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Wheat Production Systems For Southwestern North Dakota

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Abstract

The wheat-black fallow rotation has been used extensively as a production strategy for spring wheat in western North Dakota and throughout the Great Plains. Economic inefficiency and other problems associated with this rotation suggest that alternatives are needed. The objectives of this research are to determine (1) how cultivar selection, seeding rate adjustments, and tillage practices affect wheat yield and kernel crude protein (CP) concentraion in a wheat-fallow sequence, and (2) compare wheat yield and kernel quality in wheat-black fallow, wheat-corn, and wheat-wheat sequences. To do this, an experiment was begun in 1995 in which five wheat cultivars were seeded at 500 000, 1 000 000, and 1 500 000 pure live seed (PLS)/acre in conventional- (<5% wheat stubble after planting), reduced- (30-50% wheat stubble after planting), and no-tillage seedbeds following the fallow period in a wheat-fallow sequence. Wheat yield was affected by cultivar selection and seeding rate, but not by tillage, at the $P < 0.05$ level of significance. A seeding rate x cultivar interaction existed for yield in 1996, but not in 1995 or 1997. Tillage x seeding rate and tillage x cultivar interactions did not exist for yield. Cultivar selection affected kernel CP concentration, but seeding rate and tillage generally did not. In a separate experiment, five semidwarf and five conventional height wheat cultivars were seeded in wheat-corn, wheat-black fallow, and wheat-wheat rotations. Wheat yield did not vary across rotations in 1994 or 1995, but tended to be more following black fallow than either corn or wheat in 1996 and 1997. However, the CP concentration of wheat grain was higher following corn than black fallow. Results of these two experiments indicate that wheat yield and quality can be maintained in alternatives to the wheat-black fallow rotation.

Introduction

The wheat-black fallow rotation has been used extensively as a production strategy for spring wheat in western North Dakota and throughout the Great Plains. There are several benefits that the black fallow period provides: organic nitrogen can be mineralized, weeds can be controlled mechanically, soil water recharge can occur, and crop loss risk can be minimized (Smika, 1970). Along with these benefits have come costs, including the formation of saline seeps, uncontrolled wind and water erosion, and reduced soil nutrient levels over time (Haas et al., 1957; Halvorson and Black, 1974). Moreover, the idling of productive land in a wheat-black fallow rotation has raised economic efficiency questions (Ali and Johnson, 1981), particularly when the Freedom to Farm Act is considered. Alternatives to the wheat-black fallow rotation must be developed for the long-term viability of wheat production in North Dakota.

The objectives of this project are to:

1. Identify how cultivar selection and seeding rate adjustments affect spring wheat performance across a wheat-fallow rotation in conventional-, reduced-, and no-tillage environments.
2. Determine the agronomic performance of several spring wheat cultivars across wheat-black fallow, wheat-wheat, and wheat-corn rotations.

Objective 1

Most hard red spring wheat is sown after fallow in the Southwest Crop Reporting District (Anonymous, 1997). Several cultivars are sown each year, depending on seed costs, seed availability, and other factors. The cultivars vary in agronomic performance, depending on the environmental factors present during their growth and development. Changes in tillage alter the environment in which crop plants grow, and a cultivar x tillage interaction has been demonstrated when wheat has been rotated with other crops (Ciha, 1982). A cultivar x tillage interaction has not been considered in a wheat-fallow rotation, even though knowledge of this interaction would aid producers in selecting cultivars best suited to their fallow management strategies. It also is unknown if seeding rates should be adjusted according to the cultivar and tillage system used. Knowledge about cultivar x tillage and cultivar x tillage x seeding rate interactions might result in more efficient spring wheat production in reduced- and no-tillage environments.

Objective 2

Spring wheat cultivars respond differently in contrasting environments. It is unclear how wheat grain yield and quality, and other phenotypic characteristics, are influenced by cropping sequence. North Dakota producers need this information as they explore alternatives to black fallow in a wheat-black fallow rotation. Understanding the cultivar x crop rotation interaction is needed to explain why crop yields vary in regions of the state where rotations differ.

Materials and Methods

Objective 1

A field experiment was conducted under dryland conditions at Dickinson in 1995, 1996, and 1997. Plots were arranged in a randomized complete block design in a split split-plot arrangement. Tillage system comprised main plots, seeding rate comprised subplots, and spring wheat cultivar comprised sub-subplots. Tillage systems included: (1) conventional-tillage (spring disking and leveling with a cultivator and culti-harrow until less than 5% of residue remains at the soil surface at planting); (2) reduced-tillage (leveling with a cultivator in an attempt to maintain between 30% to 50% of residue at planting); and (3) no-tillage (direct sowing into standing stubble). Subplots consisted of seeding rates of 500 000, 1 000 000, and 1 500 000 PLS per acre. Sub-subplots consisted of 2 conventional height (AC Minto, Amidon) and 3 semidwarf (Bergen, Grandin, Norm) hard red spring wheat cultivars representing a range of genotypes and phenotypes presently grown in the northern Great Plains Region.

Both phases of each tillage system (crop and fallow) were established and will be maintained throughout the trial's duration. As a result, 50% of the space allocated for plots were not planted in any year (i.e., fallow plots); weeds in these plots were either mechanically controlled (conventional-tillage), controlled both mechanically and with herbicides (reduced-tillage), or controlled solely using herbicides (no-tillage).

Main plots were 4500 square feet (90 by 50 ft). There were 6 main plots per replicate and four replicates in the experiment. Sub-subplot dimensions were 50 by 6 ft.

Plant nutrients were supplied as needed for a grain yield goal of 60 bu per acre, based on soil test results.

Postemergent herbicides were used during the crop phase in all tillage systems to control weeds. In the fallow plots, mechanical cultivation was used to control weeds in the conventional-tillage system. Two herbicide applications and a light cultivation were used in the reduced-tillage system. Non-incorporated herbicides were used in the no-tillage system.

Variables measured on each cropped plot included: number of plants at emergence, plant height, grain yield, 100 kernel weight, grain volume weight, and kernel CP concentration. Number of tillers at the six-leaf stage were counted, as were the number of heads that had developed on wheat plants at physiological maturity. Only wheat plant stand, grain yield, and kernel CP concentration have been analyzed and are reported.

Data were analysed using a computer-driven statistical program.

Objective 2

The experiment was arranged in a randomized complete block design in a split-plot arrangement. Cropping sequence comprised main plots and consisted of wheat-black fallow, wheat-wheat, and wheat-corn rotations. Five conventional-height hard red spring wheat cultivars (AC Minto, Amidon, Butte 86, Sharp, Stoa) and five semidwarf cultivars (2371, Bergen, Grandin, Hi Line, Norm) comprised subplots treatments.

Both phases of wheat-black fallow and wheat-corn rotations were established and maintained throughout the trial's duration, which ended in 1997. Hence, two main plots were maintained each year for both rotations. By having both phases represented each year, wheat grain yield and quality data were generated annually by each rotation. These data were compared with that produced by the wheat-wheat rotation each year the experiment was conducted.

Main plots were 1680 square feet. There were five main plots per replicate (two each for both wheat-black fallow and wheat-corn rotations and one for the wheat-wheat rotation). There were four replicates. Subplot dimensions were 6 by 28 ft.

Variables measured on each plot included: plant height, grain yield, 100 kernel weight, and kernel CP concentration.

The data were analyzed using a computer-driven statistical program.

Results and Discussion

Objective 1

Wheat plant stand generally was not affected by tillage at the $P < 0.05$ level of significance (Table 1). An exception occurred in 1996, when fewer plants occurred in conventional-tillage than in reduced- or no-tillage plots. These data contradict our assumption that successfully establishing a crop stand would be more challenging in no-tillage than other environments because crop residue would interfere with the seeding operation. It seems that crop stand establishment may be more successful in reduced- and no-tillage than conventional-tillage systems in some years, presumably because forgoing tillage enhances seedbed firmness and reduces evaporation.

Seeding rate adjustments and wheat cultivar selection affected plant stand numbers (Table 1). A seeding rate x wheat cultivar interaction existed in 1995 and 1997, but not in 1996. More plants resulted as the seeding rate increased for each cultivar, but the magnitude of change in plant numbers associated with seeding rate adjustments varied, depending on the cultivar (data not provided).

Grain yield was not affected by tillage in any year (Table 1). Seeding rate adjustments did affect grain yield in 1995 and 1996, but not in 1997. More grain was produced as the seeding rate was increased from 500 000 PLS/acre to 1 000 000 PLS/acre in both years. Grain yield was not affected by increasing the seeding rate from 1 000 000 PLS/acre to 1 500 000 PLS/acre. A tillage x seeding rate interaction did not exist in any year, suggesting that seeding rate adjustments are not needed as tillage practices change, under conditions similar to those encountered in this experiment.

Wheat cultivars varied in grain yield in all three years (Table 1). The cultivar Bergen produced comparable or greater amounts of grain than other cultivars in 1995 and 1996, whereas Amidon produced the most grain among cultivars in 1997. A tillage x wheat cultivar interaction did not exist in any year. A seeding rate x wheat cultivar interaction did not occur in 1995 or 1997, but did in 1996. In 1996, grain yield of Bergen increased from 46 bu/acre to 54 bu/acre as the seeding rate was increased from 500 000 to 1 000 000 PLS/acre (Fig 1). A similar response in magnitude for grain yield to the same seeding rate adjustment did not occur for other wheat cultivars.

Tillage and seeding rate adjustments generally failed to affect the CP concentration of grain (Table 1). An exception occurred in 1997, when the grain CP concentration in no-tillage plots was less than that in reduced- or conventional-tillage plots. These data suggest that the

CP concentration of grain may be less in no-tillage than reduced- or conventional-tillage plots unless N fertilizer recommendations, based on soil test results, are adjusted for no-tillage environments. Bauder (1987) indicated that fertilizer rates must be increased as tillage is reduced because microbes compete with plants for nitrogen until a new equilibrium develops between the microbial population and the supply and location of crop residue.

Wheat cultivar selection influenced grain CP concentration (Table 1). The grain CP concentration of AC Minto was comparable or greater than that of the other four wheat cultivars. Tillage x wheat cultivar, seeding rate x wheat cultivar, and tillage x seeding rate x wheat cultivar interactions did not exist for grain CP concentration in any year.

Objective 2

Plant height was influenced by cultivar selection (Table 2), as expected. Plant height varied from 25 in. for the semidwarf cultivar Bergen to 34 in. for conventional-height cultivar AC Minto. Year x crop rotation and year x wheat cultivar interactions existed, indicating that factors besides cultivar selection affect wheat plant height.

A year x crop rotation interaction existed for grain yield (Table 2). Comparable amounts of wheat grain was produced following wheat, corn, or fallow in 1994 and 1995 (Fig 2), when growing season precipitation favored wheat plant development. There was a trend for grain yield to be more following fallow than either wheat or corn in 1996 and 1997, when dry conditions developed during critical stages in wheat plant development.

Grain yield varied among wheat cultivars, and year x wheat cultivar and year x crop rotation x wheat cultivar interactions existed (Table 2). For example, the cultivar Grandin tended to produce more grain following corn than fallow in 1994, whereas yield of the cultivar Amidon was similar after corn or fallow (Fig 3). In 1995, grain yield did not differ after corn or fallow for either cultivar (Fig 4). These data indicate that crop rotation x wheat cultivar interactions exist in some years but not others, under environmental conditions similar to those encountered in this experiment.

Crop rotation did not affect kernel weight but did influence kernel CP concentration (Table 2). Crude protein concentration of wheat grain was highest when wheat followed corn in a rotation, and lowest when wheat followed wheat. A year x crop rotation interaction existed, indicating that environment also affects kernel CP concentration.

Cultivar selection affected kernel weight, as well as kernel CP concentration (Table 2). Heaviest kernels were produced by the cultivars Bergen, Butte 86, Grandin, and Norm (data not provided). The cultivars AC Minto and 2371 produced kernels with the highest CP concentration. A year x wheat cultivar interaction existed for both kernel weight and CP concentration, indicating that environment influences the relative ranking of wheat cultivars for grain quality parameters.

Conclusion/Implication of Research

Objective 1

Reducing tillage can enhance plant stand establishment in wheat in some years, under conditions similar to those encountered in this investigation. A research planter equipped with Acra Planter units (Acra Planter, Inc., Garden City, KS) was used to seed all plots in this experiment. This planter was developed for seeding in a no-tillage seedbed and was similar in performance to the John Deere 750 seeder in low-residue and high-residue environments. These data indicate that crop residue in no-tillage environments does not interfere with successful planting operations when seeding equipment suited to no-tillage environments is used.

Wheat yield was not reduced in no-tillage compared to conventional-tillage environments in any year. These results contradict those of an experiment conducted at Dickinson between 1976 and 1990 where wheat yield was less in a reduced-tillage compared with a conventional-tillage environment (Vasey, 1993). It is unclear why a discrepancy in the data between the two studies exists, but we speculate that the planting equipment used in the earlier study was less suited to seeding wheat in reduced-tillage environments than the planting equipment used in the current experiment.

Kernel CP concentration was not affected by tillage in 1995 and 1996, but was in 1997. These data indicate that the CP concentration of wheat grain may be less during the transition from conventional- to no-tillage environments, unless adjustments to soil test recommendations are made for the elimination of tillage. Data will be collected in 1998 to determine if kernel CP concentration is again reduced in environments as less tillage is performed, as was the case in 1997. If so, then more N fertilizer might need to be applied than is recommended, based on soil test results, in systems where tillage is reduced.

This experiment will continue in 1998, and perhaps beyond, to determine how wheat plant development, grain yield, and kernel quality is affected by tillage, seeding rate adjustments, and wheat cultivar selection.

Objective 2

There was no benefit in wheat yield from fallowing when precipitation patterns favored wheat plant development. When dry conditions developed, wheat yield following corn was at least 80% of fallow, and 68% following wheat. These data suggest that higher wheat yields can be produced after corn and wheat, compared to fallow, than those suggested in an earlier experiment (Vasey, 1993). Grain yield of wheat after corn averaged only 76% of wheat yield after fallow, and only 56% after wheat, in an experiment conducted at Dickinson between 1983 and 1990. We suggest that cultivar selection, environmental differences, and an unconventional experimental design used in the first experiment explain why there are discrepancies in wheat yield data between the two studies.

Wheat cultivars differ in their response to contrasting rotations, in terms of grain yield and quality. This suggests that crop rotation should be considered when making wheat cultivar recommendations. Wheat cultivar recommendations based on results in a wheat-fallow rotation may not be appropriate for wheat in other rotations. If this is the case, then wheat cultivar recommendations may be less reliable if current trends in replacing wheat-fallow with other rotations involving wheat continue among producers, while wheat cultivar recommendations generally continue to be based on experiments located in fallowed environments.

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Table 1. Analysis of variance of contrasting seeding rates and hard red spring cultivars across conventional-, reduced-, and no-tillage environments in a wheat-fallow rotation experiment located at Dickinson, ND, during 1995, 1996, and 1997.

	Plant stand			Grain					
				Yield			Crude protein		
	1995	1996	1997	1995	1996	1997	1995	1996	1997
Tillage system (T)	1000 plants/acre			bu/acre			%		
Conventional tillage	597	723	750	41	46	33	14.5	15.2	15.2
Reduced tillage	644	808	792	42	44	36	14.3	15.2	15.4

No-tillage	682	800	672	37	51	31	14.1	14.8	14.6
Seeding rate (SR)									
500 000 kernels/acre	340	398	390	37	46	32	14.4	15.0	15.0
1 000 000 kernels/acre	661	804	773	41	48	35	14.3	15.1	15.0
1 500 000 kernels/acre	922	1 130	1 050	42	48	34	14.3	15.2	15.2
Wheat cultivar (WC)									
AC Minto	734	788	654	33	42	29	15.1	15.7	15.9
Amidon	648	777	775	42	46	37	14.1	15.1	14.9
Bergen	671	849	815	44	52	34	13.9	14.4	14.6
Grandin	489	739	674	39	47	32	14.5	15.7	15.3
Norm	664	731	773	41	50	34	14.1	14.5	14.6
	Analysis of variance								
T	NS[1]	*	NS	NS	NS	NS	NS	NS	*
SR	*	*	*	*	*	NS	NS	NS	NS
T x SR	NS	NS	NS	NS	NS	NS	NS	NS	NS
WC	*	*	*	*	*	*	*	*	*
T x WC	NS	NS	NS	NS	NS	NS	NS	NS	NS
SR x WC	*	NS	*	NS	*	NS	NS	NS	NS
T x SR x WC	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]NS = not significant at the *P* < 0.05 level; * = significant at the *P* < 0.05 level.

Table 2. Plant height, grain yield, weight and Crude Protein concentration for five semidwarf and five conventional-height hard red spring wheat cultivars across wheat-corn, wheat-black fallow, and wheat-wheat rotations during 1994-1997.

Crop rotation (CR)	Height	Grain		
		Yield	Weight	Crude protein
	inches	bu/acre	- g/100 kernel -	%
Wheat-Corn	29	46	3.2	15.7
Wheat-Fallow	30	49	3.2	15.5
Wheat-Wheat	29	44	3.1	15.2
Wheat cultivar (WC)				
AC Minto	34	42	3.1	16.1
Amidon	32	50	3.1	15.3
Bergen	25	51	3.3	14.8
Butte 86	29	46	3.3	15.5
Grandin	28	47	3.3	15.7
HiLine	26	44	3.0	15.1
Norm	26	48	3.3	15.0
2371	33	44	3.0	16.3
Sharp	29	45	3.2	15.3
Stoa	31	45	2.9	15.3

	Analysis of variance			
CR	NS[1]	NS	NS	*
Year (Y) x CR	*	*	NS	*
WC	*	*	*	*
CR x WC	NS	NS	NS	NS
Y x WC	*	*	*	*
Y x CR x WC	NS	*	NS	NS
[1]NS = Not significant at the *P* <0.05 level; * = significant at the *P* < 0.05 level.				

Figure 1. Grain yield of five hard red spring wheat cultivars at three seeding rates across conventional-, reduced-, and no-tillage environments in 1996 at Dickinson, North Dakota. Differences in yield were detected between the 500 000 and 1 000 000 PLS/acre seeding rates for the cultivar Bergen at the *P* <0.05 level of significance.

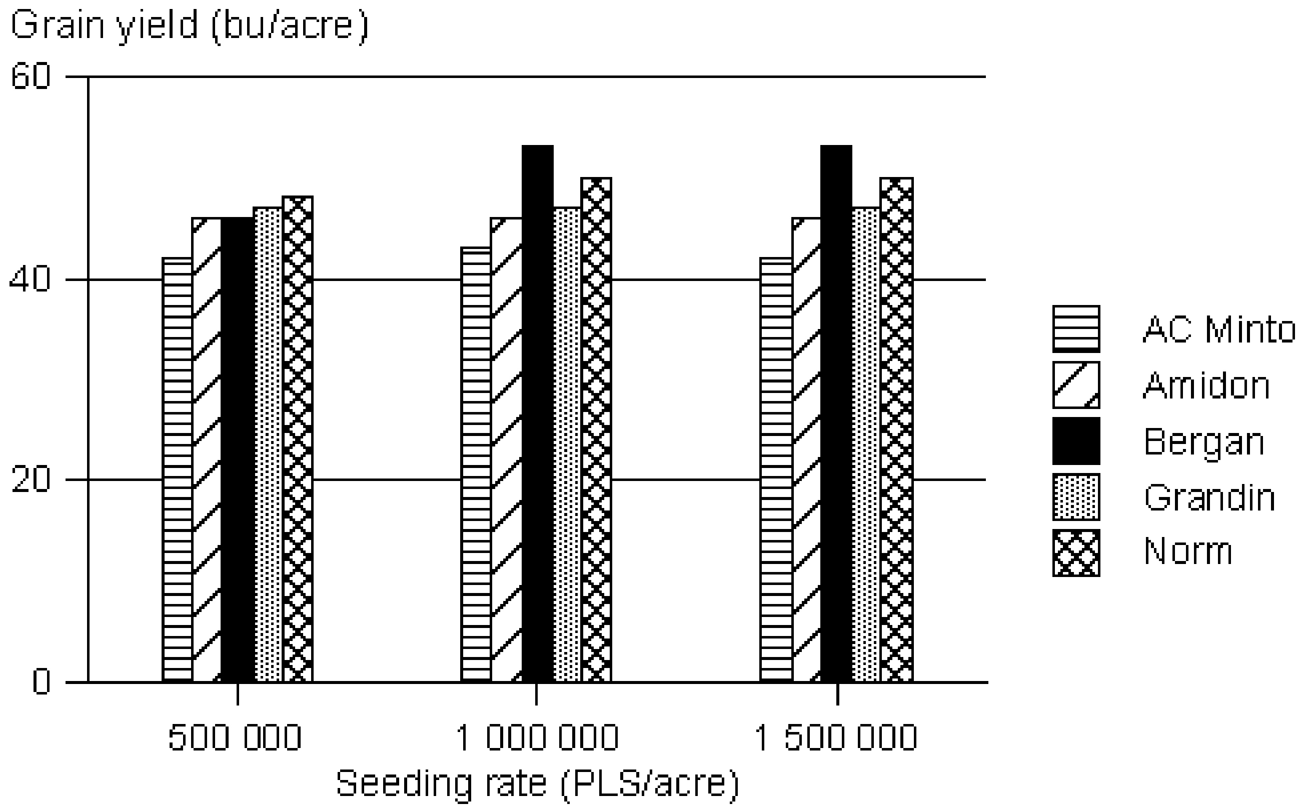


Figure 2. Grain yield of hard red spring wheat following wheat, corn, and fallow during 1994, 1995, 1996 and 1997 at Dickinson, North Dakota. Differences in yield were not detected within any year at the $P < 0.05$ level of significance.

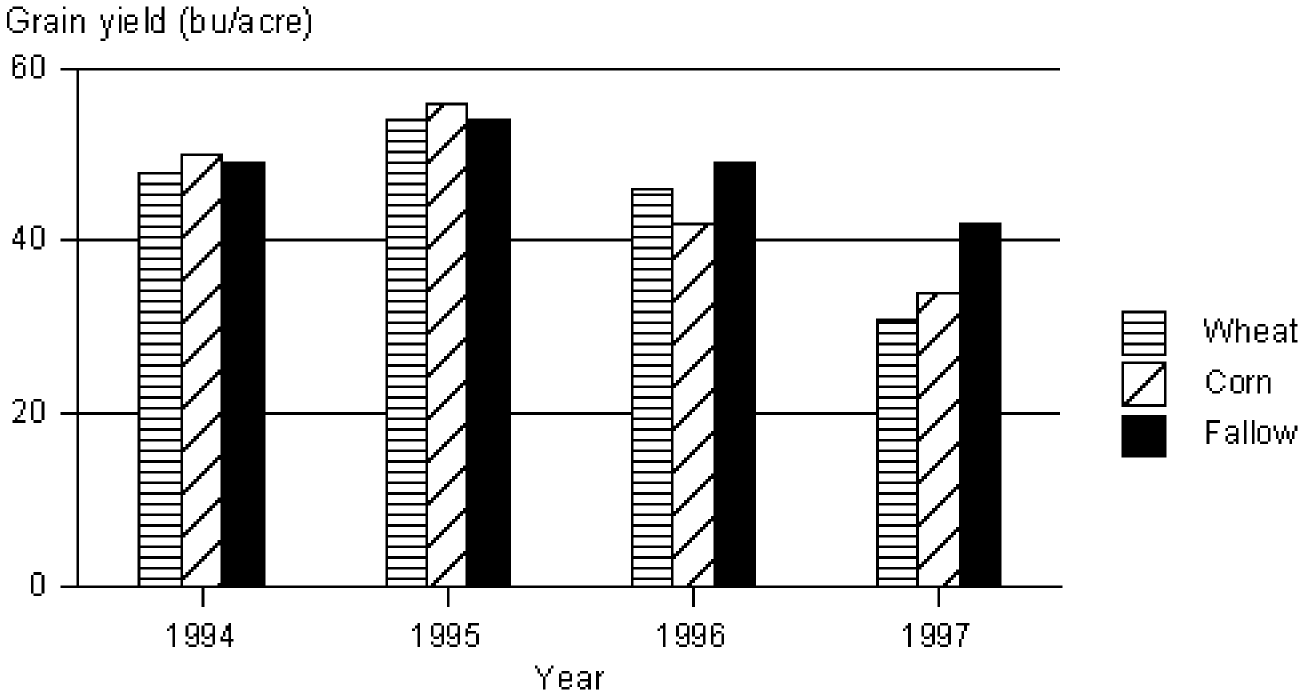


Figure 3. Grain yield of two hard red spring wheat cultivars after wheat, corn, and fallow during 1994 at Dickinson, North Dakota. Differences in yield were not detected at the $P < 0.05$ level of significance.

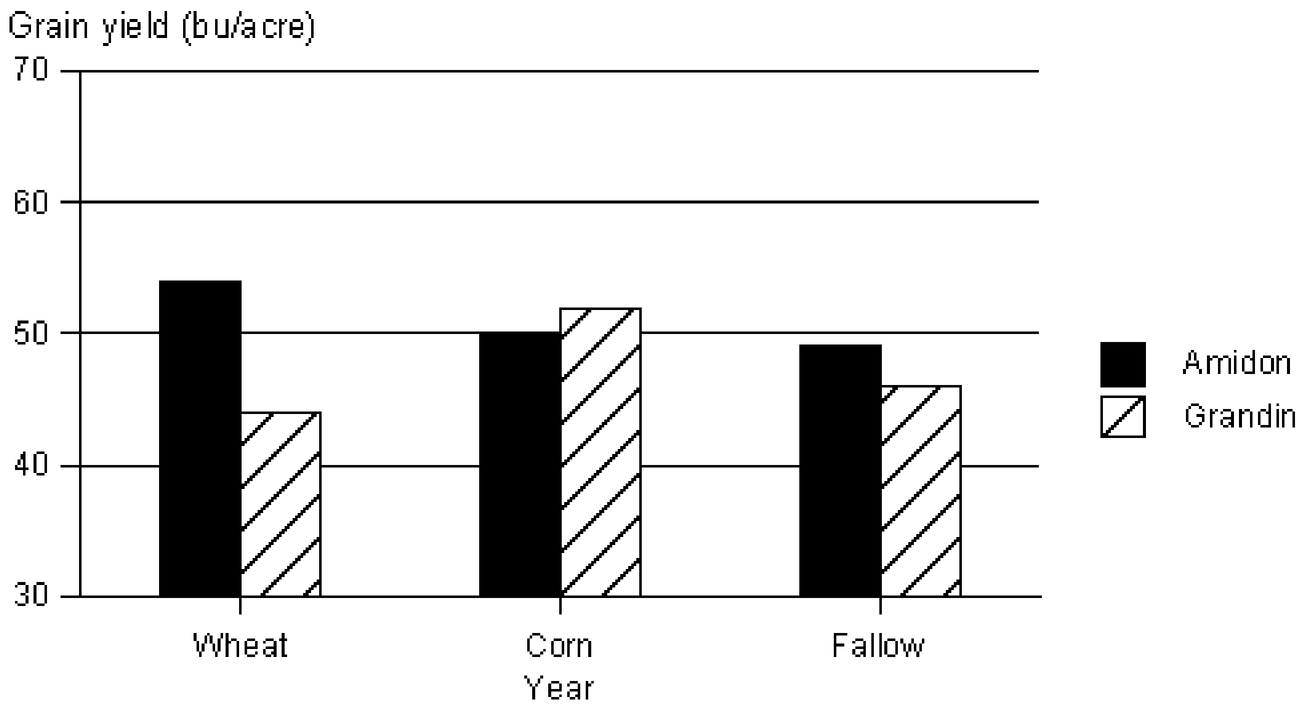
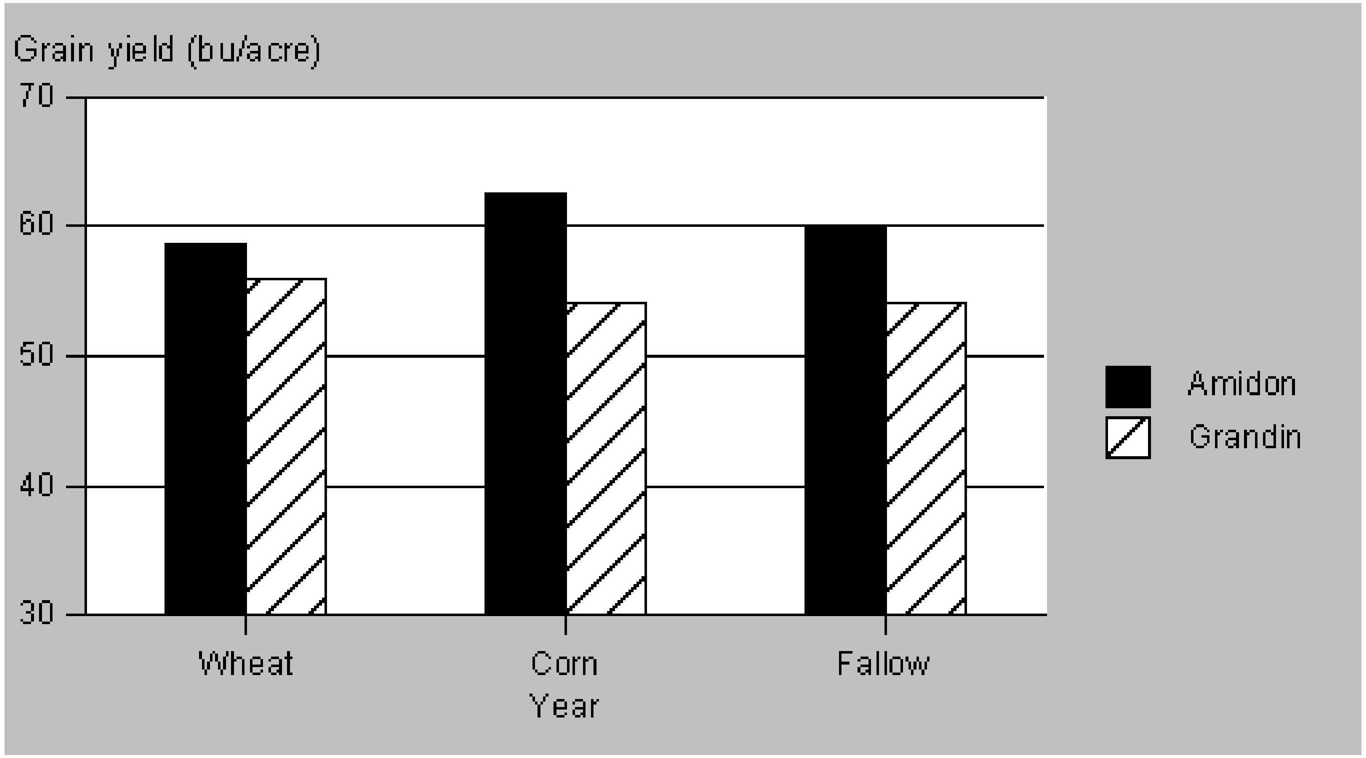


Figure 4. Grain yield of two hard red spring wheat cultivars after wheat, corn, and fallow during 1995 at Dickinson, North Dakota. Differences in yield were not detected at the *P* <0.05 level of significance.



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