Minimizing the Risk of Producing Winter Wheat in North Dakota.
II. The Effect of Tillage and Variety Selection on Winter Wheat Survival and Grain Yield

Darrell J. Cox, Jay K. Larsen and **Lynn J. Brun**

Winter wheat acreage has increased fourfold in North Dakota during 1981-84 and has stabilized at over 500,000 acres sown annually since the fall of 1983 (Carver et al., 1986). The advantages of growing winter wheat in a spring wheat region include early spring growth, greater competition with weeds, and a tendency to escape disease, temperature and moisture stresses that sometimes occur during flowering of spring wheat. However, the risk of winterkill is high for winter wheat, especially when grown under conventional management in the Northern Great Plains.

Production decisions involving tillage and variety selection must include consideration of potential winter injury and stand loss. Planting adapted winterhardy varieties and seeding into standing stubble is recommended in those regions of the state where continuous cropping is practiced (Ball et al., 1985). Snow trapped in stubble insulates the crop from air temperatures that otherwise would cause winter injury (Gusta et al., 1983; Cox et al., 1986).

The objectives of this study were: 1) to study winter survival of winter wheat in response to low temperatures under conventional, reduced and no-tillage systems, 2) to determine the influence of tillage and variety selection on winter survival, and 3) to study the relationship between grain yield and survival percentage as affected by tillage and variety selection.

METHODS

The study was conducted over a four-year period beginning in 1981 at the Microclimatic Research Station, North Dakota Agricultural Experiment Station, Fargo. Two hard red winter wheat varieties, Roughrider and Centurk 78, were grown in three contrasting cropping systems. Tillage treatments used prior to planting in September of 1981 and 1982 were identical.

Conventional tillage (CT) consisted of fall moldboard plowing of barley stubble followed by disk and harrow operations. Reduced tillage (RT) consisted of disturbing the soil surface with two disking operations. No-till (NT) involved planting directly into standing 7-inch barley stubble. The conventional tillage treatment was replaced by an additional no-till treatment, with stubble cut at a height of 2 inches prior to the 1983 and 1984 September plantings. Flax rather than barley stubble was utilized during the last two years of the experiment.

Roughrider and Centurk 78 averaged 86 and 46 percent winter survival, respectively, over five years of testing in North Dakota yield trials prior to initiation of this study.

Winter wheat was seeded at a 2-inch depth at the rate of 60 pounds per acre between September 1 and 20, the recommended planting dates for North Dakota, during each of the four years. Plots measured 13.5 × 95 feet. To ensure uniformity of snow depth over a tillage treatment, plots having tillage in common were grouped together into blocks. There were three replications of a variety within each block of tillage.

Field soil temperature at crown depth and snow depth measurements were recorded as described by Larsen et al. (1987). Climatic variables were measured for each tillage-replication combination on a daily basis for the months of December through February. Mean snow depth during this three-month period was calculated for each tillage treatment. In addition, the number of hours in which soil temperatures were below 5°F at crown depth was determined. This temperature is considered a critical temperature because most varieties will winterkill in North Dakota within the range of 5 to −5°F (Ball et al., 1985). Survival at the time of spring regrowth was determined by visual estimation.

RESULTS AND DISCUSSION

Mean snow depth and minimum soil temperature were influenced by fall tillage all four years (Table 1). Snow depth on RT plots was intermediate between snow depths on CT and NT, which had a moderating effect on minimum soil temperature in RT. During the winters 1983-84 and 1984-85, when a short stubble treatment was substituted for CT, snow depths in RT and short stubble plots were nearly identical. Soil temperatures were warmer under tall stubble due to additional snow cover; there were no significant differences in soil temperatures between RT and short stubble.

Winter injury was sustained during the winter 1981-82 with 3, 50 and 100 percent survival for CT, RT and NT wheat, respectively. There was 100 percent survival in all tillage treatments following the winters of 1982-83 and 1983-84.

Although no winterkill was recorded, climatic conditions were very different for the two winters. Snowfall received during December 1982 through February 1983 was one-

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Cox is assistant professor, Department of Agronomy, Larsen is research specialist and Brun is professor, Department of Soil Science. *The authors wish to acknowledge the assistance of Gerald Johnson, agricultural research technician, for his help in conducting this study.*

Table 1. Snow depth and minimum soil and air temperatures as influenced by tillage system for each of four years.

Tillage System	Mean snow depth	Minimum air temp.	Minimum soil temp.	Hours soil temp. <5°F
	inches	°F	°F	hr
1981-82				
Conventional	2.1	−27.8	−7.1	317
Reduced	4.4	−27.8	1.0	125
No-till	7.0	−27.8	17.4	0
1982-83				
Conventional	0.1	−12.6	2.7	21
Reduced	0.2	−12.6	−0.2	39
No-till	2.2	−12.6	12.7	0
1983-84				
Reduced	4.8	−28.7	10.6	0
No-till (2 in)	4.5	−28.7	11.8	0
No-till (7 in)	8.3	−28.7	21.9	0
1984-85				
Reduced	1.2	−25.8	−5.1	263
No-till (2 in)	0.9	−25.8	−5.1	243
No-till (7 in)	3.9	−25.8	10.0	0

third normal; however, winterkill was not realized because air temperatures averaged 8.0 to 11.7°F above normal during these months. No winterkill was recorded after the winter of 1983-84 because all tillage treatments were covered with snow in excess of 4 inches. Winterkill of wheat during the winter of 1984-85 in RT and short stubble plots was 46 and 44 percent, respectively, versus 7 percent in tall stubble. The nearly identical winter survival ratings for wheat sown in RT and short stubble reflect the similarity in soil temperatures and snow depth between the two tillage treatments.

In 1981-82, Roughrider and Centurk 78 differed in winter survival by 80 percent in RT plots, whereas they differed by only 7 percent in CT plots. Low minimum soil temperatures and prolonged period of temperatures below 5°F in CT (Table 1) ensured minimal survival of even the most winterhardy of winter wheats. However, the minimum soil temperature in RT plots was recorded as 1°F, which should cause differentiation of winter wheats for winterhardiness.

Although many of the winter wheats adapted to the Central Great Plains have greater yield potential than winterhardy wheats, their yield advantage often is not expressed due to winter injury. The 10 percent survival of Centurk 78 in RT suggests that its threshold temperature was reached sometime during the winter of 1981-82 and that the benefit from growing a winterhardy winter wheat such as Roughrider was significant, as evidenced by a yield advantage of 28 bushels per acre (Table 2). However, winter wheat cultivars with the level of winterhardiness of Centurk 78 were grown on less than 1 percent of the acreage in North Dakota in 1985. The range in winterhardiness of the predominant winter wheats grown in the Northern Great Plains is approximately one-half of that found between Centurk 78 and Roughrider. The advantage of growing a winterhardy wheat is greatest when soil temperatures fluctuate around 0°F at crown depth for an extended number of hours.

Table 2. Grain yield and winter survival as influenced by tillage system and variety for each of four years.

Tillage System	Variety	Years with winterkill: Grain yield	Years with winterkill: Winter survival	Years without winterkill: Grain yield	Years without winterkill: Winter survival
		bu/A	%	bu/A	%
		1982		1983	
Conventional	Roughrider	13.5	6.7	47.4	100.0
	Centurk 78	0.0	0.0	50.0	100.0
Reduced	Roughrider	44.3	90.0	47.2	100.0
	Centurk 78	16.5	10.0	51.9	100.0
No-till	Roughrider	51.9	100.0	47.7	100.0
	Centurk 78	59.7	100.0	50.8	100.0
		1985		1984	
Reduced	Roughrider	52.8	72.5	49.9	100.0
	Centurk 78	17.4	18.6	62.0	100.0
No-till (2 in)[1]	Roughrider	55.9	70.9	39.1	100.0
	Centurk 78	11.6	16.4	54.2	100.0
No-till (7 in)	Roughrider	60.4	97.0	41.7	100.0
	Centurk 78	70.3	88.9	48.4	100.0

[1]Stubble height at seeding.

There were differences of 54, 55 and 8 percent in survival of Roughrider and Centurk 78 in RT, short, and tall stubble NT plots in 1984-85, respectively. The similar response of Roughrider and Centurk 78 in RT and short stubble plots could have been predicted since there were only minimal differences in duration and intensity of cold soil temperatures (Table 1).

Tillage and variety choice had a significant effect on grain yield and winter survival in the two years in which winterkill was recorded (Table 2). Mean grain yields of CT and RT wheat were 12 and 54 percent, respectively, of the yield of grain harvested from NT plots in 1982. In 1985, mean grain yields of the RT and short stubble wheat were approximately one-half of the tall stubble (NT) wheat. There was no difference among tillage treatments in the grain yield of winter wheat harvested in 1983 and 1984, years in which no winterkill was recorded.

Roughrider yielded from 13 to 44 bushels per acre more than Centurk 78 under conditions that resulted in significant winterkill (CT and RT in 1981-82, RT and short stubble in 1984-85). The mean grain yield of Roughrider, across tillage treatments, was 5 bushels per acre greater than that of Centurk 78 for the entire four-year period. However, Centurk 78 yielded more grain than Roughrider in years in which no winterkill was recorded and when sown into tall stubble during years that winterkill occurred.

Yield losses due to winter injury may occur even when there is little winterkill. For example, there was a substantial yield reduction in Roughrider planted in RT (1982) and short stubble (1985) as compared to Roughrider in tall stubble, even though the spring stands for all of these tillage treatments would have been rated as good.

The variation in winter survival explained by tillage, variety, snow depth and minimum soil temperature is given in Table 3. The coefficients of determination (R^2) indicate that 70 percent of the variation in winter survival for the winter 1981-82 was attributable to tillage whereas only 9 percent was associated with variety. The coefficients of determination for snow depth and minimum soil temperature were less than, but similar in magnitude to, that for tillage. This should be expected because differences in survival of winter wheat due to tillage have been attributed to snow trapping and its effect on soil temperature at crown depth. The primary reason for differences in the magnitude of R^2 values associated with tillage and varieties between the two winters in which winterkill occurred (1981-82 and 1984-85) was the change of tillage treatments. The additional NT (short stubble) treatment was characterized as being similar to RT in terms of snow cover and soil temperature.

The interrelationships of survival with variety selection and climatic variables also were examined separately for each of the tillage treatments (Table 3). Soil temperature and snow depth accounted for the greatest percentage of variation in survival of CT wheat in 1981-82. This would suggest that at least part of the variation in survival was due to factors causing differences in snow cover, such as proximity to other tillage treatments and variability in the roughness of the soil surface. Although the variability in snow depth of RT and NT plots may have been greater than for CT plots, once adeuqate snow cover had been achieved there was little effect of additional snow on soil temperature and survival. Variety selection, wtih tillage held constant, accounted for greater than two-thirds of the variation in winter survival of winter wheat in RT and NT plots.

SUMMARY

Tillage and variety selection have a significant impact on winter survival of winter wheat and ultimately on grain yield. For example, the correlation between grain yield and winter survival percentage was greater than 0.9 for the two years of the study when winterkill was significant. Regression analysis indicated that selecting the proper tillage system potentially can have a greater effect on winter survival than variety choice. Neither Roughrider nor Centurk 78 winterkilled significantly (or enough to influence yield) when sown in tall stubble. Wheat growers who can successfully raise winter wheat seeded no-till into tall stubble may be able to take advantage of the greater yield potential of winter wheat varieties with less winterhardiness than Roughrider.

Table 3. Proportion of the total sum of squares for winter survival percentage that is attributable to tillage, variety, minimum soil temperature (MST) and snow depth (SD) for two winters in which winter injury occurred.

Independent variable	R^2			
	1981-82			
	Combined	Conv.	Reduced	No-till†
Tillage	0.70**			—
MST	0.64**	0.37	0.04	—
SD	0.56**	0.28	0.04	—
Variety	0.09*	0.20	0.92**	—
	1984-85			
Tillage	0.32**			
MST	0.43**	0.09	0.01	0.14
SD	0.44**	0.05	0.02	0.06
Variety	0.32**	0.66*	0.87**	0.77*

*, **Significant at 0.05 and 0.01 probability levels, respectively.
†Spring regrowth survival score was 100% for all no-till plots in 1982.

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