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RESPONSE OF CORN, *ZEA MAYS* (L.), TO LEVELS OF WITHIN-ROW SPACING VARIABILITY

by

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INTRODUCTION

Corn, *Zea mays* (L.), is an important grain crop widely grown in the central plains of the United States. In addition to its increasing importance as livestock feed, corn is also an important food crop in many countries of the world. The production of corn in the United States has significantly increased over the past four decades. Successful production of corn in this country can be attributed to advances in research, adapting the corn plant to the existing environment, as well as to modifications in production methods.

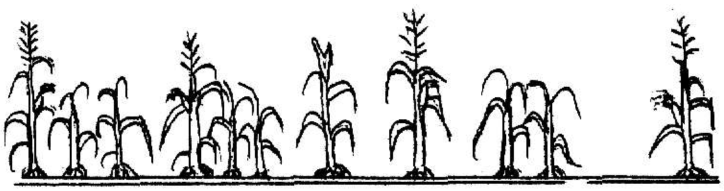
The pattern of corn plant distribution within the row has been recognized as a factor influencing corn grain yield.

Farmers often are concerned with the time and rate their crops are planted, but give little attention to the uniformity of plant distribution. Improved uniformity of within-row plant spacing could be expected to increase grain yield through more efficient use of available light, water, and nutrients by the plants.

One of the beneficial inventions of modern technology is the corn planter. However, it has been observed that uniform distribution of seeds within the row is difficult to achieve with the planters.

The purpose of this study was to determine how grain yield relates to within-row spacing variability; to see how much yield increase could be obtained by increasing planting precision and to determine the yield components influencing grain yield response to spacing variability.

Unlike row spacing and plant density studies, this study was conducted at uniform plant population and row spacing. However, the three types of studies are related in that intra-row plant competition may be involved in the studies. Within-row spacing variability may give rise to a situation of localized high and low plant population densities within the row.



Level of within-row spacing variability

High plant density   Low plant density

It seems, therefore, that the influence within-row spacing variability may have on corn grain yield depends on the magnitude of the spacing variability and the combined effects of the different localized plant population densities within the row.

LITERATURE REVIEW

Many experiments have been conducted during the past few decades on the effects of planting patterns on corn grain yields (1, 2, 4, 13). The research findings indicated that no one planting method was consistently better than the other.

There have been relatively few published research studies pertaining to the performance of corn grown at different levels of within-row spacing variability. However, review of comparison studies on hill, drill, and equidistant planting is relevant since hill planting represents a situation of high within-row spacing variability. Drill planting may give rise to a medium range of spacing variability, while equidistant planting may be regarded as low within-row spacing variability.

Several early studies compared the effects of hill and drill planting on corn grain yield. Duncan (7) reported that corn grown in single-plant hills yielded more grain than corn in multiple hills, at the same population levels. Kohnke and Miles (15) found that drilled corn was 538 kg/ha superior to hilled corn. They indicated that hilled corn had smaller ear weight than drilled corn. In an earlier experiment, Kiesselbach et al. (14) found no substantial yield increase for dilled corn over checked corn planted at the rate of three plants per hill. In experiments where the number of plants per hill ranged from 1 to 5, best results were obtained at three plants per hill.

Rounds et al. (21) reported an average yield increase of

356 kg/ha or 7 percent, from comparable populations, in favor of drilled corn. However, they concluded that rate of planting had a greater effect on corn yield than planting methods. Bryan et al. (1) showed that corn grown 1 per hill in 50-cm rows yielded significantly more than corn grown 4 per hill in 100-cm rows.

In a later work, Fayemi (11) found that planting corn at the rate of 1 plant per hill and spaced 23 cm, showed on significant yield advantage over planting 2, and 4 plants per hill spaced 46 and 92 cm apart,respectively. Colville and McGill (6) indicated that corn grain yield could be increased by as much as 840 kg/ha by drill planting instead of hill planting. In a planting method and weed control experiment, Colville and Burnside (5) stated that drilled corn was superior to hilled corn because the uniformity in single-plant spacing allows more efficient use of water, light and nutrients. Other workers, Collins and Shedd (3), and Roberts and Kinney (20) also reported higher average grain yields in favor of drilled corn.

The findings of Latta (18) seemed to contradict the above reports (3, 5, 6). In a three-year average results, he showed a slightly higher corn grain yield in favor of hilled corn. Also, Woolley et al. (25) reported that yield performance tended to be higher at 2 plants per hill, although in many cases it was not found significantly different from 1 plant per hill. In within-row plant competition studies, Haynes and Sayre (12) found that rooting patterns changed from circular to oblong with increase in within-row plant competition and that this increased crowding caused roots to extend further from the parent plant than would be the case in the absence of the competition. The research results of Colville (4) also indicated the superiority of drill planting over hill planting. Stringfield and Thatcher (24) found no consistent yield advantage for either drilled or hilled planting. However, they observed that drilled corn produced twice more tillers than hilled corn at a given plant population.

Some research has been done studying the effect of uniform spacing and drill planting on corn grain yield. Dungan et al. (8) reported that under conditions of adequate soil moisture and equal populations, plants that were uniformly spaced produced as much as 673 kg/ha over hilled corn. Similarly, Hoff and Mederski (13) found a yield advantage of 572 kg/ha in favor of uniformly spaced corn plants as compared to drilled corn. However, they stated that adequate soil moisture was a more important factor in increasing grain yield than planting methods. Kohnke and Miles (15) found that higher yields of 404 kg/ha were obtained when corn plants were uniformly spaced than when hill planted. In later studies, Bunting (2) observed that at densities of 10 to 15 plants per square meter or more, the average yield increment associated with more uniform spacing was less than 5 percent.

The studies conducted by Colville and Burnside (5) indicated that equidistant spacing and weed control were fundamental in determining corn grain yield. They reported that single, hand weeded plants uniformly spaced 50 centimeters apart, produced 38 percent more grain yield than the same population equidistantly spaced (100 cm) hills with 4 plants per hill. Inspite of the yield advantages of uniform spacing reported by earlier workers, Erbach et al. (9) found that on a field scale, with corn planted in 76-cm rows, improving within-row plant uniformity might not significantly improve total grain yield. The research reports of Shubeck and Young (23) were in agreement with those of earlier workers (8, 13, 15). They found higher yields for uniformly spaced corn plants over hilled corn. Pfister (19) also reported that the ideal plant spacing seemed to be 50.6 cm apart in each direction.

There have been some studies on the effect of within-row spacing variability on corn grain yield. Esechie (10) found no relationship between spacing variability and corn grain yield. In a later study, Krall et al. (17) reported a yield increase of 55.5 kg/ha for each 1 centimeter decrease in within-row spacing variability, at two of three locations. In a survey of the farmers' field, Krall et al. (17) observed that the range of within-row spacing variability was between 6 to 18 centimeters. They concluded that the environment in which the plants were grown might be important in determerming the effect of spacing variability on corn grain yield. In a related study, Schaffer (22) found no interaction effect of soil type and spacing variability on grain yield. He also observed a negative relationship between spacing variability and grain yield.

The literature supports the idea that reducing within-row spacing variability could improve corn grain yield. There were also indications that the level of within-row spacing variability may be important in determining the effect spacing variability may have on corn grain yield.

MATERIALS AND METHODS

Experiments were conducted during the 1978 and 1979 growing seasons at four locations in Kansas: the Manhattan Agronomy Farm, the Ashland Agronomy Farm, the Cornbelt Experimental Field at Powhattan and the Kansas River Valley Experimental Field at Rossville. Ashland and Rossville were irrigated; the other locations were not.

The experimental design was randomized complete block with six replications. Each replicate consisted of eight plots. Individual plots were four rows spaced 76-cm apart, 6.7 meters in length. Fertilizers were applied at each location according to soil requirements.

Two corn hybrids, BoJac-56 and DeKalb XL-390, used in the experiments were chosen for their differences in maturity. Also, they are widely grown hybrids in Kansas. BoJac-56, a yellow corn hybrid, is relatively early maturing. DeKalb XL-390 is white and late maturing.

Standard deviation of within-row spacing was used as a measure of spacing variability. Corn kernels were hand planted in four 76-cm rows at 0, 6, 12, and 18 cm of within-row spacing variability. Zero level was obtained by planting the corn kernels at uniform spacings of 30.5 (44,000 plants/ha) and 22.5 cm (58,000 plants/ha) apart for the non-irrigated and irrigated locations, respectively. Other levels of spacing variability were obtained by choosing individual plant spacings such that the standard deviation from the mean spacings were

6, 12 and 18 centimeters, respectively.

Plants were double planted and three weeks after emergence, thinned to single plants. Distances between plants within each row were measured. Using individual spacing measurements, standard deviation of plant spacing was calculated for each row.

Silking and tasseling dates were recorded. At maturity, ears from each plot row were hand harvested. The statistical analysis utilized the Kansas State University computing center SAS program. Basic row data were converted to plants per hectare, grain yield in kilograms per hectare and bushels per acre, kernels per ear, and ears per plant. Ear weight, grain moisture content and weight of 100 kernels were also determined. Grain yields were adjusted to 15.5 percent moisture.

Data from rows with computed standard deviation close to the designed standard deviation of plant spacing were included in the analysis of variance. At the zero level of spacing variability, data from rows with more than 2.5 centimeters standard deviation of spacing were not included. At other levels of variability of spacing, data from rows within the range of ±1.5 centimeters of the designed standard deviation were included in the analysis. Linear regression and simple correlation analysis were run for each experiment and hybrid using the data from all the rows.

RESULTS AND DISCUSSION

Grain yield, generally, tended to decrease as spacing variability increased at all the locations (Table 1). Analysis of variance showed that grain yield was significantly affected by variability of spacing at three of the four locations (Table 1 and Appendix Tables 7-12).

Table 1. Grain yield as affected by levels of within-row spacing variability.

Location	Year	Population (pl/ha)	Level of spacing variability (standard deviation, cm)				F
			0-2.5	4.5-7.5	10.5-13.5	16.5-19.5	
			----------Yield (kg/ha)---------				
Powhattan[1]	1978	43,770	5,598	5,391	5,365	5,403	0.59
Manhattan	1978	43,860	7,320	7,177	6,758	6,732	3.05*
	1979	43,751	8,354	8,074	8,053	7,962	1.81
Rossville	1978	57,890	8,481	8,739	7,871	7,190	4.59**
	1979	57,779	8,465	8,348	7,824	7,533	8.75**
Ashland	1978	57,832	9,013	8,886	8,661	8,051	5.19**
	1979	57,781	4,203	3,794	3,797	3,289	4.94**

[1] DeKalb XL-390 only

** Significant at 1%

* Significant at 5%

Grain yields at the irrigated locations, Rossville and Ashland (1979), were higher than the dryland locations. This was expected because the irrigated locations had higher plant population (Table 1). The low yield observed at Powhattan in 1978 and Ashland in 1979 was due to insect damage (in addition to other problems to be discussed later).

Hybrid yield differences were also observed. In six of the eight experiments, hybrid yield differences were significant (Appendix Tables 7-12). BoJac-56 produced higher grain yields than DeKalb XL-390 at three locations.

Table 2. Hybrid grain yield as affected by variability of spacing at Manhattan in 1979 and Ashland in 1978.

Location and Year	Hybrid	Level of spacing variability (standard deviation, cm)				
		0-2.5	4.5-7.5	10.5-13.5	16.5-19.5	F
		Yield (kg/ha)				
Manhattan 1979	BoJac-56	8,895	9,040	8,492	8,374	4.20**
	DeKalb XL-390	7,855	7,335	7,660	7,641	1.50
Ashland 1978	BoJac-56	9,183	9,290	9,478	7,998	5.73**
	DeKalb XL-390	8,748	8,455	7,761	8,094	3.78*

** Significant at 1%

* Significant at 5%

In addition, hybrid x spacing variability interaction effect on grain yield was significant at Ashland in 1978 and Manhattan in 1979 (Table 2 and Appendix Tables 8 and 11), indicating differences in hybrid response to variability of spacing. The results were in agreement with an earlier study which showed that the effect of variability of spacing on grain yield was more apparent with some hybrids and locations than others (22).

The lack of response of ear number to spacing variability at three of the four locations was especially noticeable during harvest. Few plants were found with more than one ear. BoJac-56, generally, carried more ears per plant than DeKalb XL-390. This may be responsible for the hybrid yield differences observed. Where plants with two or more ears occurred, they were found mainly at low spacing variability and border rows where the plants appeared to be less subjected to competition. Esechie (10) found no relationship between ear number and variability of spacing.

Kernel number and grain yield were more consistently affected by within-row spacing variability than other yield components (Appendix Tables 7-12). Kernel number was significantly affected at three locations. Hybrid x spacing variability interaction effect on kernel number was also observed at Manhattan, Rossville in 1979 and Ashland in 1978 (Appendix Tables 7, 8, 10, and 11). Kernel and ear weights, although inconsistent, also responded to variability of spacing.

Corn grain yields at each of the experimental locations were related to within-row spacing variability by the linear regression equation : $Y = A + BX$ (Tables 3 and 4, and Figs 1-4). Y stands for the grain yield at zero within-row spacing variability; B represents the slope of the regression line and X is the standard deviation of spacing. S_A and B_B denoted the standard deviation of the estimated intercept and slope of the regression line, respectively.

Table 3. Linear regression of yield versus spacing variability at each location.

Location	Year	A	S_A	B	S_B	r^2	F
Powhattan[1]	1978	5,414	151	- 7.60	12.72	0.004	0.36
Manhattan	1978	7,477	146	- 45.17	11.86	0.073	14.51**
	1979	8,429	147	- 15.93	12.49	0.009	1.63
Rossville	1978	9,163	241	-108.54	19.25	0.148	31.78**
	1979	8,867	181	- 69.45	16.55	0.087	17.61**
Ashland	1978	9,164	253	- 79.33	22.17	0.066	12.81**
	1979	4,481	201	- 59.65	17.83	0.057	11.19**

1 DeKalb XL-390 only

** Significant at 1%

Negative relationship between grain yield and within-row spacing variability was found at three of the four locations (Table 3 and Figs 2, 3 and 4). The regression analysis was for the combined yields of BoJac-56 and DeKalb XL-390. The lack of significance of the regression slope at Manhattan in 1979 and Powhattan in 1978 can be attributed to the low response of DeKalb XL-390 to variability of spacing (Table 4). The percentage grain yield variability accounted for by the relationship between intra-row spacing variability and grain yield, as shown by r^2 (Table 3 and 4), varied from location to location. Hybrid response differences were also observed. Grain yield decrease of 148.2 to 1641.9 kg/ha was observed as within-row spacing variability increased from 1 to 19.5 cm

Table 4. Regression of grain yield on spacing variability of each hybrid at each location, 1978 and 1979.

Location	Year	Hybrids	A	S_A	B	S_B	r^2	F
Powhattan	1978	DeKalb XL-390	5,414	151.32	- 7.60	12.72	0.004	0.36
Manhattan	1978	BoJac-56	7,778	178.79	-51.10	14.76	0.118	11.99**
		DeKalb XL-390	7,124	218.91	-34.60	17.46	0.041	3.93*
	1979	BoJac-56	9,260	175.17	-40.46	14.52	0.080	7.77**
		DeKalb XL-390	7,766	143.08	- 6.14	12.47	0.003	0.24
Rossville	1978	BoJac-56	9,331	258.15	-74.45	22.56	0.114	12.09**
		DeKalb XL-390	8,184	448.13	-72.43	32.76	0.053	4.89*
	1979	BoJac-56	9,694	200.35	-84.20	18.17	0.187	21.45**
		DeKalb XL-390	8,194	195.19	-72.43	18.03	0.152	16.15**
Ashland	1978	BoJac-56	9,757	372.74	-81.32	34.06	0.060	5.70**
		DeKalb XL-390	9,032	325.39	-64.84	27.48	0.060	5.57*
	1979	BoJac-56	4,984	201.34	-52.61	17.39	0.090	9.15**
		DeKalb XL-390	4,094	300.45	-80.27	27.52	0.086	8.51**

** Significant at 1%

* Significant at 5%

(Table 4), indicating that improving planting precision could appreciably increase grain yield.

Discussion of results from each location follows.

POWHATTAN

In 1978, corn was attacked by European corn borer, *Ostrinia spp.*, which caused stalk breakage of the plants. The relatively early maturing hybrid, BoJac-56, was more affected because the insect attack occurred during its grain filling stage and no usable data were obtained. DeKalb XL-390 seemed to be less damaged by the insect, although grain yield reduction of this hybrid was also observed. Grain yields and yield components were not significantly affected by variability of spacing (Table 1 and Appendix Table 13). Although it was difficult to separate the effect of spacing variability from insect damage, results from other locations indicated that DeKalb XL-390 has a low response to variability of spacing (Table 4).

Regression analysis of DeKalb XL-390 (Table 4 and Fig 1) showed no relationship between spacing variability and grain yield.

In 1979, poor plant establishment at this location made it impossible to obtain the designed levels of within-row spacing variability. Consequently, the results could not be related to variability of spacing and were not included in the analysis.

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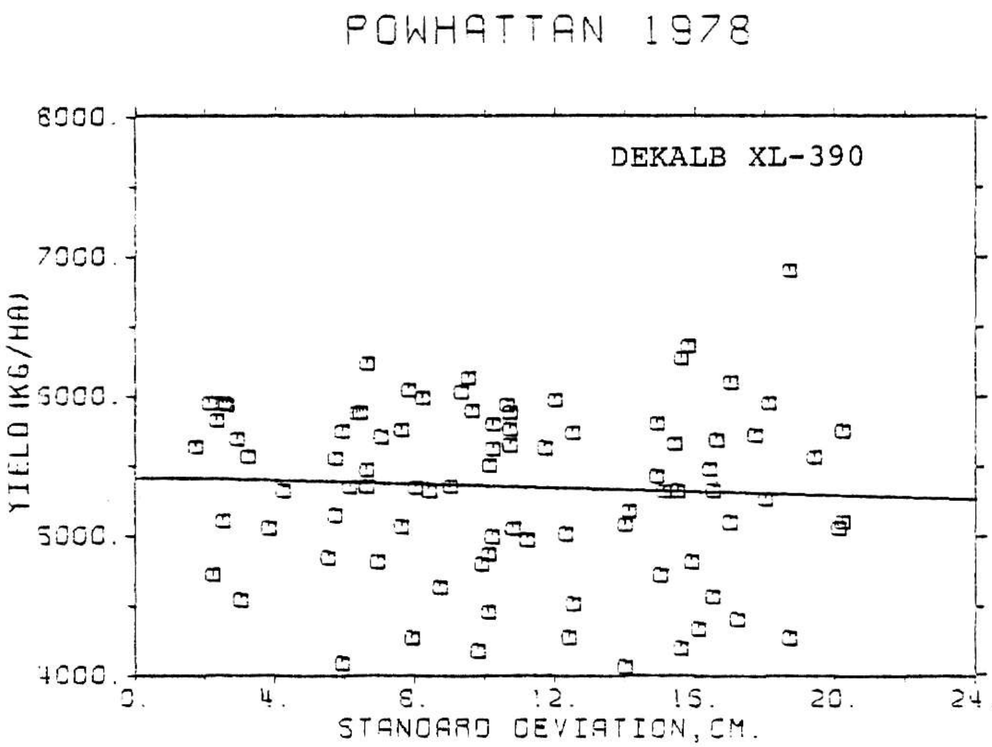

Fig. 1. Regression of yield on spacing variability at Powhattan, 1978.

MANHATTAN

Grain yields at this location were affected by intra-row spacing variability in 1978. In 1979, yield of BoJac-56 was significantly affected by variability of spacing, but DeKalb XL-390 was not (Table 2 and 4, Appendix Table 8). Ear number and weight per plant were not affected by spacing variability (Appendix Tables 7 and 8). Kernel number seemed to be the most consistently affected yield component.

Rates of development of the hybrids, as measured by the tasseling and silking dates (Appendix Table 6), indicated that BoJac-56 tasseled 7 days before DeKalb XL-390. A similar interval was required for DeKalb XL-390 to silk. Tassel and silk dates were delayed for an average of two days by increasing spacing variability from 2 to 18 centimeters. The interval between tasseling and silking was increased by one day as a result of similar increase in variability of spacing. Earlier research showed that both drilled and uniformly spaced corn silked from one to several days earlier than hilled corn (15). These effects on development rates might be responsible for the barren ears observed at high spacing variability levels during harvest.

Regression analysis showed a negative relationship between variability of spacing and grain yields for both hybrids in 1978, and for BoJac-56 in 1979 (Table 4 and Fig 2). The regression analysis was not significant for DeKald XL-390 in 1979.

Grain yield variability accounted for by spacing variability in 1978 was 11.8 and 4.1 percent for BoJac-56 and DeKalb XL-390,

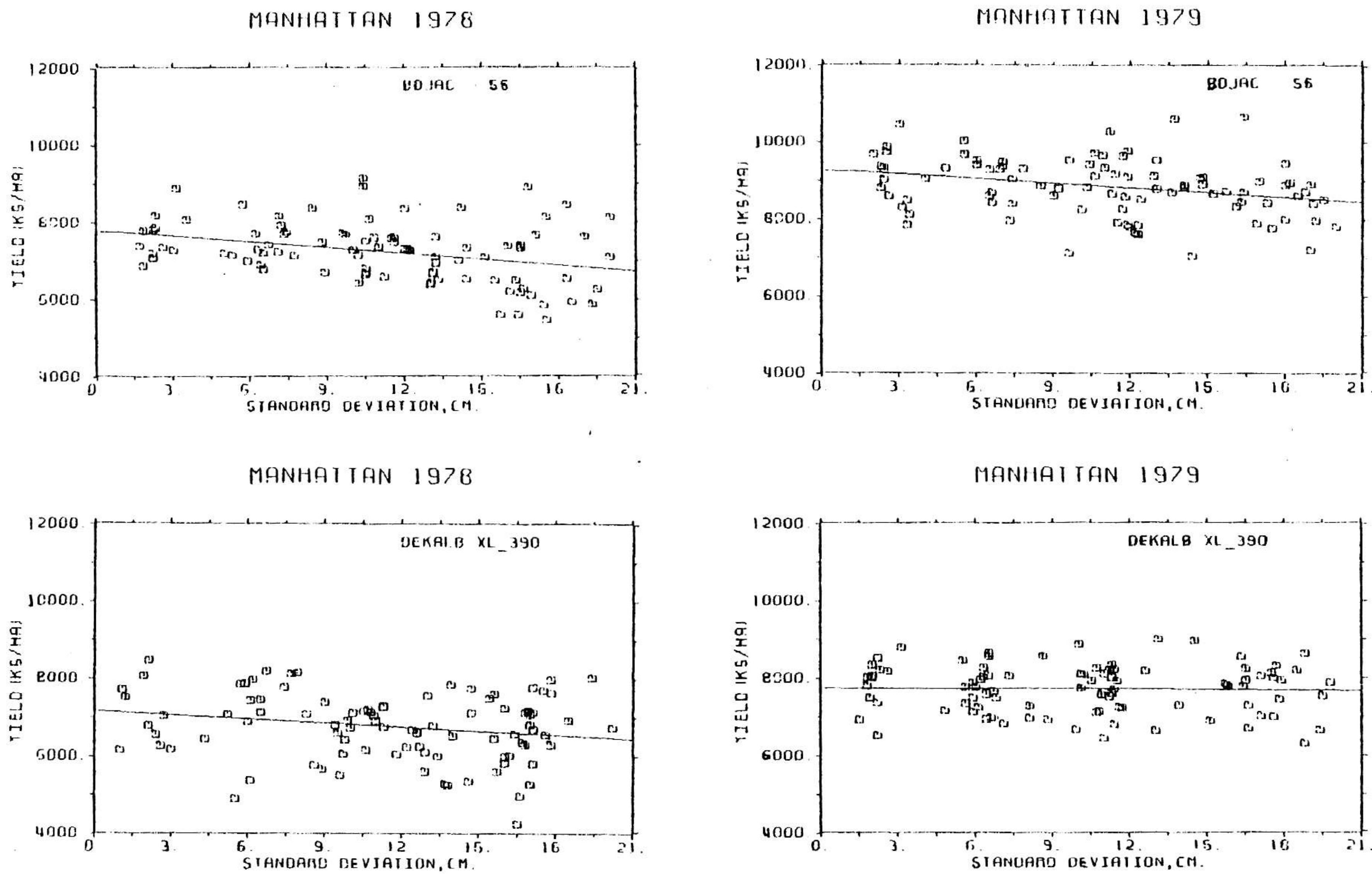

Fig. 2. Regression lines of each hybrid at Manhattan, 1978 and 1979.

respectively. In 1979, intra-row spacing variability accounted for 8 percent of the yield variability of BoJac-56 (Table 4). No such conclusion could be drawn for DeKalb XL-390 since the relationship was not significant. Thus, improving planting precision may result in little grain yield increase. The lack of response of DeKalb XL-390 in 1979 agrees with earlier studies with this hybrid which showed little response to variability of spacing (22).

Grain yield, 100 kernel weight and kernel number for BoJac-56 were correlated to spacing variability in 1978 (Table 5). One hundred kernel weight for DeKalb XL-390 was not correlated to variability of spacing in the same year. In 1979, grain yield, ear weight and kernel number for BoJac-56 were correlated to spacing variability, but not for DeKalb XL-390 (Table 5). It was thought that the affected yield components were responsible for the grain yield response to variability of spacing. Where kernel number per ear decreased in response to increase in spacing variability, it seems logical that grain yield may also proportionately decrease with increase in variability of spacing. Kernel number was the most consistently affected yield component at this location.

During harvest, barren or incompletely filled ears were more frequently observed at higher levels of spacing variability. Delay in development rate at high levels of spacing variability (Appendix Table 6), might have affected the normal pollination of the plants and consequently some ears were barren or not well filled.

Table 5. Simple correlations between spacing variability and yield and yield components, 1978 and 1979.

Location	Year	Hybrids	Grain Yield	Ears/ Plant	100 Kernels Weight	Ear Weight	Kernels/ Ear
Powhattan	1978	DeKalb XL-390	-.065	.061	.091	-.051	-.163
Manhattan	1978	BoJac-56	-.343**	-.106	-.302**	.065	-.225*
		DeKalb XL-390	-.202*	.052	.055	-.167	-.301**
	1979	BoJac-56	-.283**	.023	.004	-.223*	-.275**
		DeKalb Xl-390	-.052	.004	.063	-.054	-.071
Rossville	1978	BoJac-56	-.338**	-.289**	-.318**	-.329**	-.242*
		DeKalb XL-390	-.231*	-.173	-.063	.149	-.197*
	1979	BoJac-56	-.433**	-.131	-.016	-.008	-.302**
		DeKalb XL-390	-.390**	-.128	-.049	-.067	-.282**
Ashland	1978	BoJac-56	-.243**	-.004	-.099	-.192	-.230*
		DeKalb XL-390	-.244**	-.157	-.088	-.114	-.199*
	1979	BoJac-56	-.299**	-.278**	.083	-.042	-.161
		DeKalb XL-390	-.292**	-.003	.041	-.241*	-.245*

** Significant at 1%

* Significant at 5%

ROSSVILLE

Grain yield, generally tended to decrease with increase in variability of spacing (Table 1). The decrease was significant in 1978 and 1979. Hybrid yield differences were also observed. BoJac-56 and DeKalb XL-390 responded similarly to variability of spacing at this location. Kernel number and ear weight were not affected in 1978, but the hybrid x spacing variability interaction effect was significant in 1979 (Appendix Tables 9 and 10). This was the only location where ear number was significantly affected by spacing variability.

Regression analysis showed a negative relationship between variability of spacing and grain yield (Table 4 and Fig 3). The relationship, as shown by r^2, accounted for 11.4 and 5.3 percent of the yield variability in 1978 for BoJac-56 and DeKalb XL-390, respectively. In 1979, intra-row spacing variability accounted for 18.7 and 15.2 percent of the grain yield variability for BoJac-56 and DeKalb XL-390, respectively (Table 5). The effect of spacing variability seemed to be more consistent at this location than other locations, supporting an earlier study indicating that the effect of intra-row spacing variability varies from location to location (22). In addition, highest r^2 values were obtained for BoJac-56 and DeKalb XL-390 in 1979 (Table 4).

In 1978, grain yield and yield components for BoJac-56 were correlated with spacing variability (Table 5), but only kernel number and grain yield for DeKalb XL-390. Ear number, 100 kernel and ear weights showed no correlation with variability of spacing in 1979. Kernel number was the most

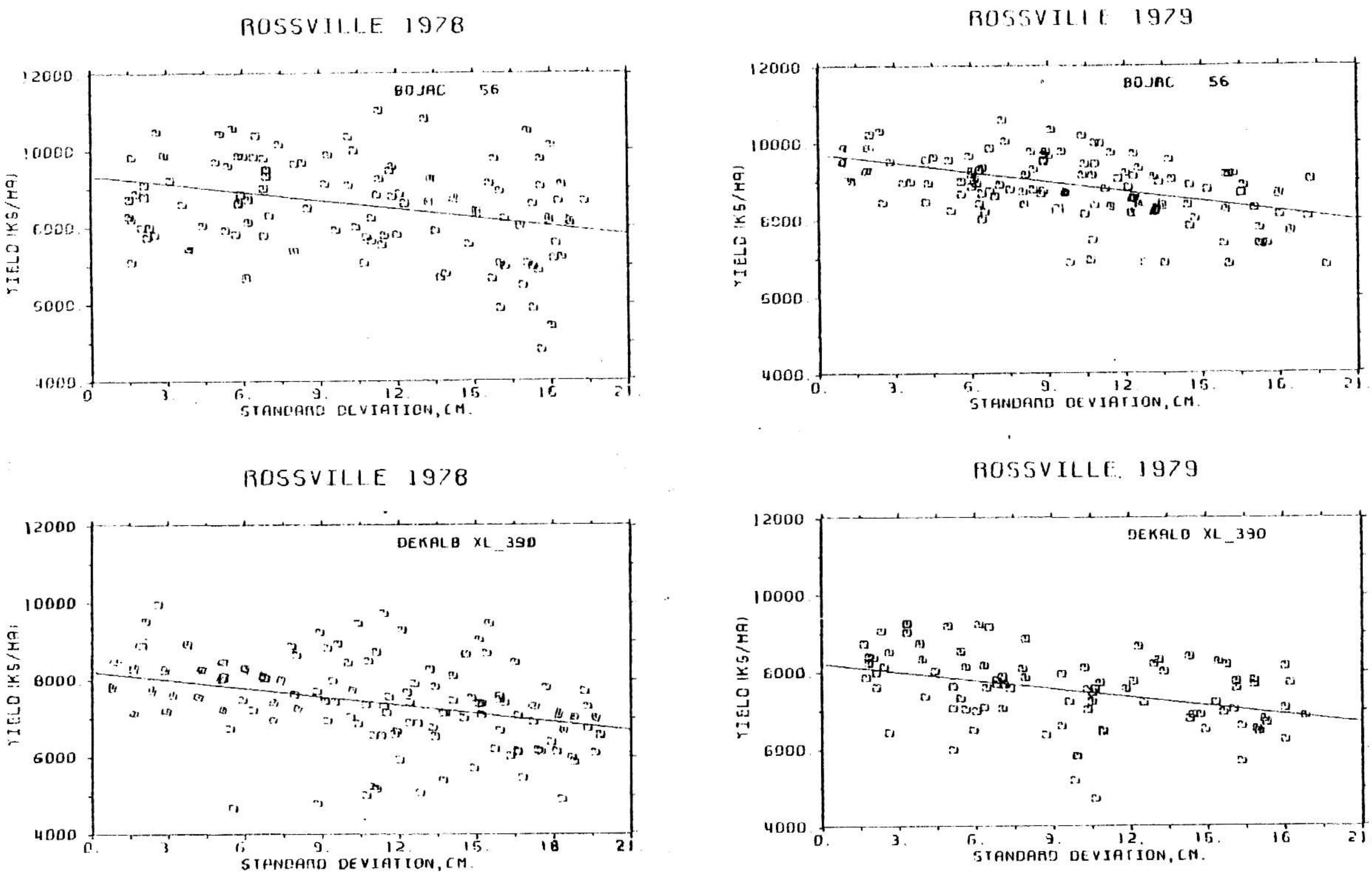

Fig. 3. Regression lines of each hybrid at Rossville, 1978 and 1979.

consistently affected yield component.

ASHLAND

Analysis of variance showed that grain yields were significantly affected by variability of spacing (Table 1 and Appendix Tables 11 and 12). In addition to significant hybrid yield differences in 1978 and 1979, there were also significant hybrid response differences to variability of spacing in 1978 (Table 2 and Appendix Tables 11 and 12). Kernel number and ear weight were similarly affected in 1978, but not in 1979. Ear number was not significantly affected by variability of spacing in either year.

Lower grain yields were obtained for this location in 1979 than 1978 (Table 1). Water logging of the experimental plots as a result of heavy rainfall in June and early weeks of July, 1979, and the consequent nitrogen deficiencies of the plants, might have contributed to the low grain yields. In addition, plant damage by corn borer and ear worm were also observed. Ear silks, generally, were damaged as soon as they were produced, thereby interfering with the normal pollination of the plants. This might have contributed to the poor grain filling of the ears observed at this location, and the resultant low grain yields. However, it seems that the nitrogen stress was an additional condition under which grain yield response to variability of spacing could be obtained.

Regression analysis shown in Table 4 indicated a negative relationship between grain yield and spacing variability.

Intra-row spacing variability accounted for 6 and 9 percent of the grain yield variability of each hybrid in 1978 and 1979, respectively (Table 4). The regression lines are shown in Fig 4.

Kernel number was the yield component most consistently affected by variability of spacing at this location (Table 5).

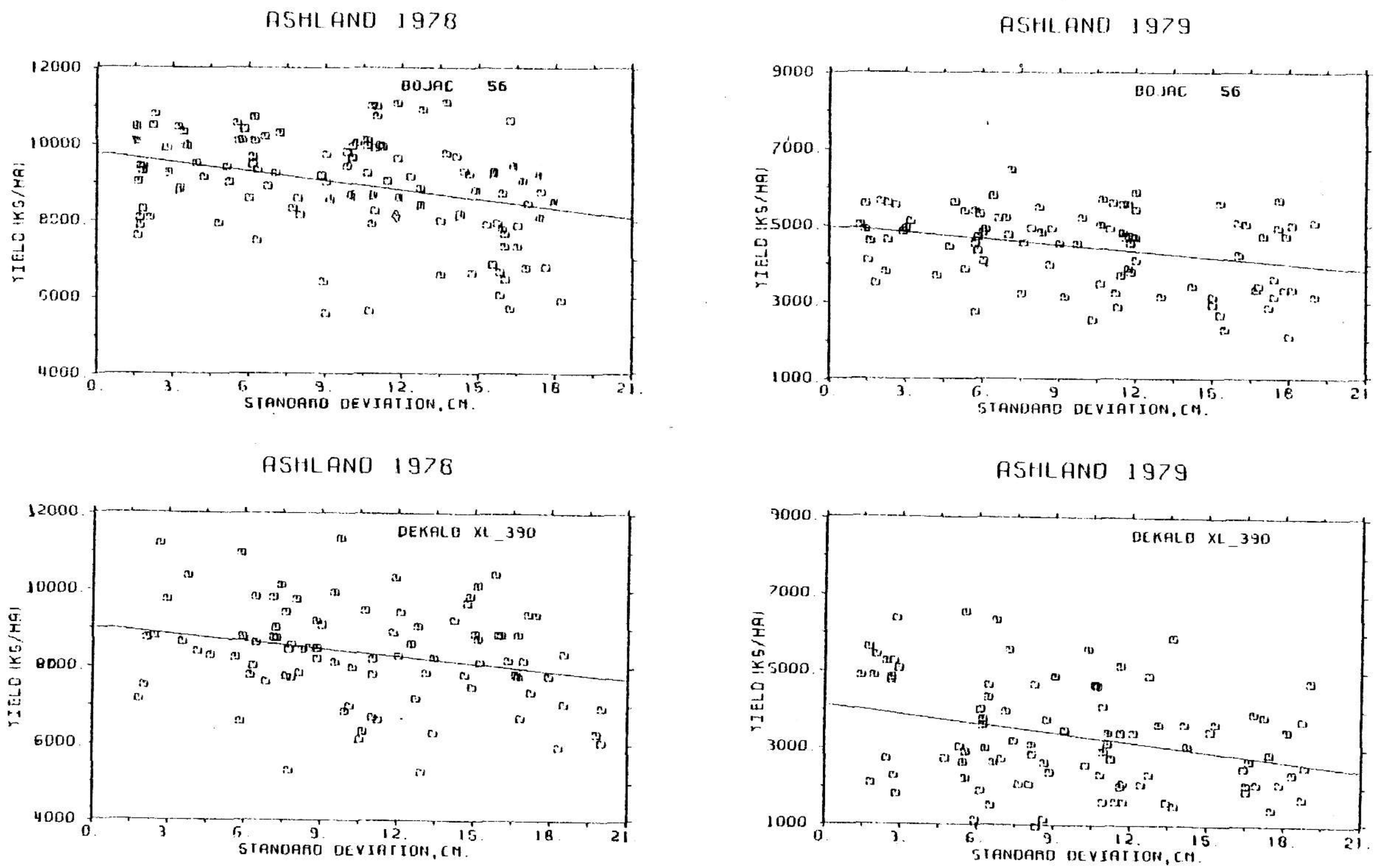

Fig. 4. Regression lines of each hybrid at Ashland, 1978 and 1979.

SUMMARY AND CONCLUSIONS

Significant negative relationship between grain yield and variability of spacing was found at three of the four locations. This indicated that grain yields, generally, decreased with increase in spacing variability. Hybrid x spacing variability interaction effect on grain yield was observed at Manhattan in 1979 and Ashland in 1978, showing that BoJac-56 and DeKalb XL-390 responded differently to variability of spacing. Hybrid grain yield differences were evident. In six of the eight experiments, BoJac-56 produced higher grain yields than DeKalb XL-390.

Yield components, generally, were affected by intra-row spacing variability, with kernel number the most consistently affected. The results also showed that reduction in grain yield as variability of spacing increased seemed to be accompanied by a similar reduction of one yield component or the other.

Grain yield decrease of 148.2 to 1641.9 kg/ha was observed as within-row plant spacing increased from 0 to 19.5, indicating that improving planting precision could appreciably increase grain yield. The effect of spacing variability on grain yield was more consistent at Rossville than other locations. Relatively higher r^2 values were also found for this location (Table 3). The observations are in agreement with an earlier study which showed that the effect of spacing variability on grain yield varied with corn hybrid and location (22).

Furthermore, rate of development, as measured by tasseling and silking dates, was delayed for two days; the interval between tasseling and silking was increased by one day as a result of increasing spacing variability from 2 to 18 cm.

The results of this work stress the need for good calibration of corn planters to improve planting precision. With good crop management practices, economic benefits could be expected from improved within-row plant spacing.

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APPENDIX

Table 6. Hybrid tassel and silk dates at Manhattan and Ashland, 1978 and 1979.

Location and Year			Level of spacing variability (standard deviation, cm.) 0-2.5	4.5-7.5	10.5-13.5	16.5-19.5	Average
			------------- Dates:	July	------------		
Manhattan 1978	BoJac-56	Tassel	6	7	8	8	8
		Silk	12	12	14	15	14
	DeKalb Xl-390	Tassel	14	16	16	17	16
		Silk	20	22	24	25	22
1979	BoJac-56	Tassel	10	10	11	11	10
		Silk	13	14	15	15	14
	DeKalb XL-390	Tassel	14	15	17	17	16
		Silk	19	19	21	22	20
Ashland 1978	BoJac-56	Tassel	--	--	--	--	--
		Silk	9	10	10	12	11
	DeKalb XL-390	Tassel	11	12	12	13	12
		Silk	15	17	16	18	17
1979	BoJac-56	Tassel	16	16	17	18	17
		Silk	18	18	21	23	20
	DeKalb XL-390	Tassel	22	21	22	23	22
		Silk	24	24	26	26	25

Table 7. Analysis of variance of yield and yield components at Manhattan, 1978.

Source of Variation	Degrees of Freedom	Grain Yield (kg/ha)	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams)	Kernel Number
Total	112	----------	----------	Mean Squares	----------	----------
Replications	5	2,841,864**	.00384	9.109**	3112**	14078
SD	3	2,206,125*	.00585	14.340**	1904	5681
Hybrid	1	2,247,725*	.00396	29.710**	1886	30868*
Row (Replications)	15	573,043	.00530	5,486**	935	8000
Hybrid x SD	3	643,610	.00122	15.370**	1959	44225**
Hybrid x Row	3	130,252	.00214	0.748	316	5919
Hybrid x Row x SD	17	769,903	.00251	2.680	713	5687
Error	62	721,881	.00397	2.330	808	7576

** Significant at 1%

* Significant at 5%

Table 8. Analysis of variance of yield and yield components at Manhattan, 1979.

Source of Variation	Degrees of Freedom	Grain Yield (kg/ha)	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams)	Kernel Number
Total	122	--------------------	--Mean Squares--	--------------------	--------------------	--------------------
Replications	5	628,762	.00824	1.293	1984**	5684*
SD	3	767,023	.00930	5.382	314	6621*
Hybrid	1	32,368,886**	.03470	102.556	6502**	424933**
Row (Replications)	15	322,880	.00432	2.034	269	1598
Hybrid x SD	3	1,764,465**	.00240	1.928	1039	6891*
Hybrid x Row	3	481,730	.00779	0.536	209	378
Hybrid x Row x SD	18	390,933	.00270	2.112	477	2313
Error	71	424,492	.00618	2.387	440	2090

** Significant at 1%

* Significant at 5%

Table 9. Analysis of variance of yield and yield components at Rossville, 1978.

Source of Variation	Degrees of Freedom	Grain Yield (kg/ha)	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams)	Kernel Number
Total	110	----------	----------Mean	Squares----------	----------	----------
Replications	5	2,694,560	.00535	5.101	952	9859
SD	3	6,129,576**	.01252*	13.698*	1544	4800
Hybrid	1	18,492,377**	.00025	5.334	505	105319**
Row (Replications)	15	719,112	.00340	2.963	466	5337
Hybrid x SD	3	374,178	.00325	14.004*	711	3081
Hybrid x Row	3	1,100,167	.00694	.066	340	3060
Hybrid x SD x Row	15	700,795	.00571	3.082	445	4313
Error	62	1,334,545	.00371	3.985	602	5837

** Significant at 1%

* Significant at 5%

Table 10. Analysis of variance of yield and yield components at Rossville, 1979.

Source of Variation	Degrees of Freedom	Grain Yield (kg/ha)	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams)	Kernel Number
Total	130	--------------------	---------Mean	Squares-------	----------	----------
Replications	5	4,804,568**	.00821	10.44	5151**	14055**
SD	3	4,765,087**	.01605**	4.65	3161**	7572
Hybrid	1	40,342,161**	.00092	39.28	14495**	334227**
Row (Replications)	15	368,120	.00543	19.49	760	3595
Hybrid x SD	3	1,026,357	.00264	28.35	3613**	10657*
Hybrid x Row	3	786,396	.00233	30.02	2689	2586
Hybrid x SD x Row	18	462,845	.00388	17.59	708	4834
Error	79	544,497	.00403	13.43	692	3191

** Significant at 1%

* Significant at 5%

Table 11. Analysis of variance of yield and yield components at Ashland, 1978.

Source of Variation	Degrees of Freedom	Grain Yield (kg/ha)	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams	Kernel Number
Total	124	--------------------Mean Squares--------------------				
Replications	5	8,598,471**	.00123	10.58**	1842**	19566**
SD	3	7,237,197**	.00339	8.92**	2178**	10846**
Hybrid	1	8,930,196**	.00183	15.32**	2221*	82940**
Row (Replications)	15	1,341,021	.00244	1.11	558	2643
Hybrid x SD	3	5,267,075**	.00024	2.07	1778*	11815*
Hybrid x Row	3	1,147,885	.00446	1.04	256	1402
Hybrid x SD x Row	17	957,981	.00288	.767	307	2195
Error	74	1,394,292	.00345	1.747	577	3924

** Significant at 1%

* Significant at 5%

Table 12. Analysis of variance of yield and yield components at Ashland, 1979.

Source of Variation	Degrees of Freedom	Grain Yield (kg/ha)	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams)	Kernel Number
Total	132	--------------------	----------Mean	Squares----------	----------	----------
Replications	5	4,906,660**	.0265	44.98**	12290**	43322**
SD	3	4,474,134**	.00964	7.06*	1454	7193
Hybrid	1	3,878,083**	.28667	333.04**	10547**	32816**
Row (Replications)	15	445,136	.01309	2.07	422	2427
Hybrid x SD	3	710,804	.01222	1.28	720	2517
Hybrid x Row	3	1,118,125	.00221	.94	800	4430
Hybrid x SD x Row	18	508,427	.00997	2.45	374	2583
Error	81	905,220	.01326	2.52	683	3570

** Significant at 1%

* Significant at 5%

Table 13. Analysis of variance of yield and yield components at Powhattan, 1978.

Source of variation	Degrees of Freedom	Grain Yield (kg/ha	Ears/ Plant	100 Kernels Weight (Grams)	Ear Weight (Grams)	Kernel Number
Total	43	--------------------	--------Mean	Squares--------	--------------------	--------------------
Replications	5	291,214	.00977	1.797	515	1420
SD	3	78,446	.01250	1.174	280	8955
Row (Replications)	13	246,230	.00862	.667	211	2674
Hybrid x SD x Row	9	186,148	.00771	2.315	161	1088
Error	10	493,759	.00656	1.143	332	4541

** Significant at 1%

* Significant at 5%

RESPONSE OF CORN, *ZEA MAYS* (L.), TO LEVELS OF WITHIN-ROW SPACING VARIABILITY

by

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AN ABSTRACT OF A MASTER'S THESIS

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Successful production of corn, Zea mays (L.), in the United States can be attributed to research and improvements in production methods. Effects of planting patterns on corn grain yield have been reported. However, there are relatively few published reports relating to the performance of corn planted at different levels of within-row spacing variability.

This study was designed to determine how grain yield is related to spacing variability; to see how much grain yield increase could be obtained by increasing planting precision and to determine the yield components influencing grain yield response to variability of spacing.

Experiments were conducted during 1978 and 1979 at four locations in Kansas: the Manhattan Agronomy Farm, the Cornbelt Experimental Field at Powhattan, the Ashland Agronomy Farm and the Kansas River Valley Experimental Field at Rossville. Ashland and Rossville were irrigated; Manhattan and Powhattan were not.

BoJac-56, a yellow relatively early maturing, and DeKalb XL-390, a white and late maturing, hybrids were used. Standard deviation of within-row plant spacing was used as a measure of planting precision. Corn was hand planted in 76-cm rows at standard deviations of within-row spacing of 0, 6, 12 and 18 cm. Plant populations were 44,000 and 58,000 plants/ha for the non-irrigated and irrigated locations, respectively. Distances between plants within each row were measured and standard deviation of plant spacing was calculated for each row.

Results showed a significant negative relationship between grain yield and variability of spacing at three of the four locations. Hybrid x spacing variability interaction effect on grain yield was also observed at two locations, indicating that BoJac-56 and DeKalb XL-390 responded differently to variability of spacing. The results further showed that reduction in grain yield as variability of spacing increased seemed to be accompanied by a similar reduction in one yield component or the other, with kernel number the most consistently affected. Grain yield decrease of 148.2 to 1641.9 kg/ha was observed as within-row plant spacing increased from 0 to 19.5 cm, indicating that imporving planting precision could appreciably increase grain yield. The results of this work show that with good crop management practices, economic benefits could be expected from improved within-row plant spacing.