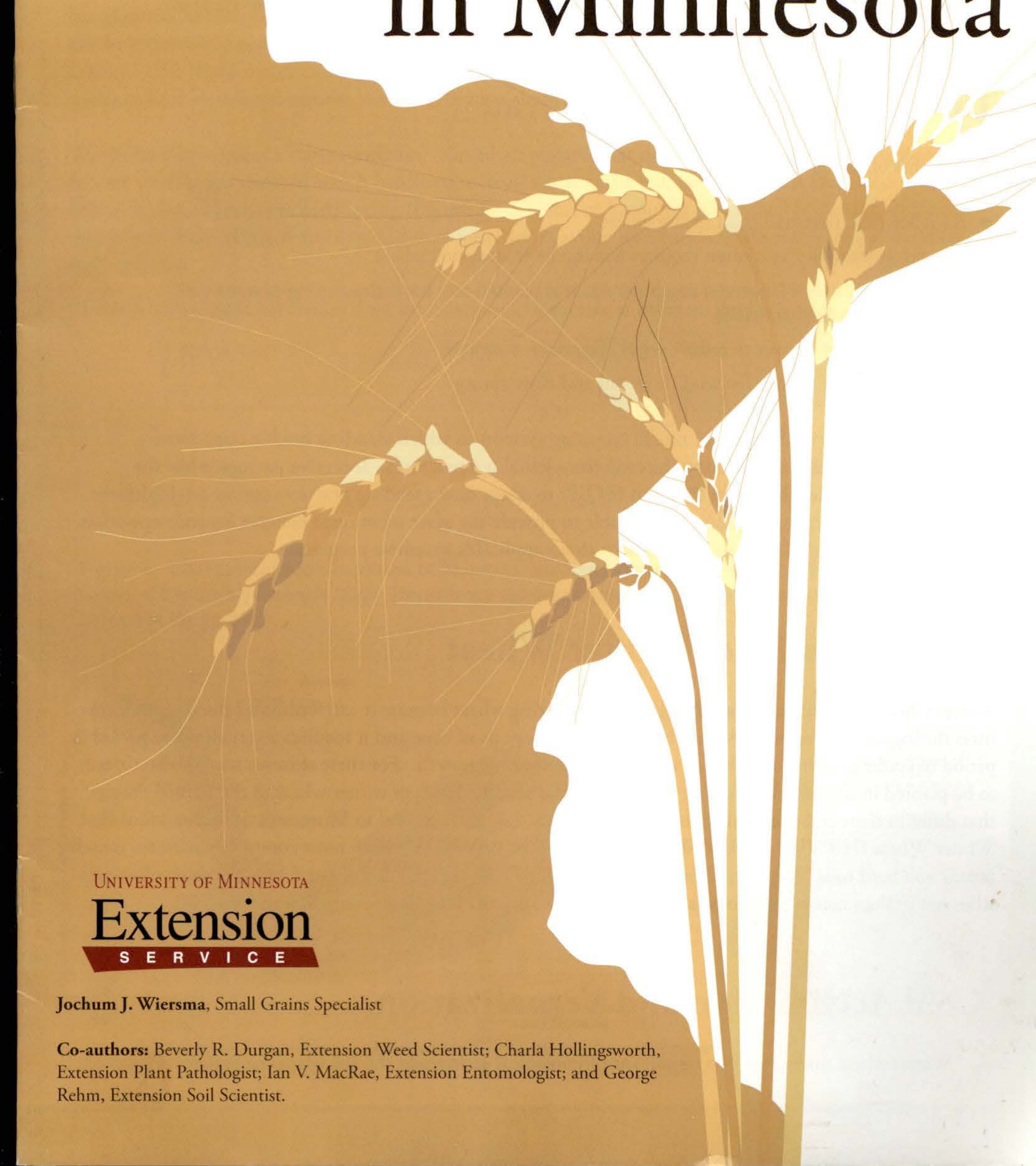
Winter Wheat in Minnesota



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Extension
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Introduction

Winter wheat acreage has always been much smaller than that of spring wheat in Minnesota. From 1999 to 2004, the winter wheat acreage in Minnesota varied from 15,000 to 60,000 acres. The primary costraint to winter wheat production in Minnesota is winter kill. Newer varieties and production practices have reduced this risk, making winter wheat a more viable option in the cropping systems of the state.

The Benefits of Winter Wheat:

The benefits of winter wheat include:

- A higher yield potential than spring wheat
- Greater profitability as it often requires less inputs than spring wheat
- More efficient use of labor and machinery as it is planted and harvested during periods with few competing field activities
- Establishment of a cover to reduce wind and water erosion
- Establishment of a cover for wildlife in fall and early spring

Winter wheat is very well suited for no-till cropping systems in which standing residue traps snow and reduces winter kill by insulating the crop from lethal temperatures. Incentive payments like the Environmental Quality Incentive Program (EQIP) to adopt direct seeding practices and/or establishment of winter wheat as a cover crop may be available to provide the afore mentioned benefits for your operation. Check with your local NRCS and FSA offices about applicable incentive programs.

Characteristics of Winter Wheat

Winter wheat (*Triticum aestivum* L.) differs from spring wheat because it can withstand freezing temperatures during its early vegetative growth for extended periods of time and it requires a vernalization period (a period of cooler growing conditions) to trigger reproductive growth. For these reasons, winter wheat needs to be planted in the fall. Like spring wheat, there are several classes of winter wheat in the United States that differ in their end-use quality characteristics. The varieties adapted to Minnesota are either Hard Red Winter Wheat (HRWW) or Hard White Winter Wheat (HWWW), both most commonly used for dough breads and hard rolls. Varieties of both classes generally have acceptable flour and bread making characteristics but protein content is almost always lower than that of Hard Red Spring Wheat (HRSW).

Cold Acclimation and Vernalization

Winter wheat undergoes two important physiological changes in the fall when the plants are exposed to cooler growing conditions, namely cold acclimation and vernalization. Cold acclimation is needed to induce the winter hardiness that allows the plant to survive the freezing temperatures during the winter months. Vernalization enables reproductive growth and allows winter wheat to reach flowering earlier the next summer. Both vernalization and cold acclimation require a period of growth when temperatures are between 30° and 60°F, with near 40°F being optimum. If the vernalization requirement is only partially met in the fall because of late planting, it will result in a delay in maturity the next summer, as reproductive growth will eventually be triggered by day length. The period needed for vernalization differs among winter wheat varieties. Likewise, the winter hardiness differs among winter wheat varieties. The most winterhardy varieties can withstand crown temperatures as low as -15°F for a short period of time (**Table 1**).

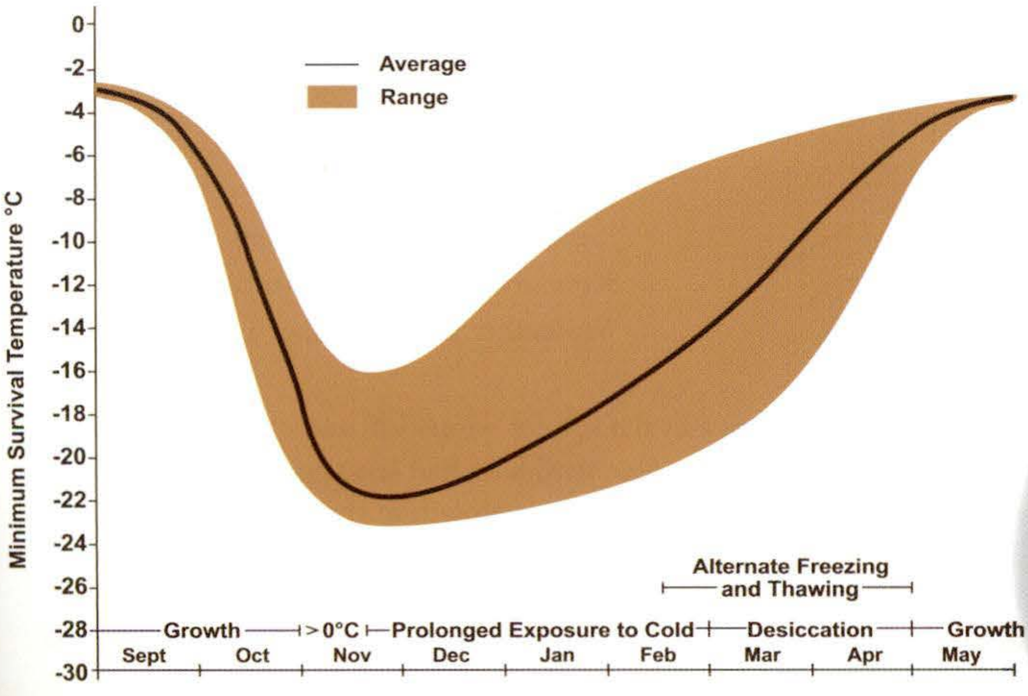
Winter hardiness is not a static condition. Canadian research has demonstrated that winter hardiness follows a bell shape curve in which hardiness increases during the fall, peaks between December and February, and decreases in early spring (**Figure 1**). The loss of hardiness is hastened by factors such as a mid-winter thaw, alternate freezing and thawing, frost heaving, desiccation, suffocation (due to ice sheeting), and rain.

Table 1. Maximum number of days winter wheat can survive at different crown temperatures.

Temperature (°F)	Maximum Length (days)
27.0	150.0
5.0	6.0
- 15.0	0.5
- 20.0	0.0

(Source: Winter Wheat Production in North Dakota. NDSU Extension Service)

Figure 1. Changes in winter hardiness of Norstar Canadian Western Red Winter Wheat (CWRW) over period of September through May. The primary factors responsible for these changes are shown at the bottom of the graph.



(Source: Dr. Brian Fowler. Winter Wheat Production Manual. Crop Development Centre, University of Saskatchewan, Saskatoon, Canada)

Rotations and Planting into Residue

Direct seeding winter wheat into standing crop stubble is recommended in order to retain snow during the winter. Snow insulates, protecting the crown of winter wheat from the potentially lethal temperatures that are common during the winter in Minnesota. Standing stubble maintains a cooler soil environment so the plant doesn't break dormancy as early in the spring or during a mid-winter thaw as plants that are grown on bare ground. Three inches of snow provides sufficient insulation during most winters, and 4 to 6 inches will further reduce winter kill (**Table 2**).

Table 2. Predicted daily minimum temperatures at crown depth relative to two daily minimum air temperatures for differing snow depths.

Snow Depth	- 22°F	- 44°F
1.2 – 2.5	0.9	- 9.9
2.5 – 3.5	6.1	- 3.6
3.5 – 4.7	11.1	2.5
< 4.7	20.5	18.1

(Source: Winter Wheat Production in North Dakota. NDSU Extension Service)

Winter wheat can be direct seeded into a wide range of standing crop residues, though best results are obtained when winter wheat is seeded into standing stubble of early maturing crops such as barley and canola. Seeding into wheat stubble will increase the risk of residue-born diseases, but even this practice is preferred to seeding into clean tilled fields for moisture conservation and reduction of winter kill. Winter wheat can be successfully produced in abandoned alfalfa stands and even after a low residue crop such as soybeans. When following alfalfa, allow some regrowth in late summer and early fall before killing the stand with a broad spectrum herbicide like glyphosate. Direct seed winter wheat into the killed alfalfa stand. To follow soybeans requires either that the producer selects an early maturing soybean or delays seeding past the recommended seeding date (**Table 3**). For best results when following soybean, follow an early maturity variety such that the optimum seeding date is not delayed excessively.

Table 3. Optimum date for direct seeding winter wheat into standing stubble in Minnesota.

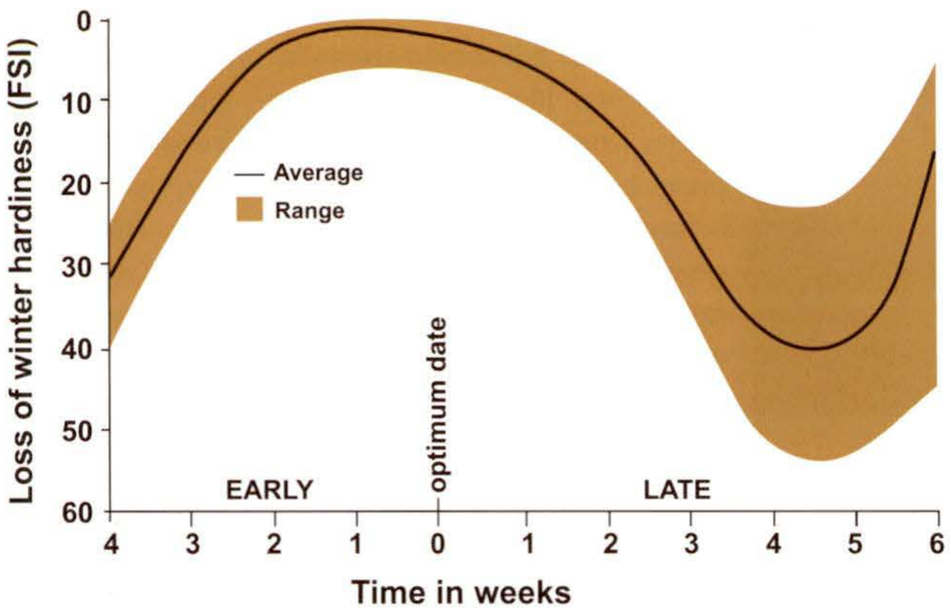
Location	Date
South of I 90	September 20 – October 10
South of I 94	September 10 – September 30
North of I 94	September 1 – September 15

A delay in planting past the optimum seeding date increases the risk for winter kill and can reduce grain yield since the crowns will not be as well developed and the plant will have had less opportunity to store nutrients (**Figure 2**). Likewise, seeding too early can result in excessive growth in the fall, making plants more vulnerable to winter kill. Early planting also creates a green bridge, or overlap, between volunteer wheat and alternate hosts and the emerging winter wheat for a number of important winter wheat pests. Seedling infections of, for example, barley yellow dwarf virus and wheat streak mosaic virus can reduce grain yield dramatically.

Plants that have initiated the first tillers are at the optimum growth stage to go dormant while plants with two to three tillers will generally survive the winter well. Plants with only the first leaf emerged can survive Minnesota winters, although late planting poses the risk that the vernalization requirement will not be met prior to dormancy. This will result in a delay of maturity the next summer (**Figure 3**).

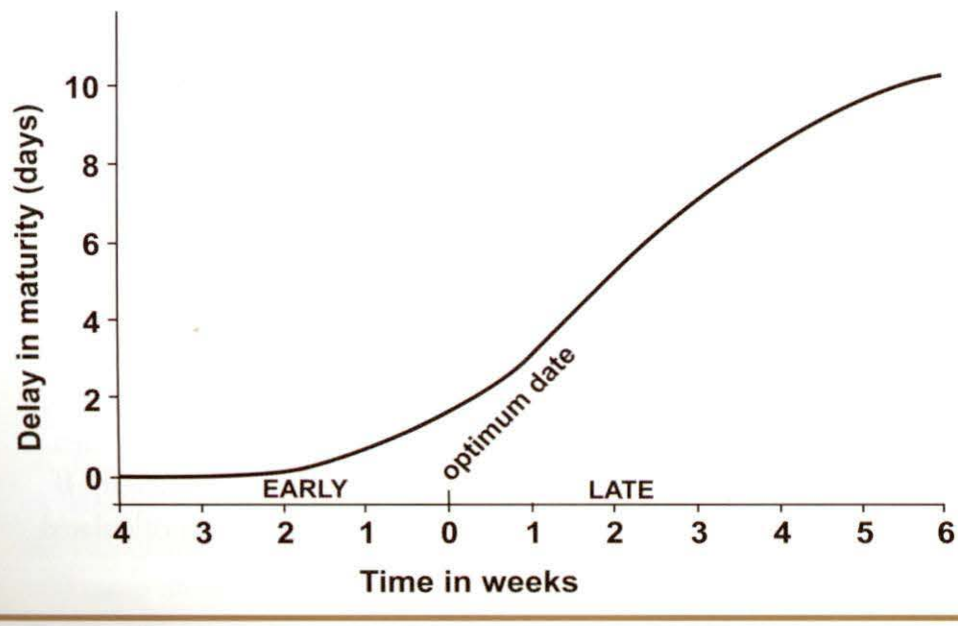
Research in northwest Minnesota has demonstrated that winter wheat can be established well with little risk of winter kill when seeding immediately following soybean harvest in the first days of October. In the years the research was conducted, the winter wheat was seeded on October 1, immediately following soybean harvest. Growing conditions in the first two weeks of October were mild enough that the winter wheat germinated and the first true leaf emerged prior to the first killing frost forcing dormancy in the third/fourth week of October.

Figure 2. Influence of seeding date on winter hardiness of winter wheat.



(Source: Dr. Brian Fowler. Winter Wheat Production Manual. Crop Development Centre, University of Saskatchewan, Saskatoon, Canada)

Figure 3. Influence of seeding date on maturity of winter wheat.



(Source: Dr. Brian Fowler. Winter Wheat Production Manual. Crop Development Centre, University of Saskatchewan, Saskatoon, Canada)

Seeding Rate and Depth

Winter wheat should be seeded at 1 – 1½-inch depth to facilitate rapid emergence. Seeding shallower than 1-inch depth will predispose the crowns to a higher risk for winter kill, seeding deeper will delay emergence. The seeding rate is calculated using the following equation:

$$\text{Seeding Rate (lb/A)} = \frac{\text{Desired Stand / (1 – Expected Stand Loss)}}{\text{(Seed/Pound) x Percent Germination}}$$

The optimum stand of winter wheat is 900,000 to 1,000,000 plants per acre or 21 to 23 plants/ft^2. The optimum stand is less than HRSW since the crop will have more opportunity to tiller in the early spring. Increase the desired stand to 23 to 25 plants/ft^2 when planting is delayed or if seedbed conditions are unfavorable for rapid emergence.

Photo 1. Winter wheat field showing winter kill in patches throughout the field
(Photo by J. Ransom)

Some winter kill should always be expected in Minnesota. However, do not be too quick to destroy winter wheat stands in the spring. Wait until the plants break dormancy and fields begin to green up before making any decision on replanting. Roots are generally less winter hardy than crowns and regrowth may be very slow, even if roots and shoots appear dead. It may take until the end of April before the degree of winter kill can be determined. If stands are reduced uniformly across the field, stands of 17 plants/ft^2 can still produce near maximum grain yields. Even stands as low as 11 plants/ft^2 can still produce a 40 bu/A yield.

More often than not, winter kill is not uniformly distributed across the field but occurs in patches throughout the field. If smaller patches have stands of 8 plants/ft^2, leave the whole stand (**Photo 1**). If large areas are lost, consider destroying the winter wheat and planting spring wheat in those areas. Avoid inter-seeding winter wheat and spring wheat as this creates a mixture of contrasting wheat classes which can result in marketing problems.

Fertility Management

Fertilizer guidelines for winter wheat are similar to, but not the same as, those used for HRSW. For the western portion of the state, the soil nitrate test is the best and most accurate management tool for predicting the amount of nitrogen (N) needed. This soil test is recommended in western Minnesota and when legumes do not precede wheat in the rotation. Use **Table 4** when legumes precede the winter wheat. If the soil nitrate test is used, the amount of fertilizer N required to meet the expected yield is calculated from the following equation.

$$N_{Rec} = (2.5 \times YG) - STN_{(0\text{-}24)}$$

Where N_{Rec} is the recommended amount of N to use, YG is the yield goal in bu/A, and $STN_{(0\text{-}24)}$ is the soil nitrate test value at 0-2 feet depth in lb/A. The soil nitrate test is not used for making fertilizer N suggestions for wheat grown in eastern and southern Minnesota. For situations where the soil nitrate test is not used, suggestions for fertilizer N are based on a consideration of previous crop, expected yield, and soil organic matter content (**Table 4**).

Table 4. Nitrogen recommendations for winter wheat where the soil nitrate test is not used.

Previous Crop	**Organic* Matter Level**	**Yield Goal (lb/A)**					
		<40	40-49	50-59	60-69	70-79	80+
		- - - - - - - - N to apply (lb/A) - - - - - - -					
Alfalfa (4+ plants/ft^2),	low	0	0	30	55	80	95
Non-harvested sweet clover	medium/high	0	0	0	35	60	75
Soybeans	low	35	60	85	110	135	150
	medium/high	0	40	65	90	115	130
Edible beans, Field peas,	low	45	70	95	120	145	160
Harvested sweet clover	medium/high	25	50	75	100	125	140
Any crop	low	0	30	55	80	105	120
in Group 1	medium/high	0	0	35	60	85	100
Any crop	low	55	80	105	130	155	170
in Group 2	medium/high	35	60	85	110	135	150
Organic soils		0	0	0	0	30	35

** Low = less than 3.0%; medium and high = 3.0% or more*

CROPS IN GROUP 1	**CROPS IN GROUP 2**		
alfalfa (2-3 plants/ft^2)	alfalfa (0-1 plants/ft^2)	grass pasture	sugar beets
alsike clover	barley	millet	sunflowers
birdsfoot trefoil	buckwheat	mustard	sweet corn
grass/legume hay	canola	oats	triticale
grass/legume pasture	corn	potatoes	wheat
fallow	flax	rye	vegetables
red clover	grass hay	sorghum-sudan	

In contrast to spring wheat, split applications of fertilizer N should be used for winter wheat production. Thirty to 40 lb. N per acre should be broadcast and incorporated just prior to planting. The remainder of the amount of fertilizer N needed should be topdressed in early spring. Two sources of N (28-0-0, 46-0-0) can be used for topdress applications. There is some potential for leaf burn if 28-0-0 is used. Therefore, early season application is suggested. This timing coincides with limited leaf development and subsequent damage attributed to leaf burn is minimized. To reduce the potential for damage to a minimum, all in-season fertilizer N should be applied as early as possible and prior to jointing. Do no apply N over snow covered ground. It will increase the risk of winter kill in the wheel tracks and increases the risk that the N will move offsite with spring run-off.

The phosphorus (P) status of Minnesota soils is determined by using either the Bray or the Olsen analytical procedure. In general, the Olsen test provides more accurate guidelines when the soil pH is 7.4 or higher. The phosphate fertilizer suggestions change with soil test level for P and placement. At very low, low, and medium soil test levels, the needed phosphate can be broadcast and incorporated before planting or applied in a band near the seed at planting (**Table 5**). Rates can be reduced substantially if phosphate fertilizer is applied in a band near the seed. Phosphorus aids winter survival as it stimulates root growth and fall tillering.

Table 5. Phosphate fertilizer suggestions for winter wheat production in Minnesota.

		Phosphorus (P) Soil Test (ppm)									
Yield Goal	Bray: Olsen:	v. low 0-5 0-3		low 6-10 4-7		med 11-15 8-11		high 16-20 12-15		v. high 21+ 16+	
		Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band
bu/A		P_2O_5 to apply (lb/A)[1]									
less than 40		40	20	30	15	15	10	0	10-15	0	0
40-49		40	20	30	15	15	10	0	10-15	0	0
50-59		50	25	35	20	20	15	0	10-15	0	0
60-69		60	30	45	25	20	15	0	10-15	0	0
70-79		70	35	50	25	25	20	0	10-15	0	0
80 or more		80	40	55	30	25	20	0	10-15	0	0

1 Use of the following equations if a phosphate recommendation for a specific soil test and a specific yield goal is desired.

P_2O_{5Rec} *= [1.071 – (.054) (Bray P, ppm)] (Yield Goal)*

P_2O_{5Rec} *= [1.071 – (.087) (Olsen P, ppm)] (Yield Goal)*

No phosphate fertilizer is suggested when the Bray P test is 21 ppm or higher or the Olsen P test is 16 ppm or higher.

Potash (K) application rates vary with placement and soil test level for K. No broadcast potash fertilizer will be needed when the soil test for K is in the range of 121 to 160 ppm. No potash fertilizer (either banded or broadcast) is suggested when the soil test for K is 161 ppm or higher (**Table 6**).

Table 6. Potash fertilizer suggestions for winter wheat production in Minnesota.

		Potash (K) Soil Test (ppm)									
Yield Goal	Bray: Olsen:	v. low 0-40		low 41-80		med 81-120		high 121-160		v. high 161+	
		Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band
bu/A		K_2O to apply (lb/A)1									
less than 40		95	50	70	35	40	20	0	15-20	0	0
40-49		105	55	75	40	45	25	0	15-20	0	0
50-59		130	65	95	50	55	30	0	15-20	0	0
60-69		155	80	110	55	65	35	0	15-20	0	0
70-79		180	90	125	65	75	40	0	15-20	0	0
80 or more		190	95	135	70	80	40	0	15-20	0	0

[1] Use the following equation if a potash recommendation for a specific soil test and a specific yield goal is desired.

K_2O_{Rec} *= [2.710 – (.017) K Soil test, ppm)] (Yield Goal)*

No potash fertilizer is suggested when the K is 161 ppm or higher.

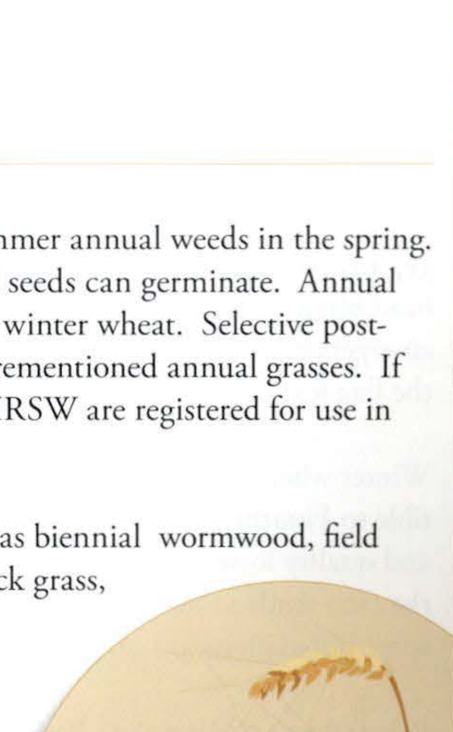
Sulfur (S) fertilization is an important consideration if winter wheat is grown on sandy soils (loamy fine sand, sandy loam textures). The broadcast application of 25 lb. S per acre in the sulfate form will be adequate for these situations. For more efficient applications, use 10 to 15 lb. S per acre in a band at planting. The effect of micronutrients on production of winter wheat has not been evaluated in Minnesota. However, there is no reason to suspect that the response of winter wheat should be different from the response of hard red spring wheat. The impact of micronutrient application on the yield of hard red spring wheat has been evaluated. Both soil and foliar application of micronutrients (zinc, iron, manganese, and copper) were used. There was no increase in yield. There was leaf burn if foliar applications were used. Therefore, the application of micronutrients is not suggested for winter wheat grown on mineral soils. Copper (Cu) is suggested only if winter wheat is grown on organic (peat) soils. For these situations, broadcast and incorporate 6 to 12 lb. Cu per acre before planting.

When air seeders are used for planting, there are a variety of options for placement of phosphate and potash fertilizers. Any reduction of seedling emergence as affected by fertilizer placement is a concern. If fertilizer (P and K materials) is placed in a band close to the seed, lower rates can be used. Rates of MAP or DAP needed to satisfy phosphate requirements should have no negative effect on emergence. The rates of potash suggested for banded application should not have a negative effect on emergence. The relatively low rates of nitrogen suggested for application at planting should not have a negative effect on emergence. The total amount of N needed at planting can be applied as MAP, DAP, or a combination of either with urea (46-0-0). Considering suggested rates of nitrogen, phosphate, and potash, application of fertilizer in the fall with an air seeder at planting should not be a problem.

Weed Control

Healthy, uniform stands of winter wheat are very competitive with any summer annual weeds in the spring. The regrowth in the early spring will create ground cover before most weed seeds can germinate. Annual grasses such as wild oats and green or yellow foxtail are rarely a problem in winter wheat. Selective post-emergence grass herbicides are, therefore, seldom needed to control the aforementioned annual grasses. If a grass herbicide is needed, most of the grass herbicides labeled for use in HRSW are registered for use in winter wheat.

The primary weed problems in winter wheat are winter annual weeds such as biennial wormwood, field pennycress, shepherd's purse, and perennial weeds like Canada thistle, quack grass, and perennial sow thistle. Use a fall burndown application prior to planting to control emerged winter annual weeds, volunteer crop, and perennial weeds. Control remaining and newly emerged annual weeds in early spring with broad spectrum herbicides such as 2,4-D, MCPA, bromoxynil and dicamba, individually or as prepackaged tank mixes. Refer to the University of Minnesota Extension Service 'Cultural and Chemical Weed Control in Field Crops' publication for rate information and growth stage restrictions (http://appliedweeds.cfans.umn.edu).



Disease Control

Winter wheat is susceptible to many of the same diseases as spring wheat. Those disease issues with the largest potentials to cause economic loss in Minnesota are 1) tan spot, 2) leaf and stripe rusts, and 3) Fusarium head blight.

Tan spot, a residue-born disease, is more severe when winter wheat is planted into wheat residue and the weather remains wet for extended periods (**Photo 2**). If the disease becomes established in the fall, storage of nutrients by plants is disrupted, resulting in a greater likelihood for winter kill. If environmental conditions promote disease development, an application of fungicide may be needed to protect the crop. Systemic fungicides labeled for the disease have good control activity.

Photo 2. Tan spot lesions *(photo by C. Hollingsworth)*

Stripe and Leaf Rusts can cause yield losses in susceptible varieties when weather conditions promote disease development (**Photos 3 and 4**). Most winter wheat varieties are susceptible to stripe rust while some are susceptible to leaf rust. Stripe and leaf rusts generally don't over-winter in Minnesota. The diseases re-establish each year after spores are transported to Minnesota by winds originating in more southerly winter wheat production areas. Rusts can cause crop loss if they become established in the lower canopy prior to flag leaf emergence and the weather conditions are wet and cool (stripe rust), or wet and warm (leaf rust). If one or more rusts establish on a susceptible variety immediately prior to heading, a fungicide application is recommended at the early-flowering growth stage to control rust, as well as to suppress Fusarium head blight. If disease development is severe prior to flag leaf emergence, a fungicide application may be needed to protect the flag leaf before the early-flowering growth stage timing.

Photo 3. Leaf rust *(photo by C. Hollingsworth)*

Winter wheat varieties adapted to the northern U.S. are susceptible to Fusarium head blight or scab (**Photo 5**). Overall, yield and quality losses in winter wheat are limited in Minnesota as the crop tends to flower earlier than HRSW, when Fusarium spore populations are small, escaping infection.

Photo 4. Severe stripe rust on a winter wheat head *(photo by C. Hollingsworth)*

Photo 5. Fusarium head blight *(photo by R. Jones)*

Researchers in Minnesota have recently identified brown root rot caused by the fungus *Phoma sclerotioides* in winter wheat. The adapted cold temperature snow mold is known to cause disease on crops such as alfalfa, sweet clover, and grasses during the winter. Susceptible plants appear healthy in the fall, but are slow to green or killed in the spring. Above ground symptoms are subtle and are often dismissed as weather-related 'winter kill'. Research is continuing into brown root rot of winter wheat to determine its economic importance in Minnesota.

Insect Control

Insect pests in winter wheat are the same as in spring wheat in Minnesota. The risk for economic losses from a number of these insect pests is different, however, for winter wheat than for spring wheat. For example, although Hessian fly is rarely a problem in spring wheat, the risk of economic losses from this insect in winter wheat is higher than in spring wheat, especially if the winter wheat is planted early and directly into wheat stubble. Avoid creating a green bridge by destroying any volunteer wheat and grassy weeds at least two weeks prior to planting winter wheat. None of the currently available winter wheat varieties are resistant to either Hessian fly or wheat stem saw fly. Treat all other insect pests in winter wheat as you would do in spring wheat. Consult the 'Small Grains Field Guide' (MI-07488) for additional details and economic thresholds.

Barley yellow dwarf virus or BYDV is an aphid vectored disease in winter wheat. Several cereal aphid species, notably the bird-oat cherry aphid (one of the most numerous cereal aphids in Minnesota) can vector BYDV. If winter wheat gets infected by BYDV in the fall, infected plants will be severely stunted and yield losses can be as high as 90%. Because cereal aphids feed on a number of other grasses which can host BYDV, a greater proportion of the aphids in late season populations will tend to be infectious. Avoid planting early and destroy any volunteer wheat and grassy weeds at least two weeks prior to planting winter wheat to reduce the incidence of the different cereal aphids.

Wheat streak mosaic virus, vectored by wheat curl mite can be a serious potential problem in winter wheat. Currently in Minnesota, the problem is negligible, largely because winter wheat acreage is very small. It is anticipated that the risk for wheat streak mosaic infections increase as acreage increases. Winter wheat is frequently infected in the fall and may lack symptoms until the spring. Losses are linked to time of infection; the earlier the plant is infected, the greater the loss. Stunting, lack of head production, reduced or no grain production or low test weight can all occur. Generally, losses in winter wheat are not severe unless infection occurs in the fall. Destruction of all volunteer wheat and grassy weeds at least two weeks prior to planting winter wheat will reduce the incidence of wheat curl mite. If possible, do not plant closer than 1/8 mile to corn or fields with volunteer wheat. Later planting will also reduce the chance of a fall infection and build-up of wheat curl mite and wheat streak mosaic virus before freeze-up.

Harvest and Storage

A number of the current HRWW varieties are very tall with plant heights well above most of the semi-dwarf HRSW varieties. Straight cutting may prove to be challenging with these tall stature varieties and swathing is probably the best option to ensure a speedy harvest. At a grain moisture content of 12-13%, winter wheat can be stored up to 12 months if the temperature of the grain is below 55°F. Aeration is suggested to obtain a uniform temperature throughout the bin. Clean and treat grain bins with an insecticide prior to storing winter wheat. Consult the 'Small Grains Field Guide' (MI-07488) for additional details.

Marketing

HRWW is a class of wheat separate from HRSW. The market for HRWW in Minnesota is mature with regional demand. The price difference between HRSW and HRWW is often less one would expect. Do not mix classes of wheat when delivering wheat to your local elevator. One percent of a contrasting class of wheat will automatically result in a lowering of the grade from grade # 1 to grade # 2. Additional percentages will lower grades further. No lot of wheat can exceed 10% of a contrasting class.

In Summary

Winter wheat is a viable alternative in cropping systems in Minnesota. Lower input costs, a high yield potential, efficient use of available machinery and labor, and availability of financial incentives are some of the advantages of winter wheat. Including winter wheat in no-till cropping systems is especially advantageous as standing stubble aid in snow cover, effectively reducing winter kill. Winter wheat can be successfully established following soybean, despite a delay in seeding date past the optimum planting date in most years, if winterhardy varieties are used.

References:

Fowler, D.B. 1992. Winter Wheat Production Manual. Crop Development Centre, University of Saskatchewan, Saskatoon, Canada.

Peel, D.P and N. Riveland. 1997. Winter Wheat Production in North Dakota. Extension Bulletin 33. North Dakota State University Extension Service, Fargo, ND.

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