INFLUENCE OF WITHIN-ROW VARIABILITY ON CORN, *ZEA MAYS* (L.), GRAIN YIELD

by

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INTRODUCTION

Corn, Zea mays (L.), is an important feed grain crop in the United States. The advent of hybrids, along with efficient use of fertilizers, herbicides, pesticides and irrigation have contributed greatly to its success. In the same context plant population (density) and row spacing has been researched extensively to provide maximum yields. There are indications however that another factor, planting precision or within-row variability, may have an effect on yield.

This study sought to determine the effect of within-row variability on corn grain yield. It should not be confused with row spacing studies, which deal with row widths, or population studies, which deal with varying planting rates. Instead, the within-row variability study attempts to compare yields of areas containing equal plant populations and equal row spacing but with different arrangements of the plants in the row (Figure 1).

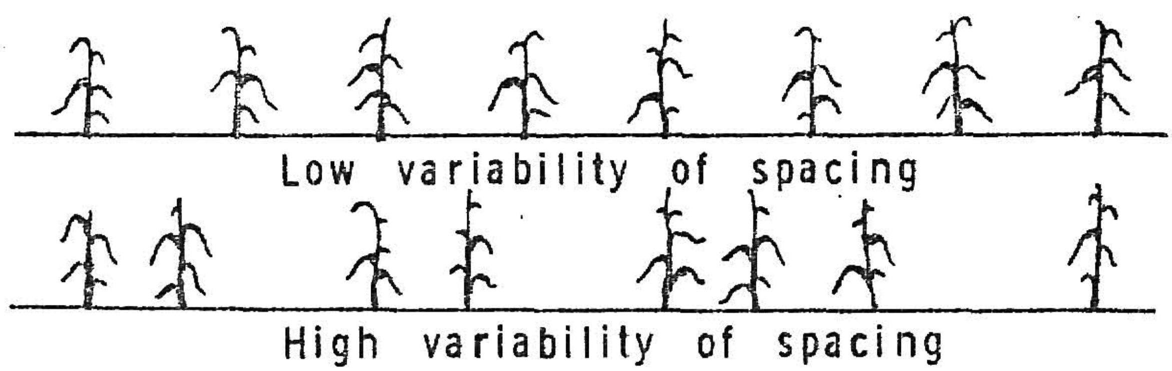


Figure 1. High and low variability of plant spacing. (Note same number of plants in each row.)

With todays planters it is difficult, if not impossible, to space corn plants precisely within the row. However, a careful operator with a well calibrated planter can achieve a planting pattern very close to uniform. The objective of this study was to see if yields could be increased by more precise planting and, if so, how much yields can be increased and how precise the planting should be.

REVIEW OF LITERATURE

Little research has been done directly on the influence of within-row variability on corn grain yields, but since hill planting represents a situation of high within-row variability of plant spacing, studies comparing drill versus hill planting are pertinent. As another measure of within-row variability, equidistant planting will also be discussed.

Hill Versus Drill Planting

Results from seven corn growing states covering a total of 39 station-years according to Dungan, Lang, and Pendleton (6) showed a weighted average yield for drilled corn that was 100 kg/ha or 3 percent above checked corn. Kohnke and Miles (12) found that drilled corn produced 509 kg/ha more corn than hill planting. In an 11 year test, Kiesselbach, Anderson, and Lyness (11) determined that surface planted corn checked at the rate of three plants to the hill yielded 2164 kg/ha as an average compared to 2221 kg/ha for corn drilled at a corresponding rate.

Rounds, et al. (17) studied the effects of planting in six experiments at three locations over two years. They found that drilled corn averaged 337 kg/ha, or 7 percent more than corn planted in hills. The differences in yield were small but were consistantly in favor of drill planting. Roberts and Kinney (15) also found that drilled corn outyielded hilled corn when seeding rates were equal.

In comparing four inbreds and six single crosses at 1, 2, and 4 plants per hill, Woolley, Baracco, and Russell (21) found that yields tended to be higher at 2 plants per hill, although in many cases it was not significantly different than at 1 plant per hill. While Fayemi (9), who planted corn at 1, 2, and 4 plants per hill at 22.5 cm, 45 cm, and 90 cm apart respectively, found that 1 plant per hill at 22.5 cm spacing consistently gave higher yields, although they were not significant.

Williams and Welton (20) reported on a three year study that showed a 286 kg/ha increase in favor of one plant every 30 cm as compared with three plants every 90 cm, the number of plants per hectare being equal. Collins and Shedd (2) compared 4 plants per hill to 1 plant per hill over an eight year period and with populations being equal found that single hill planting increased yields by 541 kg/ha. In a trial conducted by Colville and McGill (3) similar results were noted. The single plant method yielded 624 to 1425 kg/ha more than the hill method. Dungan (5) reiterated the superiority of single plant hills and also pointed out that differences were greatest when conditions of plentiful moisture and productive soil existed.

In contrast, Bryan, Eckhardt, and Sprague (1) found that the difference in yield of plants spaced 4 per hill 106.6 cm apart and 1 plant per hill 53.3 cm apart was not significant for a four year trial. Morrow and Hunt (13) attained the same conclusion when they found that a hill planted plot yielded 1245 kilograms compared to 1255 kilograms for a drilled plot.

As the literature indicates, reports on hill versus drill planting are inconsistent although the tendency favors drill planting. This review concurs with the findings of Rossman and Cook (16) who found that by states over a range of years, locations, populations, etc., the yield differences in favor of the drilled pattern ranged from 0 to 13 percent.

Equidistant Planting

Colville and Burnside (4) report that single, hand-weeded plants, spaced equidistantly 50 cm apart yielded 34 percent more corn, at the same population, than equidistantly spaced (100-cm) hills with four plants per hill. Pfister (14) also indicated that ideal spacing appears to be about 50 cm in all directions.

Corn uniformly spaced (equidistant planted) gave 38.2 kg/ha more yield than hilled corn according to experiments conducted by Kohnke and Miles (12). Yao and Shaw (22) determined that yield and efficiency of water use increased as plant spacing was made more uniform. In contrast, Hoff and Mederski (10) indicated that planting pattern has little effect on yield. Adequate soil moisture was the most important factor for obtaining high yields.

Spacing plants singly and equidistant in all directions was noted by Dungan (5) to provide less competition than any other method of distributing the same number of plants per hectare. He added, however, there was not much likelihood that anyone would want to grow a commercial crop by this method. Yet practical modifications of it could be readily devised, if tests of this distribution showed a significant advantage.

Erbach, Wilkins, and Lovely (7) indicated that on a field scale, with corn planted in 76 cm rows, improving intra-row spacing may not significantly improve total yield. Therefore, it may not be economical to improve upon the intra-row plant spacing uniformity obtained with conventional planters. Findings of Shubeck and Young (18) tend to contradict this conclusion. Their findings show that 50 cm rows, random staggered, outyielded 100 cm rows, drilled with tool bar planters, 8400 kg/ha to 7600 kg/ha. They also described a simple modification to a conventional planter that would provide for staggered planting.

Esechie (8) sought to determine the influence of within-row variability on yield. The results were inconclusive because he was unable to maintain uniform plant population, thus plant population effect could not be distinguished from the effect of within-row variability.

From reviewing the literature, while controversy does exist, indications were that increasing planting precision or decreasing within-row variability will increase yields. The amount of increase remains in question.

EXPERIMENTAL PROCEDURE

Field Experiments

To obtain a wide range of within-row variability two planting methods were used. Standard machine planting usually provided a wide range of within-row variability while hand planting insured low within-row variability of plant spacing.

The experiment was conducted during the 1973 and 1974 growing seasons at three irrigated locations in Kansas; the Kansas River Valley Experiment Field at Silver Lake, Sandyland Irrigation Experiment Field at St. John, and the Irrigation Experiment Field at Scandia. At all three locations bulk areas were planted by machine with corresponding areas being planted by hand at the same population as the machine planted. Machine and hand planting occurred on the same day and uniform application of water, fertilizer, herbicides and insecticides were made.

Several weeks after emergence 3-m lengths of rows containing the same number of plants were staked out in hand and machine planted areas. The distance between individual plants in each 3-m subplot was then measured. To obtain a measurement of variability the standard deviation and coefficient of variability, according to Steele and Torrie (19), was calculated for each subplot using the plant spacing measurements.

The variety planted and plot area varied from location to location (Table 1). At St. John a four-row Buffalo planter was used thus a replication consisted of four hand and four machine planted rows side by side. A six row John Deere, plate planter was used at Silver Lake and replications consisted of three machine and three hand planted rows. At Scandia six rows planted by an International Cyclone planter, four rows planted by a Buffalo planter and two rows planted by hand comprised a replication. All locations were planted in 75-cm rows and were bordered by corn.

Plant population and thus plants per subplot varied from one experiment to the next but remained the same for a given experiment based on the population planted (Table 2).

Table 1. Variety, replications and plot area for St. John, Silver Lake, and Scandia in 1973 and 1974.

Year	Location	Brand	Variety	Replication	Plot area (Rows X Length in Meters) Hand	Machine	
						Buf.	Cyc.
1973	St. John	Pioneer	3390	4	4X30	4X30	
	Silver Lake	Pioneer	3369A	6	3X30	3X30	
	Scandia	DeKalb	XL-72A	3	2X18	4X18	6X18
1974	St. John	Pioneer	3390	4	4X30	4X30	
	Silver Lake	DeKalb	XL-72A	6	3X30	3X30	
	Scandia	Pioneer	3388	4	2X9	4X9	6X9

Table 2. Plant population, plants per subplot, and number of subplots at St. John, Silver Lake, and Scandia in 1973 and 1974.

Year	Location	Population (Pl/ha)	Plant/subplot (3 Meter)	No. of subplots Hand	Machine		Total
					Buf.	Cyc.	
1973	St. John	55973	13	26	25		51
	Silver Lake	51667	12	53	53		106
	Scandia	51667	12	27	27	26	80
		60278	14	27	27	25	79
		68889	16	27	22	23	72
1974	St. John	60278	14	34	33		67
	Silver Lake	55973	13	48	48		96
	Scandia	47361	11	20	23	23	66
		55973	13	22	21	22	65
		64584	15	22	18	23	63
	Total						745

Generally there were eight or nine subplots per hand or machine planted section of a replication depending on the study size and how many 3-m sections of row containing the same number of plants could be found.

At maturity each subplot was hand harvested; ear number, ear weight, grain weight, and percent moisture was determined. Grain yields were adjusted to 14.5 percent moisture. Linear regressions were run for each of the six experiments between yield and standard deviation and yield and coefficient of variability.

Farm Field Survey

A survey of farm fields in three prominent corn growing areas of the state was conducted to determine where the farmer stands in the spectrum of within-row variability. Table 3 shows the counties where the survey was conducted, the number of fields surveyed and the number of 3-m subplots surveyed.

Table 3. Location, number of farm fields surveyed, and number of subplots surveyed during 1973 and 1974.

Year	Location (County)	Fields Surveyed	Subplots Surveyed
1973	Douglas	10	62
1974	Douglas	8	49
	Shawnee	10	60
	Stafford	9	56
	Total	37	227

Each field was surveyed by measuring the distance between plants in 3-m subplots selected at random. Six to eight subplots were measured per field. The survey took place in mid-summer with county agents from the respective counties helping to locate interested farmers. Plants per subplot varied from field to field due to random selection, row width and germination.

Standard deviation was calculated for each of the farm subplots surveyed. The average standard deviation was calculated for each field. High and low fields for each of the four surveys was determined and the mean standard deviation of all subplots for each survey was calculated and used to indicate where the farmer stands with respect to within-row variability.

RESULTS AND DISCUSSION

Grain yields for each of the six site-years were related to variability of within-row spacing by the linear equation: Y=A+BX, where Y represents yield (kg/ha) and X represents standard deviation or coefficient of variability.

In the text the influence of standard deviation on corn grain yields is discussed. Table 4 shows this regression analysis. Since population remains the same for a given experiment results of standard deviation and coefficient of variability should be similar, therefore regressions of corn grain yields on coefficient of variability are given in the Appendix (Tables 9-11).

Table 4. Linear regression analyses of yield versus standard deviation of spacing.

Location	Year	A	B	S_A	S_B	F	r
St. John	1973	10862	-70.20	185	22.91	9.39**	-0.401
	1974	11662	-114.95	282	37.13	9.58**	-0.359
Silver Lake	1973	9895	-76.18	197	29.91	6.49*	-0.242
	1974	8881	-84.85	258	33.82	6.29*	-0.251
St. John and Silver Lake Combined		10102	-84.33	157	21.28	15.70**	-0.217
Scandia	1973	9091	32.34	139	16.04	4.09*	0.132
	1974	8194	34.72	224	24.84	1.95	0.100

* Statistically significant at the 5% level.
** Statistically significant at the 1% level.

St. John

Although soil variability problems caused the elimination of one replication in 1973, all other yields were near normal for St. John in 1973 and 1974.

Figure 2 shows the regression lines for 1973 and 1974. As standard deviation of plant spacing increased yields decreased both years. The points

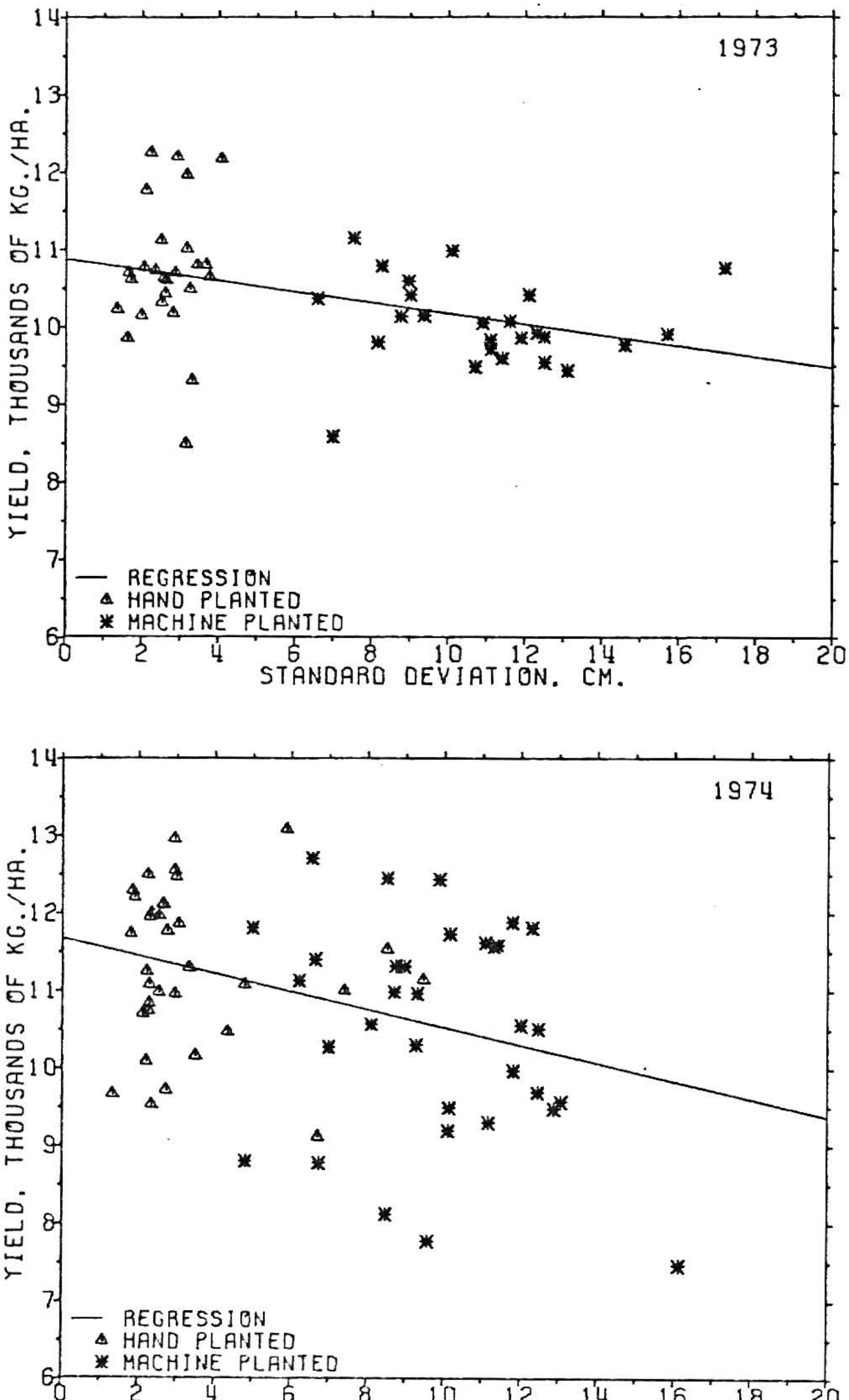


Figure 2. Comparison of yield with standard deviation of spacing showing machine and hand planted subplot points at St. John.

indicate that hand planting provided a low degree of within-row variability while machine planting provided a high degree of within-row variability of plant spacing.

Silver Lake

Considerable lodging took place in 1973 and 1974 at Silver Lake. In 1974 field conditions were substandard due to volunteer corn, weeds, and a poor stand in two replications of the plot area. These factors coupled with an abnormally hot, dry summer caused below normal yields for irrigated corn in 1974. Regardless of these conditions there was still a significant negative correlation between yield and standard deviation of spacing in 1973 and 1974 (Table 4).

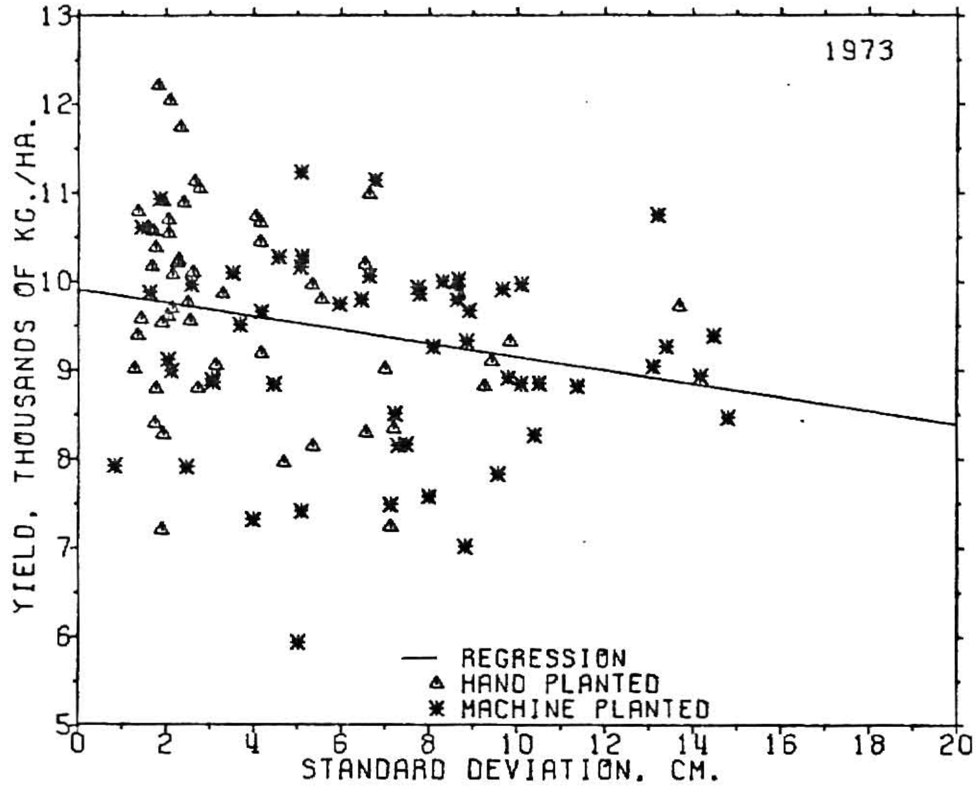
As standard deviation of plant spacing decreased, yields increased (Figure 3). The indications are, at both St. John and Silver Lake, that yields could be increased significantly by using more precise planting methods.

Scandia

In 1973 yields were near normal for irrigated corn at Scandia while in 1974 hot dry summer weather caused yields to be slightly below normal. In 1973 there was a significant positive correlation between yield and standard deviation of spacing and in 1974 no significant correlation was noted (Table 4).

Indications were that as standard deviation of spacing increased yields did not decrease as they did at the St. John and Silver Lake locations. In fact just the opposite occurred, the tendency being for yields to increase as standard deviation of spacing increased (Figure 4).

In an effort to explain the Scandia results, linear regressions were calculated at each of the six population levels. The theory being that at



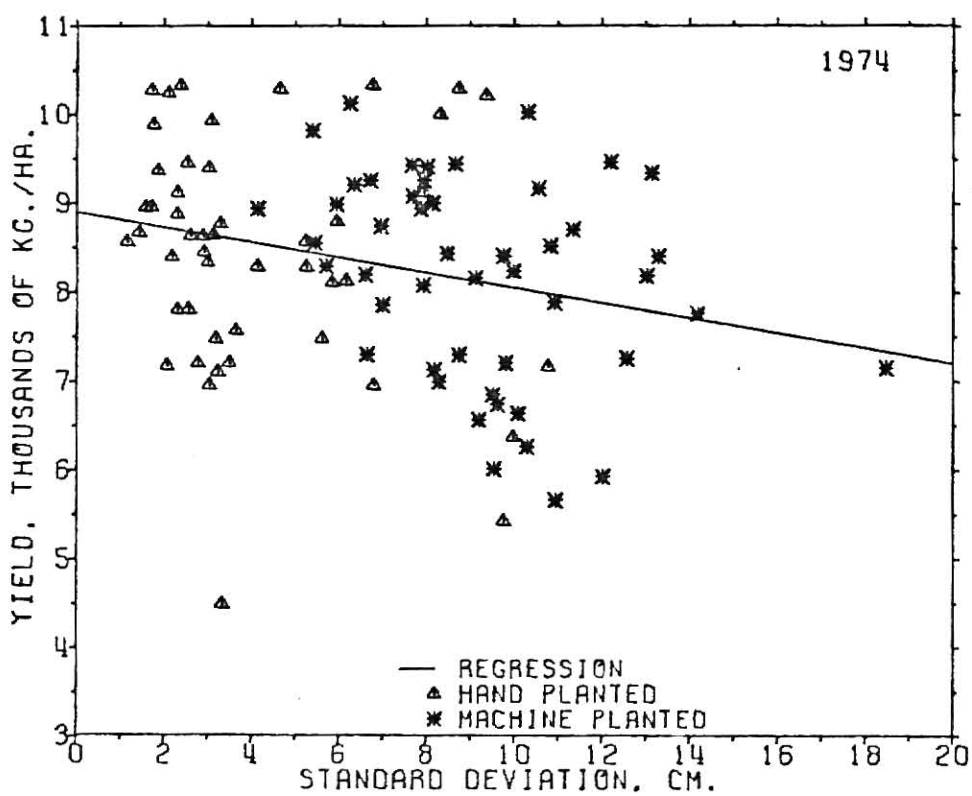
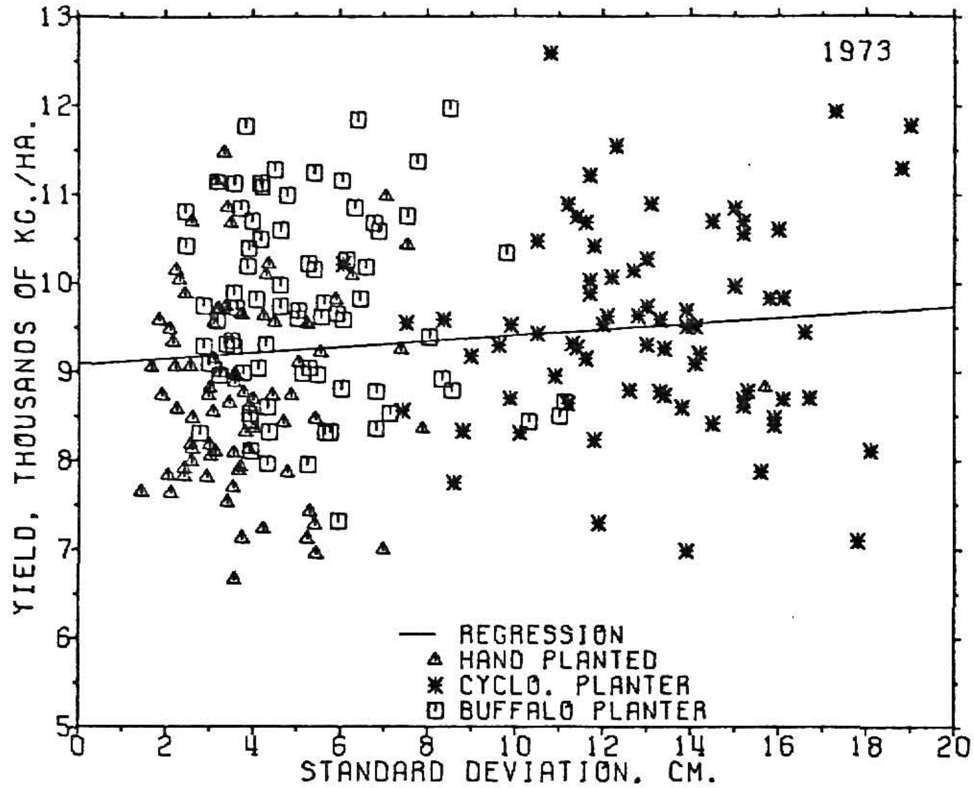


Figure 3. Comparison of yield with standard deviation of spacing showing machine and hand planted subplot points at Silver Lake.



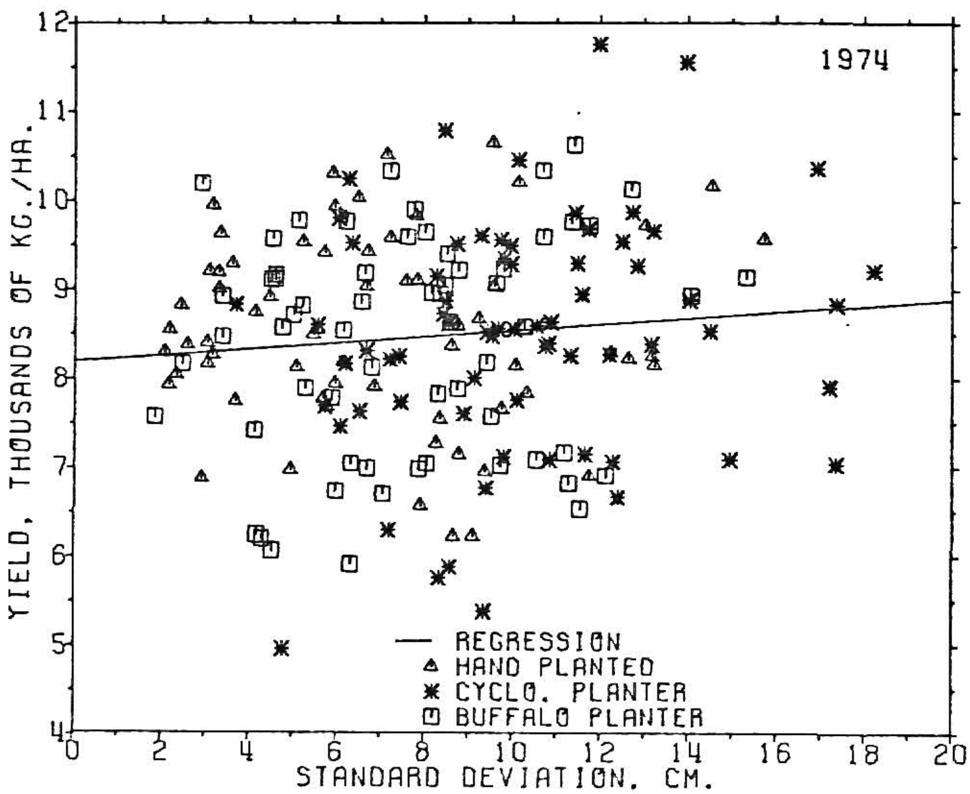


Figure 4. Comparison of yield with standard deviation of spacing showing machine and hand planted subplot points at Scandia.

different plant densities within-row variability may have had differing effects on yield. Table 5 shows the results of these linear regressions.

Table 5. Linear regression analyses of yield versus standard deviation of spacing at each population level at Scandia in 1973 and 1974.

Population (pl/ha)	A	B	S_A	S_B	F	r
1973:						
51667	9004	51.54	239	24.79	4.32*	0.229
60278	9077	4.58	234	28.84	0.03	0.018
68889	9311	22.79	258	31.78	0.51	0.085
1974:						
47361	8313	7.43	289	30.15	0.06	0.031
55972	8037	68.63	451	51.99	1.74	0.164
64584	8021	56.23	462	52.91	1.13	0.135

* Statistically significant at 5% level.

The 1973 findings indicate that at 51667 plants/hectare yields increased significantly as standard deviation of spacing increased. All the other populations over the two years were not significant. These results do little to explain the Scandia findings but they do show a consistant trend of a positive correlation between yield and standard deviation of spacing (Figure 5).

In 1973 the hand planting technique at Scandia differed from that used at other experiments. Two seeds were planted per hill and then thinned while elsewhere only one seed was planted per hill. Also, emergence was delayed in hand planted areas due to cool-wet spring conditions. Lodging was observed at Scandia during the 1973 growing season. It is thought that hand planted areas may have been affected most since corn spaced singlely would probably lodge easier than corn clustered closer together as suggested by Colville and McGill (3). These factors are believed to have caused reduced yields in hand planted corn in 1973. This explains the positive significant correlation of

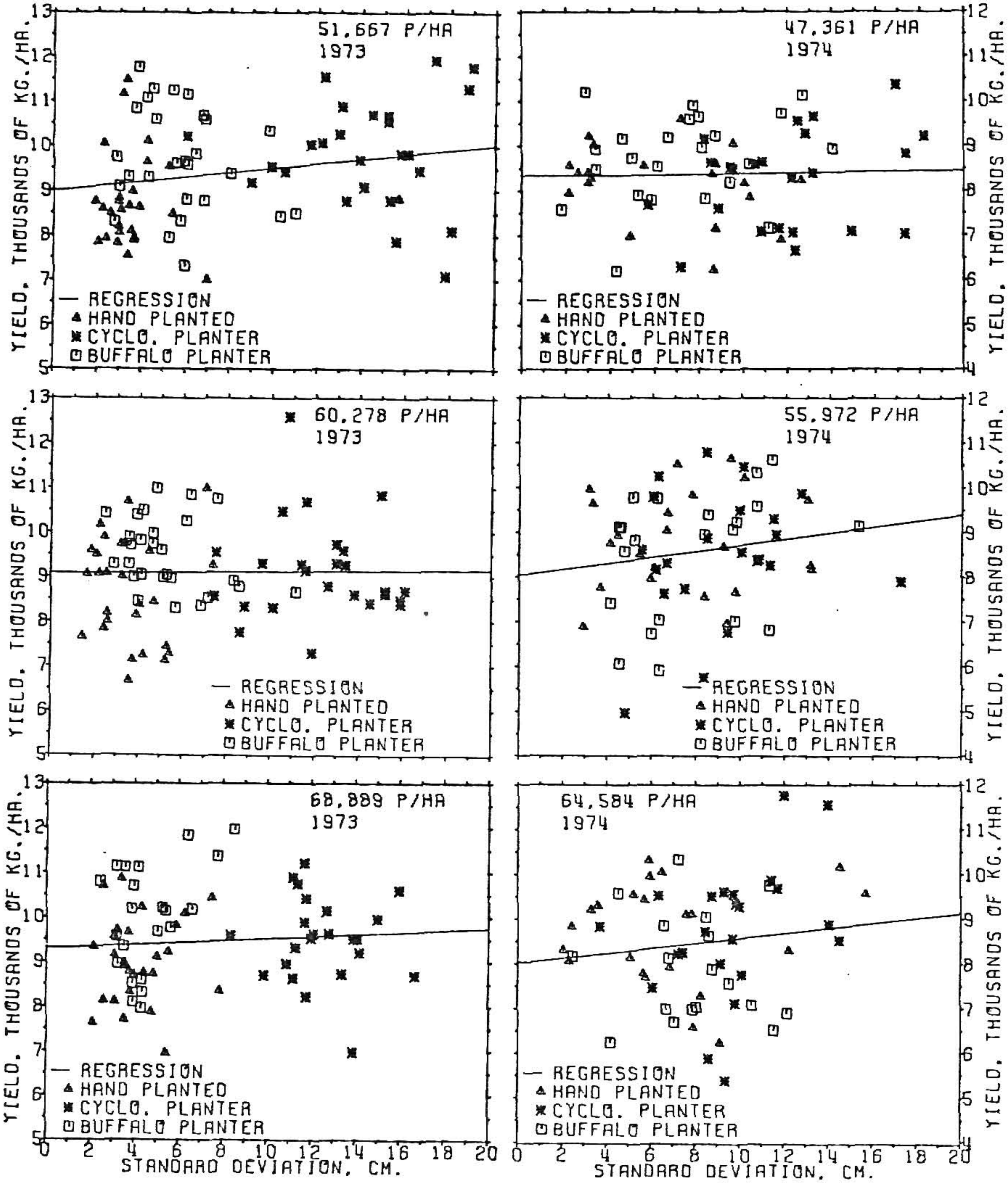


Figure 5. Comparison of yield with standard deviation showing subplot points at each population level at Scandia.

the 1973 results, because when the hand planted data is excluded the trend is reversed (Tables 4 and 6). The 1974 data with and without hand planted data remains essentially the same showing a slight non-significant positive trend between yield and standard deviation of spacing. The Scandia results taken in this light indicate that within-row variability does not have any effect on yield.

Table 6. Linear regression analyses of yield versus standard deviation of spacing excluding hand planted data at Scandia in 1973 and 1974.

Population (pl/ha)	A	B	S_A	S_B	F	r
1973:						
Total	9771	-17.99	197	19.12	0.89	-0.077
51667	9721	4.55	348	30.60	0.02	0.021
60278	9793	-53.92	304	31.74	2.88	-0.233
68889	10048	-35.50	372	38.43	0.85	-0.139
1974:						
Total	7882	63.18	321	33.46	3.56	0.165
47361	8311	16.10	409	39.27	0.17	0.062
55972	7576	109.45	627	69.94	2.45	0.237
64584	7240	128.54	755	81.56	2.48	0.245

It was thought that perhaps the Scandia results differed from those of St. John and Silver Lake because of overall differences in yield. The effect of within-row variability changes may depend upon conditions producing high yields. If this were true average yields at Scandia would consistantly differ from those at the other two locations. The average yields show no such tendency, although 1974 yields were lower both at Scandia and Silver Lake (Table 7).

Average standard deviations and coefficients of variability were consistantly greater for the Scandia experiment indicating less precision and a different spectrum of variability (Table 7). Since at Scandia there were positive correlations, while at the other locations there were negative correlations between yield and standard deviation of spacing, a curvilinear relationship may exist in which yields decrease as standard deviation increases up to a point and then yields are not affected or are increased as standard deviation of spacing continues to increase. Further research is necessary to determine if this is the case.

Table 7. Average yield, standard deviation, coefficient variability, and mean spacing for the 1973-1974 results at St. John, Silver Lake, and Scandia.

Location	Population (Pl/ha)	Average Yield (Kg/ha)	Average Standard Deviation	Average Coefficient Variability	Average Mean Spacing (cm)
1973:					
St. John	55973	10392	6.71	0.284	23.89
Silver Lake	51667	9476	5.49	0.218	25.47
Scandia	Total	9328	7.31	0.328	22.69
	51667	9415	7.98	0.307	26.23
	60278	9109	6.91	0.313	22.30
	68889	9471	7.00	0.366	19.16
1974:					
St. John	60278	10913	6.52	0.299	22.06
Silver Lake	55972	8314	6.68	0.278	24.16
Scandia	Total	8482	8.31	0.338	24.74
	47361	8377	8.66	0.305	28.36
	55972	8593	8.10	0.335	24.16
	64584	8478	8.14	0.377	21.55

Perhaps the amount of influence within-row variability has on yields varies depending on soil type. At St. John and Silver Lake where sandy soils exist decreasing within-row variability caused a marked increase in yields, while at Scandia where the soil is higher in clay within-row variability had little or no effect. More research is suggested to verify this theory.

Farm Field Survey

Average standard deviation was calculated for each field surveyed. Then the standard deviation range of high and low fields at each survey was determined (Table 8). The mean standard deviation and the average of high and low fields over the four surveys is an indicator of where the farmer stands in the spectrum of within-row variability.

Table 8. Standard deviation ranges and means for farm field survey locations in Douglas, Shawnee, and Stafford counties for 1973 and 1974.

Year	Survey Locations (County)	Standard Deviation (cm) Range of Fields	Overall Mean
1973	Douglas	6.6-16.1	11.4
1974	Douglas	11.1-18.4	14.9
	Shawnee	7.1-13.4	11.0
	Stafford	8.1-14.6	10.3
	Average	8.2-15.6	11.8

A standard deviation of four was used as an arbitrary point of maximum precision obtainable with mechanical planting. By interpolating these values onto a graph of the combined regression line of the St. John and Silver Lake trials an estimate of how much yields could be increased can be obtained. In Figure 6, (A) represents the maximum precision (S.D. = 4 cm) obtainable by machine planting; (B) is the average of the low fields over the four surveys while (D) is the average of the high fields, and (C) is the mean standard deviation. Yields could be increased from 371 kilograms/hectare (A minus B) to 978 kilograms/hectare (A minus D) with a mean increase of 658 kilograms/hectare (A minus C). This is enough of an increase to merit attempts to improve planting precision, although under some conditions as indicated by the Scandia results, improving planting precision may not increase yields.

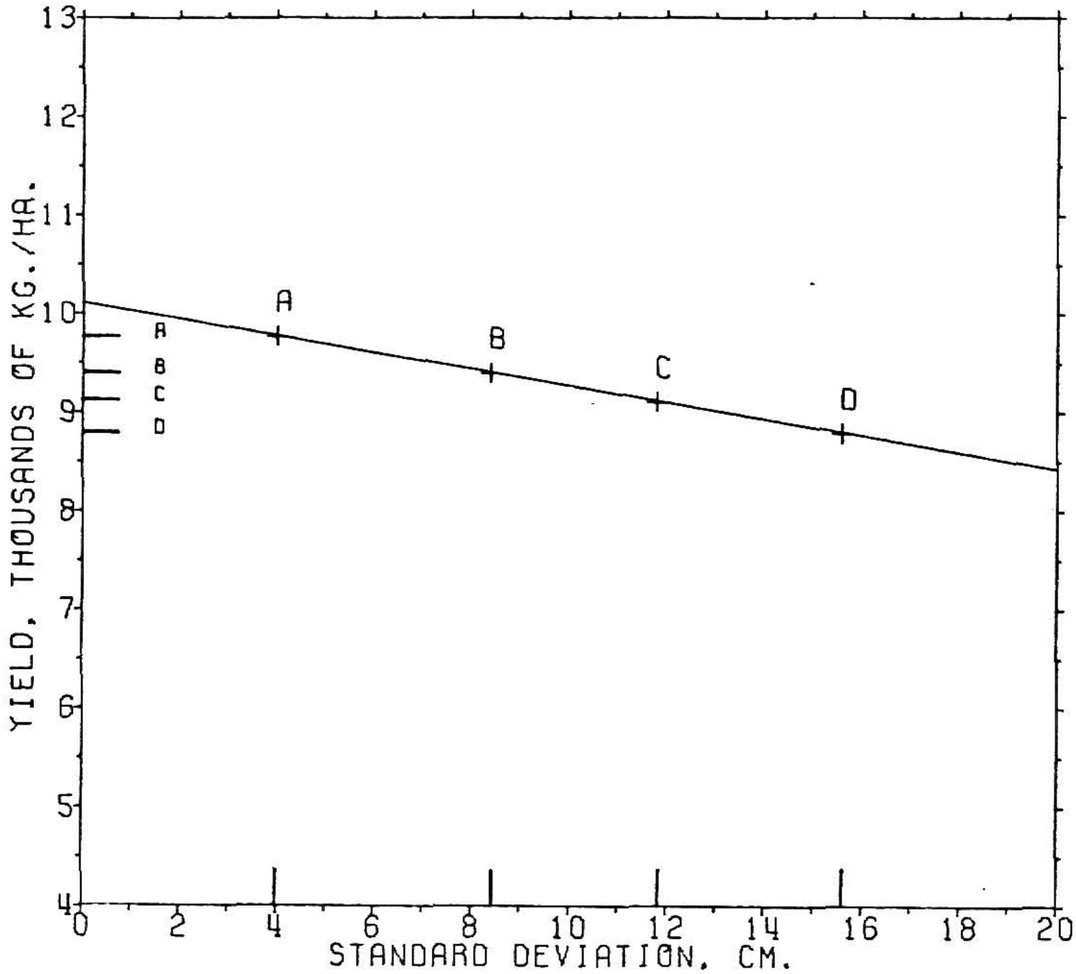


Figure 6. Combined regression of the St. John and Silver Lake experiments showing range and mean standard deviation of farms surveyed.

SUMMARY AND CONCLUSIONS

Corn grain yields can be increased substantially by using more precise planting methods. Four of the six experiments showed significant increases in yield as within-row variability decreased. The Scandia experiments produced an opposite response in both 1973 and 1974, with the 1973 results being significant.

No definite conclusions explaining the Scandia results can be drawn, however, it is known that plant population level and yield level were not factors, although lodging, hand planting technique, and the cool-wet spring could have had an effect in 1973. It is speculated that a curvilinear regression relationship between yield and standard deviation of spacing could exist. Also, it is thought that soil type could have been a factor. Further research is suggested, particularly at Scandia, to determine exactly under what conditions decreasing within-row variability does not increase yields.

A survey of farm fields indicates that yields could be increased by an average of 658 kilograms/hectare by using more precise planting methods. It is suggested that farmers increase precision by using well calibrated planters in good repair, preparing good seed beds, and driving at proper speeds. Equipment manufacturers should make an effort to further improve the precision of the corn planters they produce.

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LITERATURE CITED

1. Bryan, A. A., R. G. Eckhardt, and G. F. Sprague. 1940. Experiments with corn. J. Am. Soc. Agron. 32:707-715.

2. Collins, E. V. and C. K. Shedd. 1941. Results of row spacing experiments with corn. Agr. Eng. 22:177-178.

3. Colville, W. L. and D. P. McGill. 1962. Effect of rate and method of planting on several plant characters and yield of irrigated corn. Agron. J. 54:235-238.

4. Colville, W. L. and O. C. Burnside. 1963. Influence of method of planting and row spacing on weed control and yield of corn. Trans. Am. Soc. Agr. Eng. 6:223-225.

5. Dungan, G. H. 1946. Distribution of corn plants in the field. J. Am. Soc. Agron. 38:318-324.

6. Dungan, G. H., A. L. Lang, and J. W. Pendleton. 1958. Corn plant population in relation to soil productivity. Adv. in Agron. 10:436-471. Academic Press Inc., N. Y.

7. Erbach, D. C., D. E. Wilkins, and W. G. Lovely. 1972. Relationship between furrow opener, corn plant spacing, and yield. Agron. J. 64:702-704.

8. Esechie, H. A. 1973. Effect of variability in intra-row spacing on corn (Zea mays L.) yield. M.S. thesis, Kansas State University.

9. Fayemi, A. A. 1962. Effect of plant population and spacing on the yield of maize in the humid tropics. Empire J. Exp. Agr. 31:371-375.

10. Hoff, D. J. and J. H. Mederski. 1960. Effect of equidistant corn plant spacing on yield. Agron. J. 52:295-297.

11. Kiesselbach, T. A., A. Anderson, and W. E. Lyness. 1935. Cultural practices in corn production. Nebraska Agr. Expt. Sta. Bull. 293.

12. Kohnke, H. and S. R. Miles. 1951. Rates and pattern of seeding corn on high-fertility land. Agron. J. 43:488-493.

13. Morrow, G. E. and T. F. Hunt. 1891. Field experiments with corn. Illinois Agr. Expt. Sta. Bull. 4.

14. Pfister, L. T. 1942. Results of drilled corn experiment. Agr. Eng. 23:134.

15. Roberts, G. and E. T. Kinney. 1912. Corn production. Kentucky Agr. Expt. Sta. Bull. 163.

16. Rossman, E. C. and R. L. Cook. 1966. Soil preparation and date, rate, and pattern of planting. Advances in Corn production: Principles

and practices. 53-101. Iowa State Univ. Press.

17. Rounds, W. T., E. C. Rossman, W. Zurakowski, and E. E. Down. 1951. Rate, method, and date of planting. Michigan Agr. Expt. Sta. Quart. Bull. 33. No. 4.

18. Shubeck, F. E. and H. G. Young. 1970. Equidistant corn planting. Crops and Soils. 22(6):12-14.

19. Steel, R. D. G. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc. N. Y.

20. Williams, C. G. and F. A. Welton. 1915. Corn experiments. Ohio Agr. Expt. Sta. Bull. 282.

21. Woolley, D. G., N. P. Baracco, and W. A. Russell. 1962. Performance of four corn inbreds in single-cross hybrids as influenced by plant density and spacing patterns. Crop Sci. 2:441-444.

22. Yao, A. Y. M. and R. H. Shaw. 1964. Effect of plant population and planting pattern of corn on water use and yield. Agron. J. 56:147-151.

APPENDIX

Table 9. Linear regression analyses of yield versus coefficient of variability of spacing ($Y = A + BX$).

Location	Year	A	B	S_A	S_B	F	r
St. John	1973	10876	-1705	182	528	10.41**	-0.419
	1974	11629	-2392	278	791	9.14**	-0.351
Silver Lake	1973	9929	-2072	197	754	7.55**	-0.260
	1974	8882	-2045	254	802	6.51*	-0.254
St. John and Silver Lake Combined		10016	-1676	155	497	11.39**	-0.186
Scandia	1973	9128	610	139	358	2.90	0.112
	1974	8296	549	230	629	0.76	0.063

* Statistically significant at the 5% level
** Statistically significant at the 1% level

Table 10. Linear regression analyses of yield versus coefficient of variability of spacing at each population level at Scandia in 1973 and 1974 ($Y = A + BX$).

Population (pl/ha)	A	B	S_A	S_B	F	r
<u>1973:</u>						
51667	9038	1227	238	638	3.70	0.213
60278	9138	-94	229	620	0.02	-0.017
68889	9297	476	257	605	0.61	0.094
<u>1974:</u>						
47361	8477	-329	292	866	0.14	-0.047
55972	8198	1181	478	1345	0.77	0.110
64584	8128	927	476	1181	0.62	0.100

Table 11. Linear regression analyses of yield versus coefficient of variability of spacing excluding hand planted data at Scandia in 1973 and 1974.

Population (pl/ha)	A	B	S_A	S_B	F	r
<u>1973:</u>						
Total	9841	-572	149	421	1.84	-0.111
51667	9781	-36	343	777	0.002	-0.006
60278	9871	-1386	292	666	4.33*	-0.282
68889	10002	-580	370	731	0.63	-0.120
<u>1974:</u>						
Total	8033	1130	338	864	1.71	0.115
47361	8607	-415	419	1140	0.13	-0.055
55972	7590	2591	685	1855	1.95	0.213
64584	7288	2607	776	1781	2.14	0.228

* Statistically significant at the 5% level

INFLUENCE OF WITHIN-ROW VARIABILITY ON CORN, *ZEA MAYS* (L.), GRAIN YIELD

by

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Corn, Zea mays (L.), is an important feed grain crop in the United States. Development of hybrids, along with efficient use of fertilizers, herbicides, pesticides, and irrigation have contributed greatly to its success. In the same context plant population (density) and row spacing have been researched extensively to provide maximum yields. There are indications, however, that another factor, planting precision or within-row variability, may have an effect on yield.

The objective of this study was to see if yields could be increased by more precise planting, and, if so, how much yields can be increased and how precise the planting should be.

The experiment was conducted during the 1973 and 1974 growing seasons at three irrigated locations in Kansas: the Kansas River Valley Experiment Field at Silver Lake, Sandyland Irrigation Experiment Field at St. John, and the Irrigation Experiment Field at Scandia.

To determine the effect of within-row variability on corn grain yield, yields of 3-m sections of rows containing equal plant populations and equal row spacing but with different arrangements of the plants in the row were compared. These 3-m subplots were located in bulk machine and hand planted areas which provided a wide range of within-row variability. The distance between each plant in each subplot was measured. The standard deviation of spacing per subplot was calculated and used as an indicator of within-row variability of spacing. Linear regressions were calculated comparing yield and standard deviation for each location and year.

A farm field survey was conducted in Douglas, Shawnee, and Stafford counties to determine where the farmer stands in the spectrum of within-row variability. The survey was made by measuring the distance between plants in six to eight 3-m sections of row selected at random per field. The standard deviation of spacing was calculated for each of these 3-m sections of row using the spacing measurements.

The results indicate that yield could be increased substantially by using more precise planting methods. The Silver Lake and St. John experiments showed a significant increase in yield as within-row variability decreased or as planting precision increased. The Scandia results indicated an opposite trend with only the 1973 results being significant.

No definite conclusions explaining the Scandia results can be drawn, however, it is known that plant population level and yield level were not factors, although lodging, hand planting technique, and the cool-wet spring could have had an effect in 1973. It is speculated that a curvilinear regression relationship between yield and standard deviation of spacing could exist. Also, it is thought that soil type could have been a factor. Further research is suggested, particularly at Scandia, to determine under what conditions decreasing within-row variability does not increase yields.

Using a standard deviation of 4-cm as an arbitrary point of maximum precision obtainable by mechanical planting, the farm survey indicated that yields could be increased from 371 kilograms/hectare to 978 kilograms/hectare with a mean increase of 658 kilograms/hectare by using more precise planting methods. It is suggested that farmers increase precision by using well calibrated planters in good repair, preparing good seed beds, and driving at proper speeds. Equipment manufacturers should make an effort to further improve the precision of the corn planters they produce.