Assessing Spatial and Temporal Variability of Corn and Soybean Yields

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Research Question

Combine mounted yield monitors and associated software enable producers to map crop yields of their fields, making variations in yield across the landscape more evident and quantifiable. This will lead more producers to ask questions like "when do spatial yield differences become important?" and "should I change my production practices because of observed yield differences across the field?"

In this study, we determined the amount of spatial and temporal variability at three locations over a 10-yr period from long-term corn and soybean research plots with no apparent soil or topographical differences. Our hypothesis is that the yield differences observed from these plots should be small, especially relative to those observed with known soil and topographical differences, and that the magnitude of the yield differences observed may shed insight on when producers should consider changing production practices on portions of their fields to positively influence yields.

Literature Summary

Several researchers have suggested that caution must be used in interpreting yield results from any 1 yr, particularly when using yield information to modify chemical inputs. Long-term field experiments conducted on small plot areas have been used to assess the potential viability of site-specific management practices. When designing field research, care is usually taken to identify uniform areas with minimal soil and site variation.

Study Description

This study examined variations in corn and soybean yields from four continuous corn plots, four continuous soybean plots, and plots in a corn-soybean rotation over a 10-yr period from 1986 through 1995 at Lamberton and Waseca, MN, and Arlington, WI. Soils at each location were uniform with no visible topographical differences and were thought to have a uniform yield potential. At each location for continuous corn and continuous soybean, location average was the average yield of four plots each year, location range was the maximum minus minimum yield of the four plots each year, and location standard deviation was the standard deviation of the four plot yields each year. From 1986 through 1995 at each location, the 10-yr average was the average yield from each plot, the 10-yr range was the maximum minus minimum yield from each plot, and the 10-yr standard deviation was the standard deviation in yield from each plot. Location averages, ranges, and standard deviations were averaged over the 10-yr, and the 10-yr averages, ranges, and standard deviations were averaged across the four plots. The average location standard deviation and the average 10-yr standard deviation were measures of location and seasonal variability, respectively.

Applied Questions

How much yield variability could we expect across years at the same spot in a field, compared with variability among several areas located near one another on a uniform soil?

Yield variability among years was approximately three times greater for soybean and four times greater for corn than was variability among plots (Table 1). For continuous soybean yields, seasonal variability was 2.8, 2.2, and 3.6 times

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that of location variability at Lamberton, Waseca, and Arlington, respectively. For continuous corn yields, seasonal variability was 2.8, 4.3, and 4.0 times that of location variability at Lamberton, Waseca, and Arlington, respectively. Similar results were observed for corn and soybean grown in rotation (Table 1). Yields were generally lower than normal in 1988 because of hot, dry conditions and in 1993 because of cool, wet conditions.

In a relatively uniform field, what difference in yield in any one year or across several years would justify modifying future corn and soybean production?

At each location, each of the four continuous corn plots and each of the four continuous soybean plots produced the highest yield compared with the other three plots at least once during the 10 yr. Over the 10 yr, the range in corn and soybean yield among the plots (location range) expressed as a percentage of the location average was 15 to 20% (Table 1).

In any single year for both continuous corn and continuous soybean, a yield range among the four plots at each location of more than 25% of the four plot average occurred in one-fourth of the growing seasons studied. When averaged over 10 yr, however, the yield range among the four plots at each location was less than 10%, and in five of six cases actual yield differences between the four plots were not significantly different. These results demonstrate a relatively high amount of inherent yield variability, and suggest producers should not change management practices to influence yields when small yield differences occur (areas yielding 20 to 25% less than the field average), unless the differences are consistent over years.

In evaluating yield variability across a field, does it make a difference whether we use data from good production years or poor production years?

Yes. In these studies, the location range was large compared with the location average in seasons with poor growing conditions such as 1988 and 1993. Changing production practice in portions of a seemingly uniform field based only on yield differences after a poor growing season may lead to erroneous conclusions. These results underscore the necessity of in-season field observations to aid yield map interpretation, especially if relatively large yield variations occur during poor growing seasons.

Table 1. Corn and soybean yields, ranges, and standard deviations from four continuous corn and four continuous soybean plots at three locations from 1986 through 1995.

Crop / Location	Yield	Avg. across 10 yr: Location range	Avg. across 10 yr: Location std. dev.†	Avg. across four plots: 10-yr range	Avg. across four plots: 10-yr std. dev.†
	bu/acre				
Continuous corn					
Lamberton	115	23.2 (20%)‡	9.9	87	27.9
Waseca	130	20.7 (16%)	9.0	114	39.2
Arlington	135	21.5 (16%)	9.4	116	37.3
Corn in rotation with soybean					
Lamberton	130	19.4 (15%)	8.6	97	31.6
Waseca	142	21.4 (15%)	9.2	112	38.3
Arlington	151	22.7 (15%)	10.5	94	31.4
Continuous soybean					
Lamberton	35.0	6.0 (17%)	2.8	21.2	7.6
Waseca	36.7	7.1 (19%)	3.1	20.3	7.1
Arlington	52.3	8.4 (16%)	3.8	43.3	14.0
Soybean in rotation with corn					
Lamberton	40.7	8.0 (20%)	3.4	21.7	7.0
Waseca	40.6	6.2 (15%)	2.8	24.6	7.8
Arlington	52.9	7.6 (14%)	3.5	36.5	11.0

† The average location standard deviation (std. dev.) and the average 10-yr standard deviation were measures of location and seasonal variability.
‡ Location range expressed as a percentage of the yield.

Assessing Spatial and Temporal Variability of Corn and Soybean Yields

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With the increased presence in the Corn Belt of combine-mounted yield monitors generating yield maps, more producers are asking questions like "when do spatial yield differences become important?" and "should I change my production practices because of observed yield differences?" This study examined variations in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] yields over time. Yields were monitored from four continuous corn plots, four continuous soybean plots, and eight corn-soybean rotation plots over a 10-yr period from 1986 through 1995 at two Minnesota locations and one Wisconsin location. At each location, all plots were on a similar soil type in a uniform 2-acre field. Plot size was at least 450 sq ft. At each location, each of the four continuous corn plots and each of the four continuous soybean plots produced the highest yield compared with the other three plots at least once during the 10 yr. In any single year for both continuous corn and continuous soybean, a yield range among the four plots at each location of more than 25% occurred in one-fourth of the growing seasons studied. When averaged over 10 yr, however, the yield range among the four continuous corn plots and among the four continuous soybean plots at each location was less than 10%, and in five of six cases yield differences among the four plots were not significantly different. At each location, the yield range averaged at least 20 bu/acre for corn and 6 bu/acre for soybean. Yield variability among years was approximately three times greater for soybean and four times greater for corn than was variability among plots. Similar results were observed for the plots in the corn-soybean rotation. These results demonstrate a relatively high amount of inherent yield variability, and suggest producers should not change management practices to influence yields when small yield differences occur (areas yielding up to 20 to 25% less than the field average), unless the differences are shown to be consistent over years.

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Published in J. Prod. Agric. 11:359–363 (1998).

WITH THE ADVENT of affordable global positioning systems, combine-mounted yield monitors, and computer mapping programs, more producers are predicted to generate yield maps in order to better identify and understand the yield variability they observe across their fields. With a better understanding of how grain yield varies across the landscape will come a better understanding of why yield variability exists. Through proper interpretation of yield, soil fertility, and topographical maps it is assumed that yields will be increased and profits will be maximized through site-specific production practices such as cultivar selection and variable-rate applications of seed, fertilizer, and pesticide.

Factors controlling crop yields are often temporally and spatially dynamic. Variations in seasonal rainfall and temperature patterns can have major impact on crop yields from year to year. Likewise, soil properties and other factors such as topography along with weed, insect, and disease competition can have major impact on crop yields across fields. The interactions of climatic growing conditions, soil properties, and other factors can result in changes in the specific factor controlling yield from year to year and from location to location within a field.

Researchers have suggested that caution must be used in interpreting single-year yield results as a basis for modifying chemical inputs in subsequent years (Jaynes and Colvin, 1997; Lamb et al., 1997). When large yield differences are observed and the explanations for the yield differences are straightforward and consistent from year to year, then corrective measures to improve the low-yielding portions of the field should be considered. Yield differences that are neither large nor consistent from year to year present a challenge for producers, especially when there is no straightforward explanation for the observed yield differences.

Long-term experiments conducted on small plot areas have been used to assess the potential viability of site-specific management practices (Huggins and Alderfer, 1995). When designing field research, care is usually taken to identify uniform areas with minimal soil and site variation. In this study, we determined the amount of spatial and temporal variability at three locations over 10 yr from long-term research plots where continuous corn, continuous soybean, and rotated corn and soybean were grown. Our hypothesis is that the yield differences observed among replications of similar treatments in these experiments should be small, given no known topographical or soil type differences at each location.

MATERIALS AND METHODS

Three studies, originally designed to evaluate corn-soybean cropping sequences in the northern Corn Belt, were established in 1981 near Lamberton, MN, on a Webster clay loam (fine-loamy, mixed, mesic Typic Endoaquoll); in 1982 near Waseca, MN, on a Nicollet clay loam (fine-loamy, mixed, mesic Aquic Hapludoll); and in 1983 near Arlington, WI, on a Plano silt loam (fine-silty, mixed mesic Typic Argiudoll). Details of the soil types, soil fertility, and agronomic practices are described by Crookston et al. (1991), Meese et al. (1991), and Porter et al. (1997). Recommended practices for optimum production were followed. Tillage at Lamberton and Waseca involved fall moldboard plowing. At Arlington, the design included different tillage systems and N fertility levels. Only data from the fall moldboard-plowed tillage system, averaged across N fertility levels, are discussed in this paper.

At all three locations there were at least 14 treatments representing various corn and soybean cropping sequences arranged in a randomized complete block design. Data from continuous corn, continuous soybean, and the 2-yr corn-soybean rotation treatments are the only crop sequences discussed in this paper. Four plots produced continuous corn and four plots produced continuous soybean over the 10 yr reported. Four plots in the 2-yr corn-soybean rotation were planted to corn one year and soybean the following year, while four other plots were planted to soybean one year and corn the following year. The plots were in the same place year after year.

Corn was planted in 30-in. rows at all three locations. Soybean was planted in 7.5-in. rows at Arlington and 30-in. rows at Lamberton and Waseca. Corn and soybean were seeded at a rate of 24 000 to 30 000 and 160 000 to 180 000 viable seeds/acre, respectively. At Lamberton, the plots were 12 rows wide and 30 ft long; harvest was from 26 ft of the four center rows. At Waseca, plots were six rows wide and 60 ft long; harvest was from 50 ft of the two center rows. At Arlington, plots were 15 ft wide and 30 ft long; harvest was from the center two corn rows and six soybean rows. At all locations, all plots were located within 3400 ft of each other in an area less than two acres. Planting and harvest dates varied according to seasonal conditions at each location. In general, planting occurred between late April and late May, and harvest occurred between mid-September and late October. Plots were harvested with a plot combine. Grain yields were adjusted to 15.5% moisture for corn and 13.0% moisture for soybean.

For continuous corn and continuous soybean, an analysis of variance of grain yield for each crop at each location was conducted using yield data from the four plots over the 10 yr from 1986 through 1995 (SAS, 1988). Location average was the average yield of four plots at each location each year. Location range was the maximum minus minimum yield of the four plots each year. Location standard deviation was the standard deviation of the four plot yields each year. Ten-year average was the average yield from 1986 through 1995 of each plot. Ten-year range was the maximum minus minimum yield from 1986 through 1995 of each plot. Ten-year standard deviation was the standard deviation of yield from 1986 through 1995 for each plot. Coefficients of variation were calculated for plot yields each year and across the years for each plot. Location averages, ranges, standard deviations, and coefficients of variation were averaged over the 10 yr, and the 10-yr averages, ranges, standard deviations, and coefficients of variation were averaged across the four plots. The average location standard deviation and the average 10-yr standard deviation were measures of location and seasonal variability, respectively. For corn and soybean grown in annual rotation, the blocks from the original complete block design were used to group plots from alternating years, allowing an analysis of variance and the calculation of the corresponding ranges, standard deviations, and coefficients of variation. Yield data were not available for corn in 1991 and for soybean in 1991 and 1993 at Waseca.

RESULTS AND DISCUSSION

Over the 10 yr, "year" had a highly significant effect on both corn and soybean yields at each of the three locations (Table 1). Yields across the Northern Corn Belt were below normal in 1988 because of hot, dry conditions and in 1993 because of cool, wet conditions (Changnon, 1996; Minnesota Department of Natural Resources, 1989; Porter et al., 1997).

Over the 10 yr, the four continuous soybean plots at the three locations did not differ in soybean yield, and the four continuous corn plots at Lamberton and at Arlington did not differ in corn yields (Table 1). The plot effect over the 10 yr was significant only for continuous corn at Waseca, where the high yielding plot averaged 8.2% more (136 vs. 126 bu/acre) than the low yielding plots (Tables 1, 2). Over the 10 yr, the yields of rotated corn and soybean were not influenced by plot at any of the three locations (Table 1).

The fact that plot did not influence yields over the 10 yr (except for continuous corn at Waseca) was not surprising. The trials at each location were conducted on relatively uniform soils with little to no visible topographical differences and thought to have a uniform yield potential.

Table 1. Analysis of variance, yields, ranges, and standard deviations from four continuous corn, four continuous soybean, and eight corn-soybean rotation plots at Lamberton and Waseca, MN, and Arlington, WI, from 1986 through 1995.

Location	Plot effect	Year effect	Overall CV	Avg. yield	$LSD_{(0.05)}$ Plot	$LSD_{(0.05)}$ Year	Avg. across 10 yr: Location range	Avg. across 10 yr: Location std. dev.†	Avg. across 10 yr: Location CV	Avg. across four plots: 10-yr range	Avg. across four plots: 10-yr std. dev.†	Avg. across four plots: 10-yr CV
	Pr>F		%	bu/acre					%	bu/acre		%
Continuous corn												
Lamberton	0.73	<0.01***	9.7	115	NS	16	23.2	9.9	9.7	87	27.9	24.3
Waseca	0.05*	<0.01***	6.5	130	8	12	20.7	9.0	7.7	114	39.2	30.3
Arlington	0.57	<0.01***	7.8	135	NS	15	21.5	9.4	8.4	116	37.3	27.7
Corn in rotation with soybean												
Lamberton	0.08	<0.01***	7.2	130	NS	14	19.4	8.6	7.5	97	31.6	24.3
Waseca	0.95	<0.01***	7.6	142	NS	16	21.4	9.4	6.9	112	38.3	26.9
Arlington	0.75	<0.01***	8.0	151	NS	18	22.7	10.3	7.4	94	31.4	20.8
Continuous soybean												
Lamberton	0.93	<0.01***	8.9	35.0	NS	4.5	6.0	2.8	8.4	21.2	7.6	21.8
Waseca	0.55	<0.01***	9.5	36.7	NS	5.1	7.1	3.1	8.9	20.3	7.1	19.3
Arlington	0.42	<0.01***	8.2	52.3	NS	6.2	8.4	3.8	9.1	43.3	14.0	20.9
Soybean in rotation with corn												
Lamberton	0.14	<0.01***	9.9	40.7	NS	5.8	8.0	3.4	8.9	21.7	7.0	17.3
Waseca	0.11	<0.01***	7.3	40.6	NS	4.4	6.2	2.8	7.5	24.6	7.8	19.3
Arlington	0.23	<0.01***	6.7	52.9	NS	5.2	7.6	3.5	6.8	36.5	11.0	20.9

*, *** Significant at the 0.05 and 0.001 probability levels, respectively. NS = Not significant at 0.05.

† The average location standard deviation (std. dev.) and the average 10-yr standard deviation were measures of location and seasonal variability.

Continuous Corn Yield Variability

At all three locations, each of the four plots produced the greatest corn yield (compared with the other three plots) at least one season during the 10 yr (Table 2). Likewise, at both Lamberton and Arlington, each of the four plots produced the lowest corn yield (compared with the other three plots) at least one season during the 10 yr. Only plot no. 3 at Waseca failed to have the lowest corn yield in any one season.

Over the 10 yr, the range in corn yield among the four plots (location range) expressed as a percentage of the location average each year averaged 20, 16, and 16% at Lamberton, Waseca, and Arlington, respectively (Table 2). Among years, the range in corn yield expressed as a percentage of the location average was as low as 4% at Lamberton in 1989 and as high as 72% at Arlington in 1988. The range in corn yield expressed as a percentage of the location average was greater than 10% in 22 of the 29 growing seasons, and greater than 25% in seven of the 29 grow-

Table 2. Continuous corn yields from 1986 through 1995 at four plots in locations near Lamberton and Waseca, MN, and Arlington, WI.

Plot	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	10-yr avg.	10-yr range	10-yr std. dev.	10-yr CV	Avg. across years
	bu/acre													%	bu/acre
Lamberton															
1	138	120	63	141	125	117	127	63	110	125	113	78	27.8	24.7	
2	155	129	91	146	137	112	138	43	98	116	117	112	33.0	28.3	
3	139	128	104	144	140	112	101	69	108	127	117	75	23.2	19.8	
4	128	134	78	141	134	102	121	57	129	105	113	85	27.5	24.3	
Location avg.	140	128	84	143	134	111	122	58	111	118					115
Loc. range	27†	14†	41‡	6	15†	16†	36‡	26‡	31‡	22†					23.2†
Loc. std. dev.	11.2	5.9	17.4	2.6	6.3	6.6	15.2	11.0	12.8	9.9					9.9
Loc. CV (%)	8.0	4.6	20.7	1.8	4.7	5.9	12.5	19.0	11.5	8.4					9.7
								Avg. across plots:			115	87	27.9	24.3	
Waseca															
1	122	181	75	169	147	--	158	54	144	117	130	126	42.4	32.7	
2	113	159	60	168	136	--	147	63	156	131	126	108	40.2	31.9	
3	122	181	84	184	150	--	149	68	159	131	136	116	39.9	29.3	
4	124	177	73	153	146	--	133	74	134	122	126	104	34.4	27.2	
Location avg.	120	174	73	169	145	--	147	65	148	125					130
Loc. range	11	22†	24‡	31†	14	--	25†	19‡	25†	14†					20.7†
Loc. std. dev.	4.9	10.3	10.0	12.7	6.1	--	10.4	8.3	11.7	7.0					9.0
Loc. CV (%)	4.1	5.9	13.7	7.5	4.2	--	7.1	12.9	7.9	5.6					7.7
								Avg. across plots:			130	114	39.2	30.3	
Arlington															
1	165	190	89	148	151	144	144	90	142	125	139	101	31.0	22.3	
2	180	161	63	141	158	135	156	81	165	113	135	117	38.3	28.3	
3	169	157	55	148	143	132	138	86	167	126	132	114	36.1	27.3	
4	176	159	44	154	152	133	151	71	174	119	133	132	43.8	32.9	
Location avg.	173	167	63	148	151	136	147	82	162	121					135
Loc. range	15	33†	45‡	13	15	12	18†	19†	32†	13†					21.5†
Loc. std. dev.	6.8	15.6	19.2	5.3	6.2	5.5	7.9	8.2	13.9	6.0					9.4
Loc. CV (%)	3.9	9.3	30.5	3.6	4.1	4.0	5.4	10.0	8.6	5.0					8.4
								Avg. across plots:			135	116	37.3	27.7	

†,‡ Range in corn yield exceeded 10 and 25% of the location average, respectively.

Table 3. Continuous soybean yields from 1986 through 1995 at four plots in locations near Lamberton and Waseca, MN, and Arlington, WI.

Plot	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	10-yr avg.	10-yr range	10-yr std. dev.	10-yr CV	Avg. across years
	bu/acre													%	bu/acre
Lamberton															
1	35.9	44.6	26.3	30.2	41.2	44.1	25.2	33.1	33.1	38.8	35.3	19.4	6.9	19.6	
2	34.6	42.3	24.4	26.1	40.6	40.8	24.7	26.0	41.9	43.8	34.5	19.4	8.3	24.0	
3	38.8	38.9	28.5	26.2	38.6	46.9	20.4	28.4	42.8	40.9	35.0	26.5	8.5	24.4	
4	40.3	39.9	32.1	28.5	40.3	45.8	27.1	26.0	33.1	40.4	35.4	19.8	6.8	19.3	
Location avg.	37.4	41.4	27.8	27.8	40.2	44.4	24.4	28.4	37.7	41.0					35.0
Loc. range	5.7†	5.7†	7.7‡	4.1†	2.6	6.1†	6.8‡	7.1‡	9.7‡	4.9†					6.0†
Loc. std. dev.	2.6	2.6	3.3	2.0	1.1	2.6	2.9	3.3	5.4	2.1					2.8
Loc. CV (%)	7.0	6.2	11.9	7.1	2.8	6.0	11.7	11.8	14.2	5.0					8.4
								Avg. across plots:			35.0	21.2	7.6	21.8	
Waseca															
1	32.8	40.3	23.0	37.2	43.8	--	30.8	--	43.9	42.7	36.8	20.9	7.5	20.3	
2	33.1	41.4	26.3	36.7	46.8	--	28.8	--	45.4	41.5	37.5	20.5	7.6	20.2	
3	34.1	45.8	27.0	37.2	44.9	--	25.6	--	42.4	40.4	37.2	20.2	7.7	20.8	
4	37.3	42.9	34.1	35.1	35.2	--	23.3	--	35.3	38.1	35.2	19.6	5.5	15.8	
Location avg.	34.3	42.6	27.6	36.6	42.7	--	27.1	--	41.8	40.7					36.7
Loc. range	4.5†	5.5†	11.1‡	2.1	11.6	--	7.5‡	--	10.1†	4.6†					7.1†
Loc. std. dev.	2.1	2.4	4.7	1.0	5.1	--	3.3	--	4.5	2.0					3.1
Loc. CV (%)	6.0	5.6	16.9	2.7	12.0	--	12.3	--	10.7	4.8					8.9
								Avg. across plots:			36.7	20.3	7.1	19.3	
Arlington															
1	49.0	59.0	12.0	65.0	67.0	66.0	44.0	38.0	45.0	59.0	50.4	55.0	16.9	33.6	
2	47.0	64.0	21.0	63.0	53.0	66.0	43.0	48.0	46.0	67.0	51.8	46.0	14.2	27.3	
3	54.0	66.0	30.0	59.0	62.0	66.0	46.0	45.0	43.0	64.0	53.5	36.0	12.2	22.6	
4	56.0	66.0	31.0	61.0	63.0	67.0	39.0	46.0	43.0	61.0	53.3	36.0	12.6	23.7	
Location avg.	51.5	63.8	23.5	62.0	61.3	66.3	43.0	44.3	44.3	62.8					52.3
Loc. range	9.0†	7.0†	19.0‡	6.0	14.0†	1.0	7.0†	10.0†	3.0	8.0†					8.4†
Loc. std. dev.	4.2	3.3	8.9	2.6	5.9	0.5	2.9	4.3	1.5	3.5					3.8
Loc. CV (%)	8.2	5.2	37.8	4.2	9.6	0.8	6.8	9.8	3.4	5.6					9.1
								Avg. across plots:			52.3	43.3	14.0	20.9	

†,‡ Range in soybean yield exceeded 10 and 25% of the location average, respectively.

ing seasons. The location range was large compared with the location average in seasons with poor growing conditions. At Lamberton and Arlington, the location standard deviation was greatest in 1988, when yields were depressed due to hot, dry growing conditions. In 1993, a year with poor growing conditions for corn due to cool, wet conditions, location standard deviation was also relatively large. The range in corn yield for each of the four plots across the 10 yr (10-yr range) expressed as a percentage of the 10-yr average was greater than 60% for all plots at all three locations.

At Lamberton, seasonal variability (average 10-yr standard deviation) in corn yield was 2.8 times that of location variability (average location standard deviation) (27.9 vs. 9.9 bu/acre). At Waseca, seasonal variability was 4.3 times that of location variability (39.2 vs. 9.0 bu/acre). At Arlington, seasonal variability was 4.0 times that of location variability (37.3 vs 9.4 bu/acre).

Continuous Soybean Yield Variability

At each of the three locations, each plot produced the greatest soybean yield (compared with the other three plots) at least one season during the 10 yr (Table 3). Likewise, at Lamberton and Arlington, each plot produced the lowest soybean yield (compared with the other three plots) at least one season during the 10 yr. Plots no. 2 and 3 at Waseca failed to have the lowest soybean yields in any one season.

Over the 10 yr, the range in soybean yield among the four plots (location range) expressed as a percentage of the location average each year averaged 17, 19, and 16% at Lamberton, Waseca, and Arlington, respectively (Table 3). The range in soybean yield expressed as a percentage of the location average was as low as 2% at Arlington in 1991 and as high as 81% at Arlington in 1988. The range in soybean yield expressed as a percentage of the location average was greater than 10% in 23 of the 28 growing seasons, and greater than 25% in eight of the 28 growing seasons studied, respectively. As with corn, the location range was large compared with the location average in 1988, when yields were depressed due to hot, dry growing conditions. The range in soybean yield for each of the four plots across the 10 yr (10-yr range) expressed as a percentage of the 10-yr average was greater than 50% for all plots at all three locations.

At Lamberton, seasonal variability in soybean yield was 2.8 times that of location variability (7.6 vs. 2.8 bu/acre). At Waseca, seasonal variability was 2.2 times that of location variability (7.1 vs. 3.1 bu/acre). At Arlington, seasonal variability was 3.6 times that of location variability (14.0 vs. 3.8 bu/acre).

Corn-Soybean Yield Variability

Yield variability among years and yield variability among plots were not influenced by whether corn and soybean were grown continuously or in annual rotation. The magnitude of the ranges and standard deviations obtained for both corn and soybean grown in a corn-soybean rotation were similar to those obtained for continuous corn and continuous soybean (Table 1), indicating that the corn and soybean yield variability reported previously are not relics of the continuous planting of each crop (plot yields for corn-soybean rotation not presented). Seasonal variability in rotated-corn yield was 3.7, 4.1, and 3.1 times that of location variability at Lamberton, Waseca, and Arlington, respectively. Seasonal variability in rotated-soybean yield was 2.1, 2.8, and 3.1 times that of location variability at Lamberton, Waseca, and Arlington, respectively (Table 1).

Implications for Interpreting Yield Variability

Year-to-year yield variability was approximately three times greater for soybean and four times greater for corn than plot-to-plot yield variability at the three locations studied. The 10-yr time frame this study encompassed included two relatively harsh growing seasons (1988 was hot and dry, and 1993 was cool and wet). These growing seasons should not be considered anomalies, as harsh climatic conditions resulting in poor crop production occur regularly (U.S. Geological Survey, 1991).

During the 10 yr, the plot effect on continuous soybean yield and corn and soybean yields grown in rotation was not significant at any of the three locations, and the plot effect on continuous corn yield was significant only at Waseca (Table 1). The range between the maximum and minimum corn yield of the four plots at Waseca was 8.2% when averaged over the 10 yr. Yet, for both corn and soybean, the range in yield among the four plots exceeded 10% of the average yield in approximately two-thirds of the growing seasons and 25% of the average yield in approximately one-fourth of the growing seasons. Basing yield predictions on individual year data would result in quite different and potentially erroneous conclusions than if yield predictions were based on longer-term (10 yr) averages.

Our results demonstrate a high amount of inherent spatial yield variability, at least relative to what many producers (and researchers) may have expected. This amount of spatial yield variability would not have been surprising had there been different soil types or elevations involved. Possible reasons for this amount of variability include variations in diseases, pests, and microclimates, as well as human error. The objective of this study was not to document the reasons for the variability, but to assess the magnitude of the variability. At all three locations studied, spatial yield variability was larger than we expected, however, relative variability as measured by coefficients of variation are not unreasonably large. It would be of interest to see if data from other long-term trials involving these crops show similar results. If our results, which were derived from small plots, can be extrapolated to on-farm conditions, they suggest producers should not change management practices to influence yields when small yield differences occur (areas yielding 20 to 25% less than the field average), unless the differences are consistent over years.

These results establish the importance of taking great care when interpreting yield maps. Emphasizing yield map variability observed in relatively uniform fields during poor growing seasons (when the location range was very large compared with the location average) can lead to erroneous conclusions. These results underscore the necessity of in-season field observations to aid yield map interpretation, especially when relatively large yield variations occur during poor growing seasons.

ACKNOWLEDGMENTS

The authors would like to acknowledge and thank the numerous faculty and staff who have been instrumental in conducting the long-term rotation trials at Lamberton, Waseca, and Arlington.

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