, and MS206 increased 4.7 to 8.2 bushels which was not significant at the 5% level. (3) W23, WR3, Hy2, MS130, M14, R53, and C103 showed very little or no increase in yield.

The six highest yielding inbreds, averaged for all treatments, were W23, W64A, W70, Oh52A, Oh43, and RW3. The six lowest yielding inbreds were MS211, MS24A, MS1334, R53, MS206, and MS131, excluding C103 and 38-11 since they were very late and stands were poor.

Single-cross Hybrids

Experiment 2

A summary of average yields adjusted for stand by covariance, and the analysis of variance are presented in Table 15 for seed produced on single-cross hybrid WF9 x Oh51A grown in 1957 with three levels of complete fertilizer, four nitrogen sidedressing levels, and five plant populations. Since pollination was not controlled as it would be in a double-cross seed production field, the seed produced by open pollination can be considered as pseudo "double-cross" seed.

Yields were not affected significantly by complete fertilizer or nitrogen sidedressing treatments. Plant population was the only factor affecting yield significantly in this experiment. Average yields were 43.2, 60.6, 69.4, 88.8, and 91.6 bushels per acre for populations of 6,100, 9,200, 11,200, 15,100 and 17,200 plants per acre. Each increase in population, except 15,100 to 17,200, produced a significant yield increase.

There were no significant effects of complete fertilizer, nitrogen sidedressing, or population on moisture content which averaged 50.3%. The experiment was planted June 2, harvested October 10, and the first killing frost occurred September 27. Seed produced in this experiment was not fully mature when harvested and yields should have been higher

TABLE 15. AVERAGE YIELDS ADJUSTED FOR STAND AND ANALYSIS OF VARIANCE FOR SEED PRODUCED ON WF9 x Oh51A SINGLE-CROSS HYBRID AT THREE LEVELS OF COMPLETE FERTILIZER, FOUR NITROGEN SIDEDRESSING LEVELS, AND FIVE PLANT POPULATIONS - EXPERIMENT 2

12-12-12 fertilizer pounds per acre	Nitrogen sidedressing pounds per acre	Plants per acre 6,100	9,200	11,200	15,100	17,200	Averages
0	0	48.5	53.2	62.2	81.7	92.4	67.6
	20	54.2	64.8	65.7	91.4	72.6	69.8
	40	41.4	62.3	80.9	91.9	92.8	75.7
	60	53.0	61.4	75.4	84.6	100.4	75.0
	Average	49.3	60.4	73.3	87.4	89.6	72.0
200	0	43.5	56.2	61.1	84.0	86.4	66.2
	20	31.9	59.1	71.2	81.5	84.7	65.7
	40	38.1	64.7	66.5	84.8	94.7	69.7
	60	44.8	59.0	69.1	94.7	88.5	71.2
	Average	39.6	59.8	67.0	86.3	88.6	68.2
850	0	43.7	72.4	69.1	103.5	102.2	78.2
	20	39.4	54.0	66.2	88.6	99.6	69.6
	40	38.3	58.2	69.4	92.1	97.5	71.1
	60	41.0	61.4	67.2	86.7	86.7	68.6
	Average	40.6	61.5	68.0	92.7	96.5	71.9
Nitrogen x Population	0	45.2	60.6	64.1	89.7	93.7	70.7
	20	41.8	59.3	67.7	87.2	85.6	68.4
	40	39.3	61.7	72.3	89.6	95.0	72.2
	60	46.3	60.6	70.6	88.7	91.9	71.6
	Average	43.2	60.6	69.4	88.8	91.6	70.7

Analysis of variance

Source	Degrees of freedom	Sum of squares	Mean square	F
Replication	1	480.4		
Fertilizer (F)	2	328.6	164.3	18.7
Error a	2	17.5	8.8	
Nitrogen (N)	3	210.1	70.1	0.8
F x N	6	929.1	154.8	1.7
Error b	9	812.2	90.2	
Population (P)	4	39082.5	9770.7	178.2**
F x P	8	701.9	87.7	1.6
N x P	12	556.0	46.3	0.8
F x N x P	24	1850.8	77.1	1.4
Error c	48	2632.6	54.8	
Total	119	47601.7		

Least significant differences--bushels per acre

Treatment	Level of probability 5%	1%
12-12-12 fertilizer	2.9	6.6
Nitrogen sidedressing	5.5	8.0
Population	4.3	5.7
Any two treatment means	24.8	33.0

**Significant at 1% level of probability

if the crop had reached full maturity. Since no measurable effects of treatments on maturity had occurred by harvest, it is likely that yields would have increased proportionately for all treatments with a longer growing season.

Specifications used for grading seed samples are given in Table 2. Grading percents and bushels per acre of each grade are summarized in Tables 16 and 17, respectively. Yields were not discounted for pollen parent rows necessary in commercial double-cross seed production. Long medium flats are separately listed to show effect of treatment on kernel length, but are included in total medium flats.

Complete fertilizer and nitrogen sidedressing treatments did not affect seed grades significantly. Plant population significantly affected grading expressed as either percent or bushels per acre.

As population increased, the percent of large flats and long medium flats decreased significantly and small flats increased significantly. The decrease in percent large flats was accompanied by a corresponding increase in percent small flats. Percent of medium flats and rounds were not affected by population. These data indicated that kernel width and length were reduced as population was increased.

Since total yield increased with population, bushels per acre of each grade were not affected the same as grading percent. Yield of large flats was not affected while yield of medium flats, long medium flats, small flats, and rounds increased significantly as population increased. Yields of medium flats, the most desirable grade in the seed trade, were 28.5, 40.1, 46.7, 59.8, and 61.2 bushels per acre for the five populations, respectively. All except the last increase were highly significant.

TABLE 16. AVERAGE GRADING PERCENT AND ANALYSES OF VARIANCE FOR SEED PRODUCED ON SINGLE-CROSS HYBRID WF9 x Oh51A AT THREE LEVELS OF COMPLETE FERTILIZER, FOUR NITROGEN SIDEDRESSING LEVELS, AND FIVE PLANT POPULATIONS - EXPERIMENT 2

	% Large flats	% Total medium flats	% Long medium flats[1/]	% Small flats	Rounds
12-12-12 fertilizer--pounds per acre					
0	8.4	67.3	35.4	10.6	5.6
200	8.5	66.0	37.0	11.6	5.6
850	7.9	67.0	40.2	10.8	5.9
Least significant difference 5%	1.3	3.4	19.6	1.7	1.6
Least significant difference 1%	3.1	7.7	45.0	3.8	3.7
Nitrogen sidedressing--pounds per acre					
0	6.8	67.2	39.6	11.5	5.7
20	7.7	67.7	37.8	10.8	5.6
40	9.4	66.0	37.0	11.0	5.7
60	9.2	66.0	35.7	10.7	5.6
Least significant difference 5%	2.3	3.8	7.4	1.4	0.6
Least significant difference 1%	3.2	5.4	10.7	2.0	1.0
Plants per acre					
6,100	10.9	65.8	41.0	9.2	5.9
9,200	9.6	66.2	39.5	10.3	5.9
11,200	7.5	67.7	37.2	11.2	5.5
15,100	7.2	67.3	36.8	11.6	5.5
17,200	6.2	66.7	33.1	12.8	5.5
Least significant difference 5%	2.0	2.1	4.0	1.3	0.6
Least significant difference 1%	2.6	2.7	5.3	1.7	0.8

Analyses of variance

Source	DF	Mean squares				
Replication	1	20.9	9.1	49.4	2.4	4.9
Fertilizer (F)	2	4.3	17.6	233.5	12.0	1.0
Error a	2	1.9	12.1	416.0	3.0	2.8
Nitrogen (N)	3	45.2	22.2	75.4	3.2	0.2
F x N	6	3.5	22.6	74.0	17.3	0.3
Error b	9	14.8	41.8	161.4	5.8	1.2
Population (P)	4	88.6**	14.0	217.2**	42.7**	1.0
F x P	8	23.4	2.7	20.5	9.7	1.2
N x P	12	4.3	22.0	26.9	4.7	1.0
F x N x P	24	8.2	14.4	87.3*	5.4	1.1
Error c	48	11.3	12.6	47.7	5.0	0.9

[1/]Long medium flats were separately listed, but included with total medium flats.

* Significant at 5% level of probability

** Significant at 1% level of probability

TABLE 17. AVERAGE BUSHELS PER ACRE BY GRADE AND ANALYSES OF VARIANCE FOR SEED PRODUCED ON SINGLE-CROSS HYBRID WF9 x Oh51A AT THREE LEVELS OF COMPLETE FERTILIZER, FOUR NITROGEN SIDEDRESSING LEVELS, AND FIVE PLANT POPULATIONS - EXPERIMENT 2

		Large flats	Total medium flats	Long medium flats[1/]	Small flats	Rounds
12-12-12 fertilizer--pounds per acre						
0		5.9	50.1	26.2	8.0	4.0
200		5.3	44.3	24.8	7.9	3.8
850		5.4	47.5	28.1	7.7	4.2
Least significant difference	5%	0.9	7.2	15.3	0.6	1.1
Least significant difference	1%	2.2	16.6	35.3	1.4	2.5
Nitrogen sidedressing--pounds per acre						
0		4.8	50.0	29.8	8.5	4.2
20		3.7	45.9	25.3	7.6	3.8
40		5.9	45.4	25.2	7.7	3.9
60		6.2	47.7	25.2	7.7	4.0
Least significant difference	5%	1.2	5.9	7.1	1.1	0.7
Least significant difference	1%	1.7	8.5	10.2	1.5	1.0
Plants per acre						
6,100		4.7	28.5	17.6	3.8	2.6
9,200		5.9	40.1	24.1	6.2	3.6
11,200		5.2	46.7	26.2	7.6	3.7
15,100		6.3	59.8	33.2	10.2	4.9
17,200		5.7	61.2	30.5	11.6	5.1
Least significant difference	5%	1.2	5.0	4.6	1.2	0.6
Least significant difference	1%	1.6	6.6	6.1	1.7	0.7

Analyses of variance

Source	DF	Mean squares				
Replication	1	10.1	3.3	86.7	4.4	2.1
Fertilizer (F)	2	4.0	341.5	121.2	0.6	1.7
Error a	2	0.9	56.0	253.4	0.4	1.2
Nitrogen (N)	3	14.3	129.4	147.2	5.3	0.1
F x N	6	6.4	305.4	181.5	4.4	1.4
Error b	9	3.9	102.3	146.8	3.3	1.2
Population (P)	4	9.6	4533.3**	878.4**	236.8**	25.6**
F x P	8	8.6	64.0	49.5	2.4	1.6
N x P	12	1.8	67.0	44.8	1.2	0.9
F x N x P	24	5.4	78.1	71.1	3.7	0.8
Error c	48	4.4	72.6	62.0	4.6	0.9

[1/]Long medium flats were separately listed, but included with total medium flats.

* Significant at 5% level of probability

** Significant at 1% level of probability

Experiments 11 and 12

Experiment 11 was planted on June 2, 1958 and Experiment 12 on June 10, 1958. The same treatments were applied to both of these experiments grown in the same field as Experiment 2 in 1957. Since stands were poorer in Experiment 12, resulting populations were lower than Experiment 11. Soil test results were slightly lower in 1958 but still indicated that the field was relatively high in fertility. Plots were arranged in two-row strips between five-row lands of inbred plots of Experiments 3-10 to provide additional pollen for the inbreds. Thus, plant competition was reduced to some extent.

Moisture contents of corn averaged 48.5 and 46.5% in Experiment 11 and 53.1 and 51.0% in Experiment 12 for the 0 and the 550 pound fertilizer treatments, respectively. Significant differences of 1.7 to 2.3% higher moisture contents for the three highest populations occurred in Experiment 11. The effect of population on moisture content was not significant in Experiment 12. Relative maturity (earliest to latest) of the five single crosses is normally Oh51 x R53, MS116 x MS211, W23 x MS24, WF9 x Oh51A, and WF9 x M14. The first three hybrids are early maturing while the last two are midseason and late maturing. This order was not followed in these experiments since moisture contents of WF9 x Oh51A and WF9 x M14 averaged slightly less than those for the earlier hybrids. No explanation was apparent. Differences in shelling percent were not significant in Experiment 11 for any factor. Differences between shelling percents for the hybrids were significant in Experiment 12. Since the effects on stand, moisture content, and shelling percent were either small, or inconsistent, the summarized data are not presented.

Fertilizer increased yields significantly, 8.7 and 7.3 bushels per acre for Experiments 11 and 12 (Tables 18 and 19). Yields also increased significantly as population increased. Average yields were 58.1, 71.4, 76.6, and 89.1 bushels per acre for populations of 7,300, 10,400, 12,800, and 17,100 plants per acre in Experiment 11 (Table 18), and 46.9, 59.2, 63.8, and 74.7 bushels per acre for average stands of 7,000, 9,400, 11,200, and 14,000 plants per acre in Experiment 12 (Table 19).

Grading percent was unaffected by fertilizer treatments except for the long medium flat grade in Experiment 11 where fertilizer treatment produced a significant increase in kernel length (Tables 20 and 21). Although the differences were not all significant, the percent of large flats, long medium flats, and rounds tended to decrease as population increased. Percent of medium flats was not changed significantly while percent of small flats increased significantly with increased population. There were no significant differences in grading percent among the five single-cross hybrids.

Yields of large flats were not affected by fertilizer or plant population (Tables 22 and 23). Yields of all other grades tended to increase with fertilizer and higher plant populations although not all of the differences were significant. There were no significant differences among hybrids for any of the grades in Experiment 11. Hybrid differences in Experiment 12 were due to lower yields of medium flats and rounds for MS116 x MS211.

TABLE 18. AVERAGE YIELDS ADJUSTED FOR STAND AND ANALYSIS OF VARIANCE FOR SEED PRODUCED ON FIVE SINGLE-CROSS HYBRIDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS - EXPERIMENT 11

Fertilizer	Plants per acre	Single-cross hybrid WF9 x Oh51A	Oh51 x R53	W23 x MS24	MS116 x MS211	WF9 x M14	Averages
Unfertilized	7,300	55.7	58.9	53.0	54.1	54.7	55.3
	10,400	69.5	63.9	67.8	65.1	74.3	68.1
	12,800	69.4	71.0	73.6	73.5	68.0	71.1
	17,100	84.7	80.9	80.4	95.5	74.9	83.3
Averages		69.8	68.7	68.7	72.0	68.0	69.5
Fertilized	7,300	59.7	58.6	57.3	68.4	60.4	60.9
	10.400	84.1	77.4	76.1	67.7	68.3	74.7
	12,800	77.6	84.6	92.6	76.5	79.1	82.1
	17,100	93.7	103.2	90.2	93.2	94.4	94.9
Averages		78.8	81.0	79.1	76.5	75.6	78.2
Population	7,300	57.7	58.8	55.2	61.3	57.6	58.1
x	10,400	76.8	70.7	72.0	66.4	71.3	71.4
Hybrid	12,800	73.5	77.8	83.1	75.0	73.6	76.6
	17,100	89.2	92.1	85.3	94.4	84.7	89.1
Hybrid averages		74.3	74.9	73.9	74.3	71.8	73.9

Analysis of variance

Source	Degrees of freedom	Sum of squares	Mean square	F
Replication	2	316.1		
Fertilizer (F)	1	2267.2	2267.2	56.8*
Error a	2	79.8	39.9	
Population (P)	3	14859.5	4953.2	34.1**
F x P	3	210.3	70.1	0.5
Error b	12	1742.2	145.2	
Hybrid (H)	4	135.9	34.0	0.3
F x H	4	213.9	53.5	0.5
P x H	12	1128.9	94.1	1.0
F x P x H	12	1179.4	98.3	1.0
Error c	64	6231.1	97.4	
Total	119	28364.5		

Least significant differences--bushels per acre

Treatment	Level of probability 5%	1%
Fertilizer	5.0	11.4
Population	6.8	9.5
Hybrid	5.7	7.6
Any two treatment means	27.1	35.8

* Significant at 5% level of probability
** Significant at 1% level of probability

TABLE 19. AVERAGE YIELDS ADJUSTED FOR STAND AND ANALYSIS OF VARIANCE FOR SEED PRODUCED ON FIVE SINGLE-CROSS HYBRIDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS - EXPERIMENT 12

Fertilizer	Plants per acre	Single-cross hybrid					
		WF9 x Oh51A	Oh51 x R53	W23 x MS24	MS116 x MS211	WF9 x M14	Averages
Unfertilized	7,000	45.5	44.0	41.5	39.3	46.4	43.4
	9,400	59.3	54.5	50.2	54.5	58.9	55.5
	11,200	58.2	60.4	60.4	61.6	65.6	61.2
	14,000	80.5	69.8	83.2	39.3	76.5	69.9
Averages		60.9	57.2	58.8	48.7	61.9	57.5
Fertilized	7,000	51.6	54.8	51.1	48.1	46.7	50.4
	9,400	65.1	64.7	62.3	63.2	59.2	62.9
	11,200	66.3	67.7	73.3	56.4	68.1	66.4
	14,000	79.5	73.6	89.2	70.2	85.0	79.5
Averages		65.7	65.2	69.0	59.5	64.8	64.8
Population	7,000	48.6	49.4	46.3	43.7	46.6	46.9
x	9,400	62.2	59.6	56.3	58.9	59.1	59.2
Hybrid	11,200	62.3	64.1	66.9	59.0	66.9	63.8
	14,000	80.0	71.7	86.2	54.8	80.8	74.7
Hybrid averages		63.3	61.2	63.9	54.1	63.3	61.2

Analysis of variance

Source	Degrees of freedom	Sum of squares	Mean square	F
Replication	2	40.1		
Fertilizer (F)	1	1608.2	1608.2	28.0*
Error a	2	114.9	57.5	
Population (P)	3	11909.2	3969.7	141.2**
F x P	3	77.3	25.8	0.9
Error b	12	337.0	28.1	
Hybrid (H)	4	1600.5	400.2	6.5**
F x H	4	277.7	69.4	1.1
P x H	12	2509.0	209.1	3.4**
F x P x H	12	1154.0	96.2	1.6
Error c	64	3935.9	61.5	
Total	119	23563.9		

Least significant differences--bushels per acre

Treatment	Level of probability	
	5%	1%
Fertilizer	6.0	13.7
Population	3.0	4.2
Hybrid	4.5	6.0
Any two treatment means	19.7	26.1

* Significant at 5% level of probability
** Significant at 1% level of probability

TABLE 20. AVERAGE GRADING PERCENT AND ANALYSES OF VARIANCE FOR SEED PRODUCED ON FIVE SINGLE-CROSS HYBRIDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS - EXPERIMENT 11

	% Large flats	% Total medium flats	% Long medium flats[1/]	% Small flats	% Rounds
Fertilizer					
Unfertilized	16.4	59.0	54.4	9.2	11.5
Fertilized	15.2	58.6	61.7	11.3	11.9
LSD 5%	3.6	4.9	4.8	2.2	0.3
LSD 1%	8.4	11.2	11.0	5.2	0.7
Population					
7,300	17.6	59.1	63.7	7.5	13.2
10,400	16.6	58.1	59.4	10.5	11.7
12,800	15.8	59.0	58.3	11.0	11.0
17,100	13.2	58.9	50.8	12.1	11.1
LSD 5%	3.2	3.0	10.6	2.9	1.8
LSD 1%	4.5	4.1	14.8	4.1	2.5
Hybrid					
WF9 x Oh51A	18.8	57.9	52.8	9.1	11.3
Oh51 x R53	14.5	57.8	57.2	12.8	11.5
W23 x MS24	17.8	59.3	64.7	7.4	12.5
MS116 x MS211	11.7	61.1	58.7	11.0	11.8
WF9 x M14	16.3	57.7	57.1	11.0	10.6
LSD 5%	9.3	6.4	9.2	5.8	1.9
LSD 1%	12.4	8.5	12.2	7.7	2.5

Analyses of variance

Source	DF	Mean squares				
Replication	2	5.8	56.4	61.3	62.8	1.7
Fertilizer (F)	1	41.1	5.9	1562.4*	132.9	4.9*
Error a	2	21.5	38.6	37.1	8.1	0.2
Population (P)	3	103.1	5.7	862.8	118.4*	30.7**
F x P	3	6.9	18.0	95.7	18.6	7.1
Error b	12	32.9	27.6	373.7	27.0	3.4
Hybrid (H)	4	191.9	50.8	443.6	103.2	4.5
F x H	4	33.2	21.8	221.6	10.1	4.6
P x H	12	300.0	125.6	549.9*	101.0	20.5*
F x P x H	12	290.2	120.5	698.6**	100.4	27.3**
Error c	64	261.6	121.7	253.3	101.6	10.2

LSD - Least significant difference

[1/] Percent long medium flats is the percent of total medium flats which were long. Long medium flats were separately listed, but included with total medium flats.

* Significant at 5% level of probability
** Significant at 1% level of probability

TABLE 21. AVERAGE GRADING PERCENT AND ANALYSES OF VARIANCE FOR SEED PRODUCED ON FIVE SINGLE-CROSS HYBRIDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS - EXPERIMENT 12

	% Large flats	% Total medium flats	% Long medium flats[1/]	% Small flats	% Rounds
Fertilizer					
Unfertilized	13.8	59.7	33.6	12.6	9.6
Fertilized	14.4	59.3	39.3	11.8	10.8
LSD 5%	3.0	2.1	5.9	2.3	3.0
LSD 1%	6.9	5.0	13.5	5.3	6.7
Population					
7,000	17.9	57.3	42.0	9.5	11.7
9,400	15.3	59.7	35.9	11.1	10.3
11,200	12.3	60.0	34.3	13.7	9.9
14,000	10.9	61.0	33.6	14.7	9.0
LSD 5%	2.1	2.9	9.8	2.9	1.8
LSD 1%	2.9	4.1	13.7	4.1	2.5
Hybrid					
WF9 x Oh51A	19.2	59.4	34.8	8.0	11.0
Oh51 x R53	15.0	58.4	30.8	12.3	10.0
W23 x MS24	10.9	61.5	39.8	13.6	9.5
MS116 x MS211	13.1	59.3	32.1	13.8	8.0
WF9 x M14	12.5	59.0	44.8	13.5	11.6
LSD 5%	9.1	6.0	13.0	6.0	2.0
LSD 1%	12.1	8.0	17.3	7.9	2.6

Analyses of variance

Source	DF	Mean squares				
Replication	2	3.4	36.5	22.5	93.7	26.3
Fertilizer (F)	1	11.0	7.8	991.9	17.3	41.2
Error a	2	14.6	7.5	55.6	8.5	13.6
Population (P)	3	291.1**	73.0	431.3	165.1**	38.4*
F x P	3	31.2	30.2	528.4	7.1	8.2
Error b	12	13.3	26.8	303.7	27.2	10.1
Hybrid (H)	4	246.5	33.9	808.3	145.9	26.4
F x H	4	295.5	80.3	794.9	230.7	17.6
P x H	12	152.2	98.6	377.7	96.4	22.6*
F x P x H	12	220.6	140.6	553.3	67.4	9.4
Error c	64	250.9	108.7	508.8	106.6	11.4

LSD - Least significant difference

[1/]Percent long medium flats is the percent of total medium flats which were long. Long medium flats were separately listed, but included with total medium flats.

* Significant at the 5% level of probability
** Significant at the 1% level of probability

TABLE 22. AVERAGE BUSHELS PER ACRE BY GRADE AND ANALYSES OF VARIANCE FOR SEED PRODUCED ON FIVE SINGLE-CROSS HYBRIDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS - EXPERIMENT 11

	Large flats	Total medium flats	Long medium flats[1/]	Small flats	Rounds	Discard
Fertilizer						
Unfertilized	11.1	41.0	22.1	7.4	8.0	2.5
Fertilized	11.8	45.6	28.3	8.5	9.4	2.4
LSD 5%	3.9	6.0	5.7	3.2	0.7	1.0
LSD 1%	9.0	13.9	13.0	7.4	1.6	2.1
Population						
7,300	10.4	34.3	22.2	4.5	7.7	1.3
10,400	12.1	41.2	24.7	7.2	8.5	2.5
12,800	12.2	45.2	27.0	8.2	8.6	2.5
17,100	11.0	52.5	26.9	12.1	10.0	3.7
LSD 5%	2.3	5.4	6.3	2.8	1.0	0.7
LSD 1%	3.3	7.6	9.0	4.0	1.3	1.0
Hybrid						
WF9 x Oh51A	14.0	42.9	23.6	6.8	7.6	2.5
Oh51 x R53	9.6	43.4	24.0	9.5	8.5	2.9
W23 x MS24	13.5	43.6	28.4	6.6	9.3	1.9
MS116 x MS211	8.4	45.4	26.8	9.0	8.9	2.7
WF9 x M14	11.7	41.2	23.2	8.1	7.5	2.5
LSD 5%	6.7	5.7	5.8	5.0	1.8	1.1
LSD 1%	8.9	7.6	7.8	6.6	2.4	1.5

Analyses of variance

Source	DF	Mean squares					
Replication	2	8.1	33.4	42.2	34.2	0.3	0.5
Fertilizer (F)	1	13.9	18.8	1161.3*	38.1	56.6*	0.3
Error a	2	24.7	58.7	51.5	16.6	0.8	1.3
Population (P)	3	22.3	1754.4**	156.3	299.3**	25.1**	27.4**
F x P	3	9.8	43.0	67.0	33.6	6.4	1.5
Error b	12	17.3	92.5	127.3	25.0	2.9	1.6
Hybrid (H)	4	141.5	55.8	126.4	37.6	3.3	3.5
F x H	4	25.8	28.8	16.3	13.8	1.6	2.6
P x H	12	172.1	32.3	108.0	54.8	15.8	3.5
F x P x H	12	146.3	48.7	116.5	57.4	16.7	2.3
Error c	64	133.8	98.4	101.5	74.6	9.7	3.9

LSD - Least significant difference

[1/] Long medium flats were separately listed but included with total medium flats.

* Significant at 5% level of probability

** Significant at 1% level of probability

TABLE 23. AVERAGE BUSHELS PER ACRE BY GRADE AND ANALYSES OF VARIANCE FOR SEED PRODUCED ON FIVE SINGLE-CROSS HYBRIDS WITH AND WITHOUT FERTILIZER AT FOUR PLANT POPULATIONS - EXPERIMENT 12

	Large flats	Total medium flats	Long medium flats[1/]	Small flats	Rounds	Discard
Fertilizer						
Unfertilized	7.9	34.6	12.5	7.4	5.6	2.4
Fertilized	9.0	38.6	15.0	7.6	6.9	2.5
LSD 5%	1.4	8.0	0.8	4.4	1.3	0.1
LSD 1%	3.2	18.3	1.7	10.1	3.0	0.3
Population						
7,000	8.5	26.8	11.6	4.4	5.5	1.7
9,400	9.2	35.4	13.3	6.4	6.2	2.2
11,200	8.0	38.2	14.1	8.6	6.5	2.7
14,000	8.1	46.0	16.1	10.8	6.9	3.2
LSD 5%	1.5	3.7	4.4	1.9	1.2	0.5
LSD 1%	2.1	5.2	6.2	2.7	1.7	0.8
Hybrid						
WF9 x Oh51A	12.2	37.5	13.2	5.0	7.0	1.6
Oh51 x R53	8.8	36.1	11.0	7.6	6.0	2.7
W23 x MS24	6.6	39.6	16.2	8.8	6.0	2.9
MS116 x MS211	7.0	32.4	11.3	7.3	5.1	2.5
WF9 x M14	7.5	37.4	17.2	9.0	7.3	2.4
LSD 5%	5.4	4.3	5.7	3.8	1.5	0.9
LSD 1%	7.2	5.7	7.6	5.0	2.0	1.2

Analyses of variance

Source	DF	Mean squares					
Replication	2	1.3	2.6	19.3	38.6	12.5	0.7
Fertilizer (F)	1	37.5	469.3	184.5**	1.4	53.1*	0.3
Error a	2	3.2	102.9	0.9	31.3	2.7	0.1
Population (P)	3	8.5	1882.3**	105.2	228.9**	8.9	13.3**
F x P	3	13.6	23.7	98.8	0.5	3.5	2.2
Error b	12	7.1	43.6	61.9	11.6	4.5	0.9
Hybrid (H)	4	122.9	171.0*	190.2	60.8	19.0*	5.5*
F x H	4	95.2	45.9	80.4	28.7	6.6	3.1
P x H	12	62.9	92.7	91.2	56.2	10.2	2.5
F x P x H	12	63.2	60.0	88.8	26.4	4.2	3.2
Error c	64	87.3	55.5	98.9	42.7	6.5	2.3

LSD - Least significant difference

[1/]Long medium flats were separately listed but included with total medium flats.

* Significant at 5% level of probability
** Significant at 1% level of probability

The 4.6% higher moisture and 3.3% lower shelling percent of Experiment 12 probably resulted from planting eight days later than Experiment 11. While plant population averaged 11,900 and 10,400 for the two experiments, at least part of the 12.7 bushel yield difference was due to the difference in planting dates. Average grading percents were 15.8 and 14.1% large flats, 58.8 and 59.5% total medium flats, 58.1 and 36.5% long medium flats, 10.3 and 12.2% small flats, and 11.7 and 10.2% rounds for Experiments 11 and 12, respectively (Tables 20 and 21).

Average income per acre (Table 24) for Experiment 11 was $316, $380, $404 and $463 for unfertilized plots and $345, $416, $458 and $524 for fertilized plots at populations of 7,300, 10,400, 12,800, and 17,100 plants per acre, respectively. Estimated wholesale prices for Michigan certified seed were used in these calculations. Yields were reduced 25% to compensate for pollen parent rows not usually harvested for seed. The usual planting pattern for double-cross seed production is six seed parent rows and two pollen parent rows.

TABLE 24. AVERAGE YIELDS[1/] AND GROSS INCOME FOR GRADES OF SEED AT ALL LEVELS OF SOIL FERTILITY AND PLANT POPULATION FOR ALL HYBRIDS IN EXPERIMENT 11

Plants per acre	Fertilizer Pounds per acre	Bushels per acre for each grade						
		Large flats	Total medium flats[2/]	Small flats	Rounds	Discard	Pollen parent	Total
7,300	None	6.3	24.1	2.6	5.0	3.5	13.8	55.3
	550	7.7	25.6	3.4	5.3	3.8	15.1	60.9
10,400	None	8.3	28.2	4.2	5.5	5.3	17.0	68.5
	550	8.1	31.1	5.5	5.9	5.0	18.6	74.2
12,800	None	8.3	29.7	6.1	5.0	5.6	18.0	72.7
	550	8.2	35.5	5.0	6.5	5.2	20.0	80.4
17,100	None	7.1	35.6	7.1	6.0	6.8	20.8	83.4
	550	7.7	39.3	9.2	7.4	7.5	23.8	94.9

Gross income from seed

Plants per acre	Fertilizer Pounds per acre	Grade and wholesale price per bushel						
		Large flats $6.50	Total medium flats[2/] $8.90	Small flats $5.50	Rounds $5.50	Discard $1.00	Pollen parent $1.00	Total ($)
7,300	None	41	215	14	28	4	14	316
	550	50	228	19	29	4	15	345
10,400	None	54	251	23	30	5	17	380
	550	53	277	30	32	5	19	416
12,800	None	54	264	34	28	6	18	404
	550	53	316	28	36	5	20	458
17,100	None	46	317	39	33	7	21	463
	550	50	350	51	41	8	24	524

1/ Yields of graded seed were discounted 25%, to compensate for pollen parent rows not usually harvested for seed, and an additional 10% (included in discard) to adjust these yields for short and damaged kernels which would normally be graded out.

2/ Since long and short medium flats normally sell for the same price, only total medium flats were reported for income computing purposes.

DISCUSSION

Inbred Lines

Seed yields on inbred plants were as high as 46.9 bushels per acre for Oh51 in 1957 and 69.6 for W23 in 1958. These yields were considerably higher than those usually reported for foundation inbred and single-cross seed in Michigan. In commercial foundation single-cross seed production fields, one row of the pollinator inbred usually provides pollen for two to four rows of the detasseled or male-sterile seed parent inbred depending on amount of pollen produced by the pollinator. Adequate pollen at the right time is frequently a limiting factor in single-cross seed production. The objective in these experiments was to investigate the effects of fertilizer and plant population on single-cross seed yields without the variation due to pollination. Therefore, two rows of single-cross hybrids were planted later between every five or six rows of inbreds to provide pollen in addition to that of the inbreds. Thus, pollination was not a limiting factor except for the two late inbreds C103 and 38-11 which also had poor stands.

In commercial single-cross seed production, 20% to 33 1/3% of the seed is discarded as sib-pollinated from the pollinator parent. Acre yields reported from these experiments have not been discounted for pollinator rows.

Obtaining a satisfactory stand from inbred seed is a major factor in commercial single-cross seed production. Cold-test germination and seed treating will aid in calculating the seeding rate to more nearly assure a given plant population. Starter fertilizer placed to the side and below the seed in the row may promote faster seedling growth and thereby aid in weed control. Variations in stand also occurred in these experiments. These effects were adjusted by covariance analyses which adjusts the yield of each plot for its deviation from the average stand of the particular treatment involved.

Neither WF9 nor Oh51 were fully matured in Experiment 1 and only three (W23, MS206, and R53) of the 25 inbreds were mature--below 40% moisture at harvest--in Experiments 3-10. These experiments were planted on June 2 and May 24. Since fertilizer and population treatments did not affect maturity, it is likely that yields would have increased proportionately for all treatments with full maturity and that main effects and interactions of treatments would change very little. Inbreds develop and mature more slowly than hybrids. Early planting and a favorable growing season are necessary to reach full maturity and obtain maximum yields. Since germination and seedling vigor of inbred seed are lower than for hybrid seed, planting is usually delayed until soil temperatures have warmed to $50^{o}F$ or above.

High residual soil fertility as indicated by soil tests may have limited the response to fertilizer. Also, plant populations may not have been high enough to effectively utilize the added fertilizer. All inbreds probably would not respond to further increases in population since some did not show much increase at the highest population.

When Duncan's method (2) of predicting yields at various populations was applied to the data in Experiments 3-10, the predictions indicated that population for some inbreds could be increased to 35,000 plants per acre before yields failed to increase. The highest predicted yield at 30,000 plants per acre was 82.0 bushels per acre for Oh51 compared to the actual yield of 61.7 bushels with 18,300 plants. Duncan (2) reported that yields of dwarf and semi-dwarf corn maintained a linear relationship to 78,000 plants per acre. Since competition by inbred plants for plant nutrients and moisture would be less than that of hybrid plants, inbred plant populations might be increased more than hybrid populations for maximum production.

Only one year's data are provided by these experiments to classify the 25 inbreds for predicting hybrid combinations that might be adapted to high levels of fertility and plant population. Since interactions of inbreds with environment are usually greater than interactions of hybrids, further testing of these lines would be helpful and necessary for more precise classification. Correlations of inbred and hybrid performance for many characteristics including combining ability are usually low so that prediction of hybrid performance from inbred data is difficult. Since relatively little information is available on the correlation of inbred with hybrid response to fertility and population stress, it seemed desirable to attempt to classify a group of inbreds and then evaluate their hybrid progeny.

Single-cross and double-cross hybrids from inbreds in groups 1 and 3 should be compared for their ability to respond under high population pressure. Using the letters H and L to indicate inbreds in groups 1 and 3, respectively, and numeral subscripts to indicate inbreds within a group, the following pedigrees are examples of some comparisons that should be evaluated.

$(H_1 \times H_2)\ (H_3 \times H_4)$
$(L_1 \times L_2)\ (L_3 \times L_4)$
$(H_1 \times H_2)\ (H_3 \times L_1)$
$(H_1 \times H_2)\ (L_1 \times L_2)$
$(H_1 \times L_1)\ (L_2 \times L_3)$
$(H_1 \times L_1)\ (H_2 \times L_2)$

If ability to respond to population pressure proves to be dominant in its inheritance, then one or two lines with low ability in the double-cross pedigree may not greatly alter the performance contributed by the other two or three inbreds possessing high abilities. If this ability proves to be largely recessive, then probably all four inbreds in the pedigree will need to be capable of responding to population pressure. Information concerning dominance relationships can be obtained from the single-cross data when it is available. Double-cross predictions from the single-cross data will also aid in determining the double-cross pedigrees to be evaluated.

Single-cross Hybrids

Experiments with single-cross hybrids to study double-cross seed production were conducted during two seasons, 1957 and 1958, in the same field. The Conover loam soil was in relatively high state of fertility as indicated by soil tests. In 1957, following alfalfa, there was no significant effect from 12-12-12 fertilizer applied either as 200 pounds of 12-12-12 in the row or 650 pounds plowed down and 200 pounds in the row.

Sidedressed nitrogen at 20, 40, and 60 pounds per acre did not affect yields. Soil tests for the 1958 crop were a little lower than 1957 but still indicated relatively high fertility. There were no consistent differences in soil tests on 1958 samples taken from the three 1957 fertility levels.

Significant average increases of 8.7 and 7.3 bushels were obtained in 1958 from 550 pounds of 15-15-15 applied in the row and 40 pounds sidedressed nitrogen for the two dates of planting, June 2 (Experiment 11) and June 10 (Experiment 12). The average increases from fertilizer in Experiment 11 were 5.6, 6.6, 11.1, and 11.6 bushels per acre for populations of 7,300, 10,400, 12,800, and 17,100, respectively. In Experiment 12, fertilizer increased average yields 7.0, 7.4, 5.2, and 9.6 bushels per acre for populations of 7,000, 9,400, 11,200, and 14,000. Benefits from fertilizer were increased at the higher populations. These results illustrate the importance of maintaining high populations to utilize the added fertilizer. While significant increases from fertilizer may not always occur, the possibilities for appreciable gain warrant judicious fertilizer applications based on soil test, previous cropping history, soil type, and plant population.

All three experiments were planted late (June 2 and 10) and none of the seed had reached full maturity at harvest. Since there were no consistent fertilizer effects on maturity, it does not seem likely that a longer growing season would have changed the relative differences between yields from fertilized and unfertilized plots.

Immaturity, 50.3%, 47.5%, and 52.1% average moisture at harvest for the three experiments planted June 2 and 10, demonstrates the importance of earlier planting to obtain maximum seed yields and quality. Killing frosts occurred on September 27, 1957 and October 6, 1958 and the experiments were harvested October 10, 1957 and October 15, 1958.

Plant population was the most important factor affecting double-cross seed yields. In 1957 (Experiment 2), average seed yields increased progressively from 43.2 to 91.6 bushels per acre as population increased from 6,100 to 17,200. In 1958, average yields increased from 58.1 to 89.1 bushels as population increased from 7,300 to 17,100 in Experiment 11 and from 46.9 to 74.7 with population increases from 7,000 to 14,000 in Experiment 12.

In double-cross seed fields, plant populations are usually less--about 10,000 to 12,000--than those used for grain production. Seed producers have felt that the production of the preferred medium flat grade would be reduced at higher populations. In some cases with seed parents that grade a high percent large flats, population has been increased in order to increase the production of medium flats. Detasseling can be more accurate and easier at lower populations. Increasing use of male sterile seed parents to eliminate detasseling would seem to remove the latter objection of seed producers toward increased population in seed fields.

Kernel width and length were reduced as population increased. These changes in kernel dimensions were reflected in a decrease in percent large flats and a corresponding increase in small flats. The percent medium flats remained relatively unchanged with increased population.

Percent long medium flats decreased at higher population but this is of relatively little consequence since the long and the shorter medium flats are both marketed as medium flats. When expressed as bushels of graded seed per acre, the production of large flats remained the same, and the production of medium flats, small flats, and rounds increased.

The consistent results obtained from increased plant population for the seed parents used in these experiments seem to warrant more serious consideration by seed producers toward increasing plant population in double-cross seed production.

SUMMARY

Several fertilizer and plant population treatments were evaluated for effects on seed production with inbred lines and single-cross hybrids in 1957 and 1958 on a Conover loam soil, testing high in residual fertility, in Ingham County, Michigan. Corn did not reach full maturity in any of the experiments.

Average increases in yields from fertilizer were not significant for inbreds in either year, nor significant for single-cross hybrids in 1957, but were significant for single-cross hybrids in 1958.

Plant population was the most important factor affecting seed yields.

Inbred lines

Seed yields on WF9 and Oh51 inbreds in 1957 were not affected significantly by complete fertilizer treatments of either 200 or 850 pounds 12-12-12 per acre. Sidedressed nitrogen applications of 20 and 40 pounds per acre did increase yields significantly but there was no difference between the 20 and 40 pound rates. Average yields increased significantly from 17.8 to 38.4 bushels per acre as population was increased from 5,500 to 16,000. The highest seed yields were 43.1 and 46.9 bushels per acre for these two inbreds.

Fertilizer effects on seed yields of 25 inbreds in 1958 were not significant. Average yields increased significantly from 26.8 to 50.3 bushels per acre as population increased from 7,500 to 18,300. Good agreement was obtained between actual yields and predicted yields using Duncan's method (2). Predicted yields continued to increase up to 30,000 plants per acre for most inbreds and a few predicted yields increased to 40,000 population.

As population was increased from 14,600 to 18,300: (1) yields of Oh51, Oh51A, W64A, Oh43, W22, WF9, MS116, MS211, and MS1334 increased significantly 9.2 to 12.1 bushels, (2) 38-11, W10, W70, B8, MS132, A73, MS24A, MS131, and MS206 increased 4.7 to 8.2 bushels which were not significant at the 5% level, and (3) W23, WR3, Hy2, MS130, M14, R53, and C103 showed little or no increase in yield.

Single-cross hybrids

In 1957 (Experiment 2), average yield and grading of seed from WF9 x Oh51A were not significantly affected by complete fertilizer and nitrogen sidedressing treatments. Yields averaged 43.2, 60.6, 69.4, 88.8, and 91.6 bushels at populations of 6,100, 9,200, 11,200, 15,100, and 17,200 plants per acre, respectively. Each increase except the last was significant.

In 1958 (Experiments 11 and 12), five single-cross hybrids averaged 11.6 and 9.6 bushels more when fertilized with 550 pounds of 15-15-15 and 40 pounds sidedressed nitrogen per acre at the highest plant populations.

As population increased from 7,300 to 17,100 in Experiment 11, average yields increased significantly from 58.1 to 89.1 bushels. When population increased from 7,000 to 14,000 in Experiment 12, average yields increased from 46.9 to 74.7 bushels.

In both years, kernel width and length were reduced as population increased. Percent large flats decreased and small flats increased about the same amount while medium flats remained unchanged as population increased. Production per acre of medium flats, small flats, and rounds increased and production of large flats remained unchanged as population increased.

LITERATURE CITED

1. Airy, John M., in Sprague, Corn and Corn Improvement, Academic Press, New York, 1955, pp. 383-386, 404, 405.

2. Duncan, W. G., The relationship between corn population and yield, Agronomy Journal, Vol. 50:82-84, 1958.

3. Rather, H. C., and Marsten, A. R. A study of corn maturity, Michigan Agricultural Experiment Station Quarterly Bulletin, Vol. 22, No. 4, 1940.

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