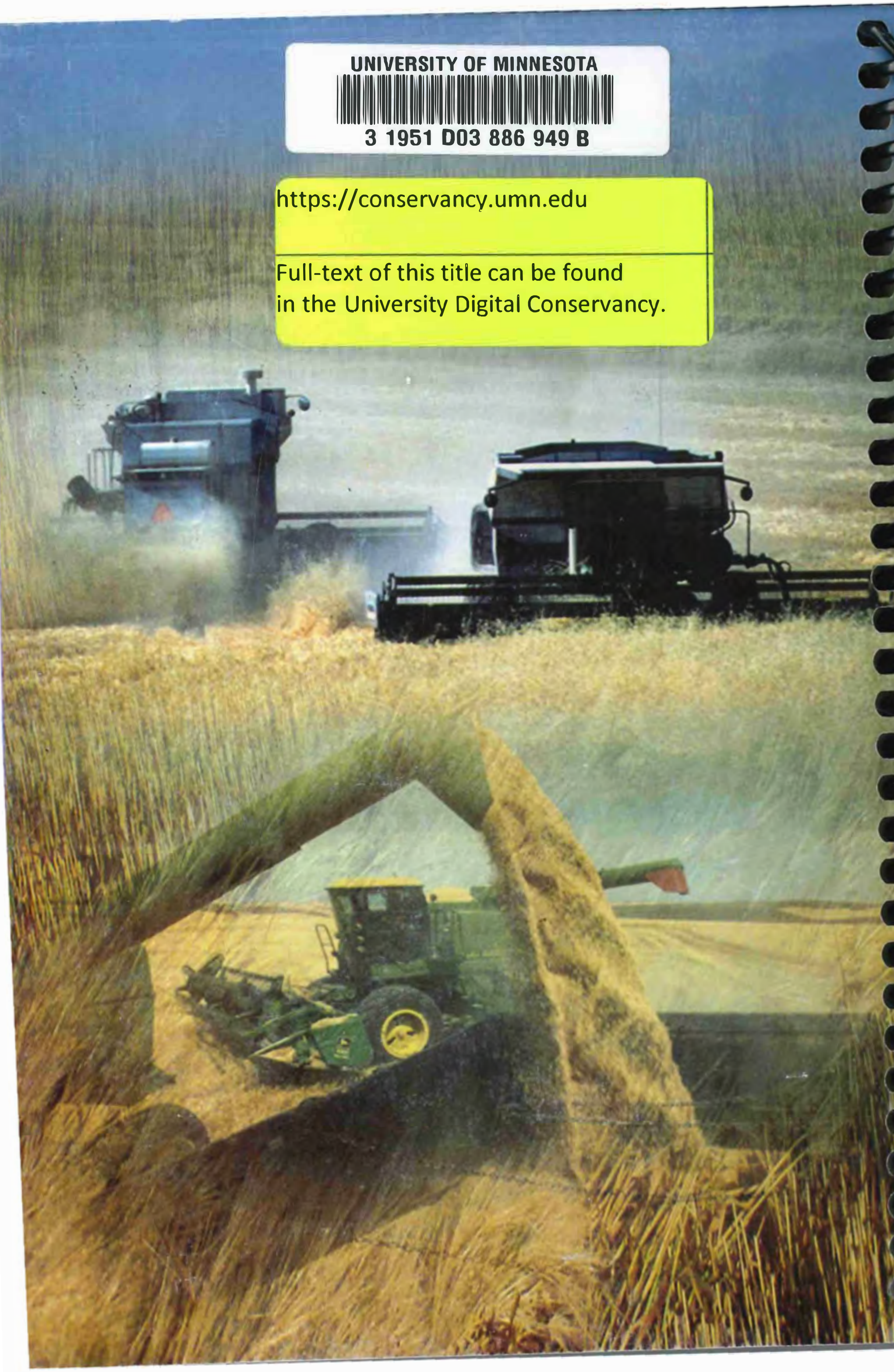

The Small Grains Field Guide

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University of Minnesota Extension Service

NDSU Extension Service North Dakota State University

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THE SMALL GRAINS FIELD GUIDE

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FOREWORD

Growing wheat, barley, or oats profitably is like piecing together a challenging puzzle. Variety selection, proper fertilization, good weed control, and the ability to identify and eliminate yield robbing diseases and pests are all pieces of this puzzle. Each piece requires attention to solve the whole puzzle profitably. This field book is intended as a quick reference and field guide for the production of wheat, barley, and oats.

In the book "Wheat Health Management," authors James Cook and Roger Veseth discuss the "four As" of crop productivity. These four As stand for absolute yield, attainable yield, affordable yield and actual yield. The authors explain each of these levels as follows: The absolute yield is what's possible with no limiting factors except the genetic potential of the crop. It is the theoretical maximum yield. The attainable yield is the yield possible in any given environment, year, and area. It is limited by the climate, weather, depth of soil, and other factors that cannot be managed. The actual yield is what's harvested in any given field. It is the outcome of the ability of the crop to respond or take advantage of the growing conditions counter-balanced by weeds, insects, diseases, soil compaction, frost, or other production problems. The actual yield is also called the allowed yield. The affordable yield is the value of the actual yield minus the production cost to achieve that yield.

When evaluating the need for inputs, it makes the most sense to have the actual yield approach the attainable yield, such that each additional amount of the input will at least pay for itself. Although we are working in a biological system, in this guide we assume each management practice will function somewhat independently of other factors. For several of the management practices, we have very well to reasonably well-defined decision guides. Soil testing and setting a reasonable yield goal (a.k.a. the allowable yield) will allow you to calculate your fertilizer needs to within the pound. For wild oats and other weeds we have thresholds available which will allow you to determine whether the use of herbicides will be profitable. We have a foliar fungicide decision guide for leaf diseases including Septoria, tan spot, powdery mildew and leaf rust. There is a degree-day based threshold for orange wheat blossom midge that can be used to track population peaks. Even for Fusarium Head Blight or scab, we have some very good environmental models that will help in the decision-making process. One underlying theme should resonate throughout this guide very clearly - if you want to control input costs, you will have to scout the crop. Only then can you make sound, economic decisions.

The information presented is organized around disciplines rather than around crop species to eliminate redundancy, as there are many similarities between wheat, barley, and oats. If and when differences are pertinent, specific data is presented for the crop in question. The book contains 10 sections: Agronomic Management, Crop Growth & Development, Fertility Management, Pesticide Management, Weed Management, Disease and Pest Management, Harvest and Storage Management, Marketing, Photographs, and Useful Internet Resources.

HISTORY OF WHEAT, BARLEY AND OATS IN MINNESOTA AND NORTH DAKOTA

In 1803 the United States negotiated the purchase of the Louisiana Territory from France for $15 million. With this single treaty, the threat of war with France was averted and the size of the young country was doubled. The purchase included over 600 million acres at a cost of less than 3 cents an acre. It opened up the heart of the American continent and allowed the land west of the Mississippi to be settled.

The Louisiana Purchase included the southern half of Minnesota and about half of North Dakota. Being part of the Oregon Country, the British Empire laid claim to the Red River and Devils Lake basins.

The Minnesota Territory was established in 1849 and included Minnesota and the eastern half of the Dakotas up to the Missouri River. There were only 5,000 white settlers in the whole territory at that time. These earliest settlers introduced wheat, barley, and oats to both states.

Wheat was not commercially important until 1858, after which production skyrocketed. By 1868, 62 percent of the cultivated land in Minnesota was devoted to wheat. The majority was grown in the southern part of the state.

Wheat production did not start in the Red River Valley until 1873. In the twenty years that followed, wheat almost completely disappeared from the southern part of Minnesota, and the center of production gravitated to North Dakota and the western and northwestern part of Minnesota.

Beginning in 1880 and for 50 years thereafter, Minneapolis was known as the "Flour Milling Capital of the World." The mills along the banks of the Mississippi received grain via rail lines stretching across the Northern Plains' grain belt. At the industry's peak, the Washburn A Mill was the most technologically advanced and the largest in the world. It could mill the flour needed for 12 million loaves of bread in a day.

Since those boom times, the flour mills in Minneapolis have long been closed. Small grains, however, continue to have a prominent place in the cropping systems of Minnesota and North Dakota. Combined, the two states account for a third of the total U.S. barley production, more than half of the U.S. spring wheat production and nearly three quarters of the U.S. durum production.

CHAPTER 1 - WATER MANAGEMENT

IRRIGATION For high yields, small grains need 14 to 17 inches of water depending on weather conditions and length of growing season. The water used for optimum growth is a combination of stored soil moisture, rain and irrigation. Small grains require about six inches of water as a threshold for grain yield. Each additional inch of water will provide four to five bushels per acre. In deep, well-drained soils, the roots of small grains will extract water to a depth of 3 to 3.5 feet.

Irrigation water management is most needed when farming on sandy soils to provide sufficient amounts of soil water to minimize moisture stress. Small grains are most sensitive to water stress in the boot to flowering stage of growth. Root-zone water deficits should be reduced to low levels during this period. Small grains are susceptible to fungal infections. Most small grains are irrigated with center pivots, so it is better to apply at least an inch of water per irrigation rather than more frequent small applications. Wheat and barley are particularly susceptible to Fusarium Head Blight (FHB) just prior to flowering through early grain filling. Irrigation during this period should be avoided if possible, so root zone water should be brought to a high level prior to flowering.

During the peak water use period, small grains can use up to 0.30 inches per day depending on air temperature and cloud cover (Tables 1.1, 1.2 and 1.3). Daily crop water use -- often called evapotranspiration or ET -- depends on plant development and local weather conditions. Small grain water use will generally peak between heading and early dough stage. Daily ET estimates in the following table are based on long-term average solar radiation and cloud cover. Daily ET estimates in northwestern Minnesota may be 5 percent to 10 percent greater than estimates found in Table 1.1 for central Minnesota because there is a greater chance for a clear and cloud-free sky.

Table 1.1 Average water use for wheat in inches/day in Central Minnesota.

Temperature	Week after emergence													
°F	1	2	3	4	5	6	7	8	9	10	11	12	13	14
50-59	.02	.03	.05	.06	.08	.09	.10	.10	.09	.09	.07	.05	.03	.02
60-69	.03	.05	.07	.09	.12	.13	.15	.14	.13	.13	.10	.07	.05	.03
70-79	.04	.07	.10	.12	.17	.17	.19	.19	.18	.17	.13	.10	.07	.04
80-89	.05	.08	.12	.16	.20	.22	.24	.24	.22	.21	.16	.12	.08	.04
90-99	.06	.10	.15	.18	.24	.26	.29	.28	.26	.25	.19	.15	.10	.05
Wheat Growth Stages			↑ Tillering		↑ Jointing		↑ Heading		↑ Early Milk		↑ Early Dough	↑ Hard Dough		

Real-time daily crop ET estimations during the growing season can be obtained from the Internet. For North Dakota, go to http://ndawn.ndsu.nodak.edu/index.html and for Minnesota go to www.soils.wisc.edu/wimnext.

For detailed instructions on how to apply the daily crop water use estimates from these tables within an irrigation scheduling program, review the irrigation scheduling in the ***Checkbook Method*** bulletin from the University of Minnesota Extension Service or order a copy of the North Dakota State University Extension Service Bulletin # AE792.

Table 1.2. Average water use for wheat in inches/day for North Dakota.

Temperature	Week After Emergence													
°F	1	2	3	4	5	6	7	8	9	10	11	12	13	14
50-59	.01	.03	.04	.06	.07	.08	.08	.08	.08	.08	.07	.06	.04	.03
60-69	.02	.04	.07	.10	.12	.14	.14	.14	.14	.14	.12	.10	.07	.04
70-79	.03	.06	.10	.13	.17	.19	.19	.19	.19	.19	.17	.14	.10	.06
80-89	.04	.08	.12	.17	.22	.24	.24	.25	.25	.25	.22	.17	.12	.08
90-99	.05	.10	.15	.21	.26	.29	.30	.30	.30	.30	.27	.21	.15	.09
Growth Stages			↑ Tillering		↑ Jointing	↑ Boot	↑ Heading		↑ Early Milk		↑ Early Dough	↑ Hard Dough		

Table 1.3. Average water use for barley in inches/day for North Dakota.

Temperature	Week After Emergence												
°F	1	2	3	4	5	6	7	8	9	10	11	12	13
50-59	.01	.03	.04	.06	.07	.08	.08	.08	.08	.08	.07	.06	.04
60-69	.02	.04	.07	.10	.12	.14	.14	.14	.14	.14	.10	.10	.07
70-79	.03	.06	.10	.13	.17	.19	.19	.19	.19	.19	.13	.14	.10
80-89	.04	.08	.12	.17	.22	.24	.24	.25	.25	.25	.16	.17	.12
90-99	.05	.10	.15	.21	.26	.29	.30	.30	.30	.30	.19	.21	.15
Growth Stages			↑ 4-5 Leaf				↑ Heading			↑ Milk			

Drainage Drainage is a necessary soil water management practice on many farmlands to remove water in excess of field capacity, improve field operations, and stabilize year-to-year yield variability. Both surface and subsurface (tile) drainage are important in water management. The combination of the two often provides the best response to excess moisture. No long-term yield response to drainage has been measured for small grains in Minnesota or North Dakota. Previous research has shown that on a clay loam soil, wheat may reach only 58 percent of its potential yield when the water table is within 15"-20" of the soil surface for extended periods of time. Check with your local Extension office and the local Soil & Water Conservation District (SWCD) office for potential yield response information related to improved drainage.

The first step in developing a drainage plan for a farm is to evaluate the feasibility of drainage by consulting the Minnesota Drainage Guide, state drainage laws, local drainage experience and expertise, and by evaluating soil survey information, wetland restrictions, downstream impacts, and economic factors. Next, further evaluate the site by identifying

outlet locations, conducting topography surveys, and making field evaluations (surface and subsurface). Visiting your local NRCS, SWCD, and/or Watershed office is an important first step in getting the process going, and for help in interpreting current wetland legalities and local restrictions.

Outlet Considerations A drainage outlet must provide for free discharge into a ditch or waterway where the flow can be carried away from the field. A drainage design for any field or farm must begin at the outlet. Tile outlets are typically located 3 to 5 feet below the elevation of the field. The bottom of an outlet pipe must be located above the water level in the receiving ditch or waterway, except during times of very high flows. Drainage outlets must be kept clean of weeds, trash, rodents, and be protected from erosion around the outlet, and damage from machinery or cattle. Where topography does not allow for a gravity outlet, pumped outlets are used, provided a surface waterway exists to discharge the drainage water. A pumped outlet or "lift station" provides the lift required to get the drainage water from the elevation of the tile to the ground surface and into the receiving waterway. Pumped outlets add to the initial monetary outlay and operation/maintenance costs of the drainage system, but have proven to be economically feasible in many situations. A pumped outlet station includes sump, pump, and discharge pipe. Important design considerations include size and shape of sump and capacity of the pump.

Drainage Pipe Size and Grade Drainage mains and laterals should be selected to provide for the desired amount of water removal, commonly referred to as the drainage coefficient. This will typically range from 3/8 to 1/2 inches of water removal per day. If some surface water is to be drained by open surface inlets, the drainage coefficient for that area should be increased to 3/4 to 1 inch per day. Refinement of these guidelines should be done in consultation with local experts. Table 1.4 shows the maximum land area that different tile sizes can accommodate, at selected grades, for a 1/2-inch drainage coefficient. For other sizes, grades, and drainage coefficients, consult a drainage engineer, contractor, or the ***Minnesota Drainage Guide***. Tile drains must not be installed at less than the minimum recommended grades, shown in Table 1.4, to prevent soil from settling within the tile.

Drainage Tile Spacing and Depth Although many combinations of tile spacing and depth can produce the desired water removal rate, spacing and depth should be based on soil type, soil permeability and stratification, desired drainage coefficient, and degree of surface drainage. Table 1.6 shows some very general spacing options that might be considered during the early planning phase for a new or improved system. These values should be refined for specific soils with information from the Minnesota Drainage Guide and local experience.

Surface inlets offer timely removal of ponded water within a field. But, these inlets can provide a direct pathway for surface waters that may carry sediment and other pollutants to downstream rivers, which otherwise may have been trapped in the field. The general public, researchers, and others are concerned about the potential impacts these inlets may have on the downstream water flow and quality. Some farmers are converting their open inlet to a "blind" or "rock" inlet. University researchers and others are investigating the flow and water quality impacts of alternative inlet designs, such as raised pipe, blind inlets with rock and sand filters, grass buffer strips and reduced tillage.

Installation Method Farmers have the option of hiring a contractor to install their drainage system or doing the job themselves with a towed implement. While the latter is certainly an option, it is one that must be carefully considered. One major consideration of your tile installer is experience and familiarity with design procedures and standards of tile drainage systems. Depth, grade, pipe size, and field layout are all extremely important in design and will determine the quality of performance of your system. The lifespan of corrugated plastic tile can be quite long—decades, if not generations. Once the tile is in the ground, it's there to stay, so make sure the installation is done correctly to avoid performance and longevity problems.

Table 1.4 Potential acres drained by selected tile sizes and grades of corrugated plastic tile with drainage coefficient = 1/2 inch/day.

% Grade	4"	5"	6"	8"	10"	12"
.10	2	4.5	8	15	25	40
.25	4	7.5	12	25	40	65
.50	6	11	17	36	58	92
1.00	8	14	23	50	80	130
2.00	12	20	32	72	118	185

Table 1.5 Minimum grades for tile drain lines (when not subjected to fine sand or silt).

Drain Size, Inches	% Grade (ft/100 ft)
3	0.10
4	0.07
5	0.05
6	0.04

Table 1.6 General parallel tile lateral spacing and depths for different soils.

Type of Soil		Drainage Coefficient			Depth
	Subsoil Permeability	1/4"	3/8"	1/2"	ft
Clay loam	Very low	70	50	35	3.0 - 3.5
Silty clay loam	Low	95	65	45	3.3 - 3.8
Silt loam	Moderately low	130	90	60	3.5 - 4.0
Loam	Moderate	200	140	95	3.8 - 4.3
Sandy Loam	Moderately high	300	210	150	4.0 - 4.5

Authors: Jerry Wright, Thomas Scherer, and Gary Sands

CHAPTER 2 – CROP ROTATIONS

Crop rotation is the order that specific crops are planted on the same field. The order a small grain crop is included in a rotation can have an important impact on grain yield and/or grain quality. When selecting a rotation, the long-term viability of that rotation to reduce weed, insect, and disease pressure, and its economic viability, must be considered. A well-developed plan that can be altered when necessary should always be followed. Otherwise, the desired crop sequence may be interrupted and the maximum benefits of the rotational effect will not be obtained. Important questions to consider when designing a crop rotation, regardless of location are: How will previous crops affect subsequent crop production? Will the previous crop increase or decrease concerns in several dimensions including disease, insect, weed pressures, soil fertility and soil structure? Given the diversity of crops grown in Minnesota and North Dakota plus the large number of potential crop sequences, research directed towards developing crop rotation recommendations is complex to implement and difficult to interpret. Nevertheless, research has established a number of principles that should be considered when establishing a rotation plan. These principles include:

- Small grains almost always yield better following another crop than when following other small grains
- Rotations can control or reduce disease, insect and weed pressure
- Rotations can improve soil fertility and soil structure
- Rotations help manage available soil moisture
- Diversity in crops grown can spread out field work, harvest time and reduce risk

Rotations consistently offer a yield advantage over continuous monocropping. Numerous studies have demonstrated the yield advantage of rotating small grains as compared with continuous small grain cropping. Often the yield advantage of the rotation can be traced to reduced levels of diseases or insects. Sometimes, however, this yield advantage cannot be attributed to any known observable factor; the crop just grows better. This is often referred to as the rotation effect. Rotation studies in Fargo over a nine-year period showed a 40 percent, 20 percent, and 15 percent increase in grain yield when wheat followed soybeans, sunflowers, or flax, respectively, as compared with continuous wheat. Recent research conducted by the USDA-ARS lab in Mandan, ND, where more than 100 crop combinations were grown in rotations, spring wheat was invariable the lowest yielding when preceded by spring wheat (Table 2.1). Similarly, barley following barley was lower yielding than when following any of the other preceding crops. This study is a rich source of information on cropping sequences, particularly for environments like those of south-central North Dakota. The results of this study have been summarized and are available on an interactive CD called the ***Crop Sequence Calculator*** available from the USDA's Northern Great Plains Research Labòratory in Mandan (www.mandan.ars.usda.gov). This research clearly shows that to optimize yield do not grow a small grain crop after a previous small grain crop of the same species.

Table 2.1 Grain yield of hard red spring wheat in the third year of selected crop sequences.

Sequence	Yield (bu/A)
1. Barley --Wheat -Wheat	42
2. Wheat - Wheat -Wheat	44
3. Wheat -Dry Beans -Wheat	49
4. Barley - Dry Beans - Wheat	54
5. Soybean - Dry Beans - Wheat	58

Source: Adapted from data contained in the Crop Sequence Calculator, USDA-Mandan.

Rotations can be an important method of controlling or reducing disease, insect and weed pressure. Pests that are more mobile are more difficult to control with crop rotation. For many environments in Minnesota and North Dakota, the most important reason for rotating small grains is to reduce disease pressure. Table 2.2 summarizes some of the small grain diseases that are controlled or reduced in severity through rotation. Given the severity of Fusarium Head Blight (FHB) in Minnesota and North Dakota, special attention should be given to avoiding rotations where wheat or barley follows another small grain crop or corn because residues of these crops can harbor Fusarium spores and predispose a subsequent small grain crop to FHB damage when environmental conditions are favorable.

Table 2.2 Common diseases in small grains entirely or partially controlled by rotation.

Disease	Crop affected	Control methods
Common root rot	Wheat, barley, oat	Rotation, seed treatment
Ergot	Wheat	Rotation, tillage
Bacterial blights	Wheat, barley, oat	Rotation
Fusarium Head Blight	Wheat, barley	Rotation, resistant varieties, fungicide
Tan spot	Wheat	Rotation, resistant varieties, fungicide
Septoria	Wheat, barley, oat	Rotation, resistant varieties, fungicide

Several small grains insect pests can be controlled or reduced with appropriate rotations (see Table 2.3). Furthermore, rotations offer options for reducing weed pressure and controlling problematic weeds. Crops that are planted at a different date than small grains, that have differing growth habits, or use different herbicides than a small grain crop, offer opportunities to reduce the build up of weeds that could become problematic in a continuous cropping situation. For example, perennial weeds such as Canada Thistle and quack grass can easily be controlled in a preceding crop of RoundupReady© soybeans, but could quickly become problematic in a continuous wheat rotation.

Table 2.3 Common insects controlled partially or entirely by rotation.

Insect	Crop affected
Wheat stem maggot	Wheat
Wheat stem sawfly	Wheat
Hessian fly	Wheat

Crops differ in water requirements and rooting depth, which can be important factors to consider, particularly in environments where water is frequently the most limiting factor of crop production. Table 2.4 summarizes the water use and rooting depth of selected crops near Mandan. Corn was not included in the study summarized in Table 2.4, but can have a rooting depth of 4 to 4.5 feet and is a relatively heavy water user. Growing two heavy water using crops in a row can increase the risk of crop losses. Furthermore, growing crops with differing rooting depth sequentially is a good way of exploiting water that may not be available to a shallower rooting crop. Too few water-using crops on the other hand may result in saline seep problems.

Table 2.4 Crop water use and maximum observed rooting depth averaged over two years (1999 and 2000), Mandan, ND.

Crop	Water use (inch)	Root Depth (ft)
Barley	11.8	N/A
Canola	12.8	4.0
Dry Beans	12.8	3.3
Field Peas	11.6	3.2
Flax	12.4	N/A
HRSW	12.4	4.1
Soybean	13.3	3.5
Sunflower	15.0	5.0

Source: Adapted from data contained in the Crop Sequence Calculator, USDA-Mandan.

Most crops adapted to Minnesota and North Dakota with potential for rotations are included in Table 2.5. Rotational benefits are maximized when crops from a common group do not follow each other in a rotation. A crop can be substituted for another of the same group in a rotation without destroying rotational benefits. The best rotational benefits are achieved when crops from groups I and II precede group III. Crops from group IV should never precede group III. Including warm- and-cool season crops in a rotation will spread planting and harvest workloads.

Table 2.5 Crops adapted for production in Minnesota and North Dakota.

	Crop Group			
Crop Type	I	II	III	IV
Cool season crop	Field pea, canola, mustard, crambe	Potato, sugarbeet, flax	Wheat, barley, durum, oats, winter wheat, rye	
Warm season crop	Dry bean: pinto, navy, black turtle; soybean; sunflower	Buckwheat, flax		Corn, sudan grass, millet
Perennial		Alfalfa		

Table 2.6 Potential rotations in Minnesota and North Dakota that include small grains.

Rotation	Year 1	Year 2	Year 3	Year 4	Year 5
One	Wheat (III-C)[1]	Corn (IV-W)	Soybean (I-W), or Canola (I-C)		
Two	Barley (III-C)	Dry bean (I-W)	Wheat (III-C)	Sunflower (I-W)	
Three	Sugarbeet (II-C)	Wheat (III-C)	Soybean (I-W)	Wheat (III-C)	
Four	Wheat (III-C)	Canola (I-C)	Barley (III-C)	Flax (II-C)	Soybean (I-W)
Five	Wheat (III-C)	Canola (I-C)	Barley (III-C)	Sunflower (I-W)	Dry pea (I-C)
Six	Wheat (III-C)	Canola (I-C)	Corn (IV-W)	Sunflower (I-W)	Dry pea (I-C)
Seven	Winterwheat (III-C)	Canola (I-C)	Barley (III-C)	Field pea (I-C)	Flax (II-C)
Eight	Wheat (III-C)	Corn (IV-W)	Canola (I-C)	Flax (II-W)	Alfalfa (II-P) years 5-7

[1] Roman numerals refer to crop group, C= cool season, W = warm season, and P = perennial.

ROTATION ONE

Strengths -- Two years between any one crop. The potential for scab is less than growing continuous small grains. Legumes in the rotation provide nitrogen for the following crop. Two years between broadleaf reduces the potential for sclerotinia. The rotation includes both cool- and warm-season crops.

Weakness -- Using corn in same rotation with small grains leaves the potential for the survival of Fusarium (scab) fungus on corn residue.

ROTATION TWO

Strengths -- Two years out of wheat or barley can break foliar and head diseases common to wheat and barley. Legumes provide nitrogen for the small grains grown in following years. Including both cool- and warm-season crops spreads planting and harvest time, and reduces the potential for wheat midge.

Weakness -- Only one year between wheat and barley can increase the potential for scab, spot blotch, and root rot. One year between broadleaf crops increases the potential for sclerotinia. Substituting flax in the second or fourth year will reduce this problem.

ROTATION THREE

Strengths -- Includes two unrelated broadleaf crops. There is a nitrogen advantage from sugarbeet tops and legumes. Includes warm- and cool-season crops.

Weakness -- Sugarbeet production is not an option when sugarbeet contract acreage is not available. A potential herbicide carryover to sugarbeet.

ROTATION FOUR

Strengths -- Achieves two year break between barley and wheat crops, but not between wheat and barley, reducing head and foliar disease potential. Wheat does well following soybeans. Herbicide rotation is possible and volunteers are controllable. Volunteer flax control in dry beans or sunflowers is difficult. Residue management is achievable.

Weaknesses -- Sclerotinia soil levels may be maintained, although the risk is low. There is only one opportunity to change planting dates. There is a frost risk with soybeans. Herbicide carryover is a potential problem.

ROTATION FIVE

Strengths -- A two-year break from small grains. Small grain disease probability is reduced and residue management is achievable. Volunteer crop management is also achievable. The wheat protein and yield is good following peas. Legumes are included in rotation.

Weaknesses -- Canola, sunflowers, and dry peas are susceptible to sclerotinia. Only one late planted crop. Canada thistle control is difficult. Peas lost to disease are not insurable with crop insurance.

ROTATION SIX

Strengths -- Two warm-season crops. High water use intensity. Three years between wheat and barley. Manageable volunteer and resistant weed control. Residue management possible. Herbicide rotation possible. Perennial weed control possible

Weaknesses -- Three crops susceptible to Fusarium (scab fungus). Two crops sensitive to sclerotinia. Frost risk to corn.

ROTATION SEVEN

Strengths -- Only one crop with high sensitivity to sclerotinia and scab. Low surface residue production. Good weed control is possible. Legumes are included. Fall planting helps with spring seeding workload.

Weaknesses -- No warm season crop. Only one deep-rooted crop. Possible winter kill of winter wheat. The harvest schedule is compressed.

ROTATION EIGHT

Strengths -- Three or more years of deep-rooted crop. Sclerotinia and scab risk on wheat is low. The potential for insect problems is minimized. Multiple choices for weed control.

Weaknesses -- The three years of deep-rooted crops may create a moisture shortage for wheat. The market for alfalfa may be limited and requires additional equipment for haying or hiring of a custom operator.

(Adapted from: Crop Rotations for Increased Profitability. M.D. Peel, North Dakota State University)

Authors: Jochum Wiersma and Joel Ransom

CHAPTER 3 – VARIETY SELECTION

PRINCIPLES OF VARIETY SELECTION

Selecting the best variety for your farm or fields is a first and important step toward profitable production. The genetic make-up of a particular variety will dictate whether the variety is suited for the region, the production system in which it is planted, and the opportunity to reach its potential. If a variety is misaligned with the environment or production system, grain yield and grain quality likely will not be optimized.

Considerations that should be taken into account when selecting cultivars are:

Mix and Match The first important consideration in variety selection is the "mix and match" principle. As described in the section on interpreting yield trials, varieties do not perform the same one year to the next. Yield replication trials are needed to get a better estimate of the variety's true yield potential in a given region. Between and within locations there are differences, and this variation is due to the environment and the variety by environment interaction.

Since yield trial results are for previous years, they only are an indicator of how a variety may perform in subsequent years. Different weather and/or occurrence of a disease can change the performance of a variety, and the ranking of the variety relative to other varieties. The best defense is to mix and match a number of varieties rather than using a single variety in all the fields on the farm. This hedging approach can be best compared with spreading risk by investing in a mutual fund rather than a single stock. By selecting two or three varieties instead of one, you hedge against the potential that one of the varieties falters due to negative environmental interaction.

Maturity Wheat (spring and winter), barley, and oats are cool-season annuals. This means that the plants grow optimally in temperatures between 32° and 85°F. Above 85°F, photosynthesis -- the process that converts light energy into chemical energy -- starts to diminish to the point that it takes more energy for the plant to maintain itself than is produced. At temperatures above 90°F, photosynthesis actually shuts down completely as key enzymes become non-functional.

Because of this upper temperature limit, and the climatic conditions in Minnesota and parts of North Dakota, it is important that a small grain crop grows and matures before the heat of summer can cut the season short. In the southern counties, the earlier maturing varieties have a better chance to reach their yield potential by escaping the heat. Further north, you can relax this standard as chances for hot temperatures decrease. Seeding early will avoid summer's heat during sensitive vegetative and reproductive stages.

Available Water Drought stress can be a serious constraint in some years and regions (i.e. western North Dakota). When rotated with crops that use more moisture than the annual rainfall provided the previous year, soil moisture levels can become depleted. Soybeans, sunflowers, corn and sugarbeets are examples of full-season crops that generally will use more moisture during the growing season than the annual amount they receive. In general, earlier maturing varieties and varieties that are of standard height rather than of semi-dwarf stature handle moisture stress better and reduce drought-related losses. The total amount of water it takes to produce a crop is described in more detail in the Physiology of Small Grains section later in this handbook.

Agronomic Characteristics Straw strength and tendency to shatter are two important agronomic characteristics that determine whether a variety fits in your production system. Larger acreage and a desire to straight cut the grain for harvest will favor selection of semi-dwarf varieties with good straw strength and resistance to shattering because it will allow you to harvest the crop without the worries of losing yield to either lodging or shattering. When selecting winter wheat varieties it is important that you consider winter hardiness in addition to other agronomic traits, such as yield and disease resistance. Only the most winter hardy varieties should be grown in the northern regions of the state or if planted into fields with little or no previous crop residue that might catch snow. The most winter-hardy varieties, generally those developed in ND and Canada, have a greater chance of survival when the winter is open (little snow) or when planted with little previous crop residue. In southern ND, less winter hardy varieties have been grown successfully in fields where high residue levels are maintained at seeding time.

Disease and Pest Resistance The most cost effective method of disease and pest control is to grow varieties that are genetically resistant to the particular disease or pest. Diseases that are of economic importance are mentioned in the Disease Management section of this book. Varieties are not tested and/or selected for resistance to all potential diseases and pests. Diseases of major economic importance are leaf and stem rust, septoria and tan spot, Fusarium Head Blight and root rots. When selecting varieties, consider the diseases that are predominate in your area of production and the previous crop of the field you are planning to plant, and try to match available genetic resistance with the likelihood a disease problem could develop.

For hard red spring and durum wheat, although all data presented should be considered when choosing wheat varieties, the scab epidemic in the hard red spring wheat growing areas have demonstrated the clear need to give greater attention to selecting varieties for tolerance to this devastating disease. Scab evaluations include disease severity, based on visual spread of the disease on the spike, and grain soundness, which reflect the variety's ability to maintain plump, sound kernels. These ratings should be considered together to reduce the risk of loss. The use of more than one variety to provide different days to heading and different seeding dates is highly recommended to reduce risk.

Authors: Jochum Wiersma and Joel Ransom

UNDERSTANDING GRAIN QUALITY

Small grains are purchased based on quality factors that give the buyer an indication of how these grains will perform or function in their intended end-use, such as an animal feed ingredient or as a food ingredient after milling, malting or other types of processing. Over the years grading standards and tests based on physical and/or chemical characteristics have been developed to measure this end-use quality.

The Federal Grain Inspection Service (FGIS) establishes and maintains the U.S. grain standards to provide uniform inspection. A description of the official standards and minimum requirements of each of the grades can be found at www.usda.gov/gipsa/pubs/pubs.htm.

Test weight, presence of foreign material or contrasting classes, and damaged or shrunken kernels are all part of the official grade. All elevators are bound by these official standards and are required by law to use FGIS approved methods when grading grain. Elevators will often perform additional quality tests. These tests have been added in response to specific market quality needs not currently addressed by the U.S. grain standards. Although not part of the U.S. grain standards, FGIS does prescribe approved methods for these quality tests. Examples include moisture, protein, falling number and deoxynivalenol (DON). When you dispute the outcome of the quality tests that were used to determine the grade and quality of your grain, you may appeal and have the sample tested by FGIS or a FGIS-approved service provider.

As the food processing industry becomes more competitive and automated, additional quality tests likely will be implemented in efforts to control processing and final product quality.

Wheat Moisture content is an important factor for determining storability and handling, but also for establishing factors based on specific moisture basis such as wheat protein, which is reported on 12 percent moisture basis.

Test weight measures the grain density in a bushel, and is the primary quality test for determining grade. It is an indicator of the amount of flour that can be extracted. Wheat with a high test weight has large, plump kernels that result in high milling or flour extraction with fewer bran particles or specks.

Protein is not an official grading factor, but it is a fundamental criterion for establishing economic value. Hard red spring wheat (HRSW) is usually traded on a 14 percent protein basis, since most of our domestic and international markets purchase it for the production of high protein flour for bread products requiring high levels of gluten. HRSW also is blended with lower protein wheat to boost the baking quality for bread production. Durum wheat protein also is very important. Durum wheat protein needs to be 13.5 percent or higher to produce 12.5 percent protein pasta.

Gluten is a term that refers to the protein complex that forms during the dough mixing process. Gluten proteins provide the cohesive, visco-elastic and gas retention properties of bread dough producing the open crumb structure of wheat breads. Gluten quantity and

quality vary with the six U.S. wheat market classes and determine the functionality or end-use quality. Low protein or low gluten wheat varieties (i.e., soft white or soft red winter) are preferred for cakes, cookies, crackers and pastries. High protein or high gluten wheat varieties (hard red spring and hard red winter) are used for breads, rolls, tortillas and other baked goods. Gluten quality is commonly determined using a Farinograph, an instrument that simulates the dough mixing process. Important results include absorption (optimum water needed), peak time (optimum mixing time) and mixing stability (amount of time before dough breaks down). The latter two give processors valuable information on gluten strength. Other tests measure dough extensibility. Varieties with strong gluten need to be extensible, so dough can be easily handled and processed. Processors (especially in export markets) want to specify gluten properties when purchasing wheat. At the moment, there is no quick and market applicable test to accurately test at vessel loading. However, FGIS is developing a quick gluten functionality test. In the future, wheat buyers may be able to specify gluten properties in their purchasing contracts, providing more consistent quality from shipment to shipment.

The falling number (FN) test is a relatively new test to this region. Like grain protein, it is not part of the U.S. grain standards. The FN test determines the amount of sprout damage in a sample of cereal grain indirectly by measuring the amount of alpha-amylase activity in a sample of grain. Sprout damage decreases the quality of bread, noodles and pasta. Buyers typically consider FN-values over 350 seconds to be a sound crop, while values below 300 are often discounted. Certain varieties have inherently low FN values. Thus, low FN values are possible even if there are no visible signs of sprouting.

Deoxynivalenol (DON) is a mycotoxin produced by FHB. DON is in the class of mycotoxins called vomitoxins. DON and vomitoxin are often used interchangeably. In years with high incidence of FHB, grain is routinely tested for DON levels. FDA advisory levels are 1.0 ppm for food grain products. Wheat is often discounted or rejected if the DON values are 2.0 ppm or higher, as milling typically removes 50 percent or more of the mycotoxin, which is concentrated in the bran. FHB damaged wheat has lower milling yield and contains enzymes that break down proteins and reduce the gluten strength, which reduces bread and pasta quality.

Barley The two main uses of barley are feed and malt. In addition, a small percentage of barley produced is used for food (pearled barley) or as a companion/hay crop. When considering the first two uses, variety selection is important. To sell a barley variety as malt, it has to be approved as malting barley by the American Malting Barley Association (AMBA).

Malting is a biological process that alters the physical and chemical properties of the endosperm of the kernel. Malting can be divided into four stages. Barley is first cleaned and graded. Foreign material and broken kernels are removed. The clean barley is then graded according to size. Different kernel size fractions are malted separately because of the different rates of water uptake and germination. The thinnest kernels are not malted. Following cleaning and grading, barley is steeped in water to raise the moisture content to approximately 45 percent. Upon reaching the desired moisture content, the barley is germinated for four to five days under carefully controlled conditions. Enzymes are synthesized within the kernel, and during germination some of these enzymes break down cell walls and a portion of the protein and starch in the endosperm. When this breakdown has adequately progressed, the germination is stopped by drying the grain to 4 percent or 5 percent moisture. The resultant product is called malt.

Malt is the principle ingredient used in brewing and is the major source of fermentable sugars. Malt also provides amino acids needed by the yeast, protein for beer foam, and compounds that contribute to beer flavor and color. In the initial stage of the brewing, known as mashing, ground malt is extracted in water. Barley components which were solubilized during malting are extracted. In addition, enzymes developed during germinations continue to break down endosperm components. During mashing, the most important of these reactions is the conversion of endosperm starch into fermentable sugars. Perhaps the most important malt quality parameter to the brewer is the level of malt extract. The level of extract is of great economic importance because it determines the amount of beer that can be produced from a given amount of malt. In modern malting varieties, approximately 79 percent to 81 percent of the malt can be extracted into solution. Principle components of malt extract are fermentable sugars, but it also contains proteins, peptides and amino acids.

The malting barley market standards not only include approved varieties for malting, but also the grain must meet the quality requirements. Test weight, and minimum or maximum limits for protein, germination, foreign material, skinned and broken kernels, and thin barley are all part of the U.S. grain standards.

Germination of malting barley has to be equal or higher than 96 percent. Barley with low germination does not properly modify during malting, and the level of malt extract is reduced. Low germination or dead kernels also causes other problems, such as poor filtration. Factors that can negatively impact germination include immature grain, pre-harvest sprouting, skinned and broken kernels, frost damage, kernel blights, excessive drying temperatures, and poor grain storage conditions.

Kernel plumpness for six-row malting barley should be in excess of 70 percent plump. Kernel plumpness is a good indicator of potential malt extract. Plumper kernels have a greater ratio of endosperm to hull. More endosperm indicates more starch, and thus greater malt extract. Kernel plumpness is one of the yield components. Early planting and reducing disease incidence will favor kernel plumpness. High nitrogen rates will reduce kernel plumpness, even with high grain yield.

Grain protein content for malting barley must be between 11 percent and 13.5 percent. Protein is important for a number of reasons. First, there is an inverse relationship between protein and malt extract. Higher protein grain tends to be thinner, have a low endosperm to husk ratio, and yield less malt extract. It also is more difficult to malt. Malts produced from high protein barley will yield beer with color and haze problems. Early planting will improve the chances for obtaining lower grain protein. Excessive nitrogen will increase grain protein above acceptable limits. However, some varieties (e.g. Foster) may meet grain protein specifications under conditions of excess nitrogen.

Skinned and broken kernels are kernels that have a third or more of the hull removed, the hull is loose or missing over the germ, broken kernels, or whole kernels that have a part or all of the germ missing. The upper limit for skinned and broken kernels is 4 percent.

Skinned kernels absorb water at a faster rate during steeping, and a high percentage of skinned kernels result in uneven growth during malting. Further, the husk protects the growing shoot during malting. When the shoot is exposed by skinning, it is easily broken off, and germination stops. Skinned kernels also seem to be more susceptible to mold growth. Broken kernels are removed by cleaning, but this represents a loss to malt companies. When broken kernels are not removed, the effects on malting and brewing are similar to those seen with poor germination. Because of these concerns, malting barley quality specifications place a limit on the level of skinned and broken kernels. Skinned and broken kernels are most often the result of poor threshing or rough grain handling. Paying close attention to combine settings and grain transfer equipment usually helps avoid these problems.

Oats When selecting and managing oats, it is important to consider whether it be used as a companion crop to establish legumes, or as a grain crop. If used as a companion crop, short and early maturing varieties with good lodging resistance are preferred because they improve the chances of a good legume stand. If grown for grain, oats is used for feed and milling. The standards for milling oats often are more rigid than the U.S. grain standards. Buyers generally are looking for clean, plump, white, bright kernels and high groat percentage.

Test weight is the primary quality test for determining grade and it will give the processor an indication of oat groat yield after dehulling. In addition, kernel and groat color are important. White seeded varieties are often preferred. Weather- or heat-damaged grain is discounted or rejected by millers.

The actual groat percentage and groat composition (which include protein, oil and ß-glucan levels) also are important quality factors. Oat groat protein content is very important, as oat protein is considered by many to have higher nutritional quality than other grains. Oats has higher oil content than other small grains, which makes it more attractive as animal feed. However, oats grown for food should be lower in oil to reduce the potential for rancidity and production of off-flavors.

IMPACT OF WEATHER AND VARIETIES ON GRAIN QUALITY:

Varieties differ genetically for quality traits, such as grain protein, test weight, and gluten strength. In addition, weather conditions impact the expression of quality traits.

First and foremost, grain protein is negatively correlated with grain yield. This means that varieties with the highest grain yield potential generally have a lower grain protein percentage. This negative correlation is caused by the physiology of grain fill and has proven to be very difficult for breeders to change. Thus, your market approach may influence variety selection. High quality wheat will generally yield less. To have an equal or better return per acre, quality premiums will need to offset the lower grain yield.

Differences in gluten functionality due to weather can be extreme. Warm and dry conditions during grain fill result in strong gluten properties even with low grain protein content. In contrast, cool and wet conditions result not only in lower grain protein content, but also weak gluten properties.

Authors: Brian Sorenson and Paul Schwarz.

UNDERSTANDING YIELD TRIALS

The University of Minnesota and North Dakota State University conduct yield trials to evaluate new and existing varieties and compare performance and agronomic characteristics. These annual trials develop performance data over a number of locations and years, also referred to as environments. Not only do varieties differ in yield in different environments, but yield relative to other varieties also may vary depending on the environment. This difference in yield is defined as a genotype by environment interaction. Understanding how genotypes perform in different environments is important for selecting a variety that will perform best for you year in and year out.

The performance of a variety in differing environments can be described as a mathematical function:

$$P = V + V x E + E$$

P = performance, V = variety, V x E = variety by environment interaction, and E= environment

Since the genotype (genetic make-up) of a wheat (or barley or oats) variety is fixed (doesn't change from year to year), differences in performance between locations and over years are a function of the environment and the variety by environment interaction. The variety by environment interaction can best be explained graphically as in Figure 3.1 In plot A, both varieties respond equally well to increased fertility. In plot B, variety 1 responds with larger increments of yield to the same increase in fertility when compared with variety 2. In other words, variety 1 takes better advantage of the additional fertility. In plot C, variety 2 initially outperforms variety 1 until the fertility reaches a certain level. Once past that level, variety 1 once again is the best yielder. The performance of the varieties in plot C results in a rank change in the varieties depending on the level of soil fertility, which can affect variety selection. The type of responses in plot C are common. Although fertility is used in this example, different factors that influence grain yield, such as temperature, moisture, or presence of diseases, can give similar changes in relative performance.

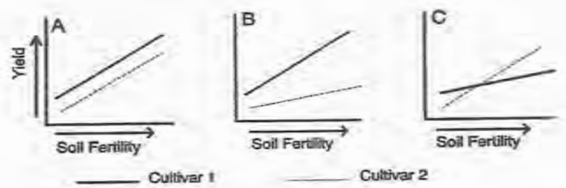

Figure 3.1. *Comparison of variety by environment interactions representing responses that might be typical for yield of two cultivars as the environment changes from low to high soil fertility (Source: Breeding Field Crops, J.M. Poehlman and D.A. Sleper)*

The existence of variety by environment interaction requires replication over a number of locations and years, such that the total number of trials represents the greatest number of environments and conditions. If this type of testing can be achieved, the ranking of the varieties is likely to be similar from one year to the next, and yield trial results become a useful tool to select varieties. Also, because of variety by environment interaction, absolute yield is less useful in variety trial data, and relative performance is more meaningful.

Importance of replicated trials The third component in the formula is the environment and error. That is the portion of the difference in performance that cannot be explained by the variety itself or the variety by environment interaction. Soil conditions are never uniform throughout a trial. Replication and random placement of each variety within each trial helps provide a fairer test for the variety and allow the researchers to estimate the error in the trial. The error estimate often is used to calculate a statistical parameter to compare varieties. The least significant difference (LSD) is a statistical method to determine if the observed yield differences between two varieties is due to varietal difference or to interactions with other variables such as a difference in soil fertility within a trial. If the difference in yield between two varieties equals or exceeds the LSD value, the higher yielding is considered superior in yield. If the difference was less, the yield difference may have been due to environment error rather than genetic differences, so we are unable to distinguish the better of the two. An LSD .05 indicates that with 95 percent confidence, the observed difference is indeed a true difference in performance. Lowering this confidence level will allow more varieties to be different from each other, but increases the chances that false conclusions will be drawn.

VARIETY TRIAL RESULTS

Small grain varieties are compared in trial plots in several experiment stations in Minnesota and North Dakota as well as in farmers' fields in numerous counties in both states. Varieties are grown in replicated plots at each location. These plots are handled so that the factors affecting yield and other characteristics are nearly the same as possible for all varieties at each location. Trials are not designed for crop (species) comparisons because the various crops are grown on different fields or with different management. The data only should be used to compare varieties within a table. For the most recent performance data, refer to the following Web sites:

Minnesota	www.maes.umn.edu
North Dakota	www.ag.ndsu.nodak.edu/aginfo/variety/index.htm
South Dakota	http://plantsci.sdstate.edu/varietytrials/vartrial.html

PLANT VARIETY PROTECTION

The Plant Variety Protection Act (PVP) was originally signed into law on December 24, 1970, and later amended on April 4, 1995. This act is a voluntary program that provides patent-like rights to breeders and developers of plant varieties. The amended act also added protection to potatoes and other tubers.

The primary purpose of the PVP is to allow plant breeders to protect their varieties to ensure that they will benefit from their development and enable them to recover their research costs. Without the PVP, the only protection available to breeders was the biological protection of hybrids so the act was passed to encourage the development of new non-hybrid varieties.

What Protection Means Varieties that are protected under the PVP can be sold or advertised for seeding purposes only by the owner of the protection certificate or with the owner's permission. The owner of the certificate may bring civil action against persons infringing on his or her rights, and may ask a court to issue an injunction to prevent others from violating proprietary rights. The damages awarded by a court must at least compensate the certificate owner for the infringement. Awards may include attorney fees and up to triple damages where willful infringement is found. The term of the protection expires 18 years after the Certificate is issued for varieties filed before April 4, 1994, and 20 years for those varieties covered under the amended act.

The passage of the amended PVP has allowed the United States to be a signatory in the International Plant Breeder's Rights Treaty (UPOV) so proprietary rights on varieties are now respected in many countries worldwide.

Types of Protection Two options for plant variety protection are available to the developer of a variety. The first option enables the developer and certificate holder to sell certified or uncertified seed of the variety. Certificate holders choosing this option must resort to civil action if their rights are infringed upon within the period of protection.

Certificate holders are not covered under Title V of the Federal Seed Act and violators cannot be prosecuted by the federal or state government. In a manner similar to patent rights, certificate holders can authorize the use of their varieties in any way they wish on a royalty or fee basis.

The second option for protecting a variety is the "certification only" option that utilizes the provision of Title V of the Federal Seed Act. Violators of these laws may be prosecuted by the federal or state government. A variety protected in this manner may only be sold as a class of certified seed. Sales of uncertified seed by variety name is a violation of the certificate owner's rights and federal and state seed laws.

Most state institutions and some private companies have chosen to protect their varieties under this option. Violations of any provision, rule, or regulation of the Federal Seed Act is a misdemeanor punishable by a fine not to exceed $2,000. Farmers who wish to produce seed of protected varieties for sale must obtain authorization from the owner of the certificate. Some acts performed without authority of the certificate owner, which constitute infringement of the owner's rights include:

1. Using seed marketed as "unauthorized propagation prohibited" to produce seed of the variety to market for growing purposes.
2. Selling or advertising for sale a protected variety.
3. Dispensing the variety to another person without informing that person that the variety is protected.

4. Importing the variety into the United States or exporting it.
5. Including a third party to commit any of the above acts.

In addition to the above infringements, sales of varieties whose Certificate of Protection was issued under the amended act after April 4, 1994, are subject to further regulations:

6. Seed protected varieties must be sold by variety name.
7. Conditioners who knowingly clean seed of protected varieties for sale are subject to the same penalties imposed on the seed sellers.

Identifying Protected Varieties It is the responsibility of the seller to inform the buyer if a variety is protected. Seed containers should be labeled indicating the type of protection for which the owner has applied. If the owner of the variety has chosen to sell either uncertified or certified seed, the label should state "unauthorized propagation prohibited – U.S. protected variety." This statement, or others similar to it as defined in the act, is sufficient notification of protection. If the seed is purchased in bulk, the appropriate statement should be printed on the bulk sales certificate.

Exemption Under the Act The original PVP specifies a farmer exemption in the "saved seed" clause that may be used by a grower who is not involved with the production of crops for seeding purposes. This exemption applies to varieties that are protected by PVPA and those protected under the "certification only" option of the Federal Seed Act and whose Certificate of Protection was issued before April 4, 1996.

Farmers whose primary occupation is the production of crops for food or feed and who have obtained seed of a variety protected under the original act, may save seed for their own use from personal crop production, or sell a certain amount to another farmer. The amount of seed that can be sold, which was established in the U.S. Supreme Court case, Asgrow vs. Winterboer, is a quantity no greater than the amount of seed that the grower originally planted to produce the seed crop. This exemption does not cover varieties whose Certificate of Protection was issued after April 4, 1994, so no sale of seed of these varieties is allowed without the permission of the certificate holder.

(Adapted from: The Plant Variety Protection Act. Colorado State University Cooperative Extension, 10/96 Authors: J. Stanelle, M.A. Brick)

Authors: Jochum Wiersma and Joel Ransom

CHAPTER 4 – ESTABLISHING A YIELD GOAL

Setting a realistic yield goal is important for developing a profitable production plan. Yield goals are used primarily in calculating the fertilizer requirements. The most frequent method used to determine a yield goal is to base it on historic production data of a particular field. Some other commonly suggested approaches to setting a realistic goal are:

1. 5-year average of the farm
2. 5-year average plus 5 percent
3. 5-year average plus 10 bushels
4. The highest yield in past five years

Consider the following factors when fine-tuning a yield goal. First, when changing to a variety with known higher yield potential, increase your yield goal to match the greater productivity of the new variety. Secondly, when using the average of the farm, adjust the yield goal up or down if experience indicates that the field in question has performed better or worse than other fields. Thirdly, adjust the yield goal upward if you made significant improvements to a field, such as improved drainage, or if you have adopted management practices that improved yields dramatically in the past few years (i.e. use of fungicide). In the western half of ND yield goals may be adjusted to account for stored soil moisture plus expected seasonal rainfall at planting time.

Should planting be delayed due to adverse conditions, the yield goal should be adjusted down to more accurately reflect the lower potential yield of a late-planted crop. For malting barley, be conservative when setting a yield goal because over fertilization can result in undesirable protein levels.

Authors: Joel Ransom & Jochum Wiersma

CHAPTER 5 – PLANTING

PLANTING DATE Small grains are cool-season annuals and are most productive when they grow and develop during cool weather. The yield potential of a crop is largely determined by the 6-leaf stage. Cool temperatures during this period are particularly important for the development of high yield potential. For example, the number of spikelets per spike is determined during the 4 to 5.5 leaf stage. Spikelet numbers are negatively correlated with temperature: Spikelet numbers are greater when temperatures during the 4.0-5.5 leaf stages are cool. One way to improve the chances that these early growth stages occur during relatively cool temperatures is by planting early. Plant as soon as is practical, but on or before the optimum date indicated in table 5.1.

Table 5.1 Average optimum seeding dates and last recommended date for small grains in Minnesota and North Dakota.

Minnesota	North Dakota	Optimum	Last Planting Date:
South of U.S. Hwy 12		1st week of April	1st week of May
South of Minn. Hwy 210	South of Hwy 13 and 21	2nd week of April	2nd week of May
South of U.S. Hwy 10	South of I-94	3rd week of April	3rd week of May
South of U.S. Hwy 2	South of U.S. Hwy 2	4th week of April	4th week of May
South of Canadian border	South of Canadian border	1st week of May	1st week of June

Research has shown that, on average, yields decreased 1 percent per day when planting is delayed past the optimum planting date. Planting after the last possible date is not recommended because the odds are greater for reduced grain yield and quality (test weight) due to heat stress.

SEED QUALITY A good plant stand is the basis for a productive crop. Stand establishment is a function of seed quality and the environmental conditions in which the seed germinates. Using good quality seed is a cost effective way to ensure good emergence. The germination test is the most commonly used measure of the viability of the seed lot. Low germination also can be an indicator that the seed lot will have poor vigor. A cold test should be performed on seed lots with poor germination to evaluate how the seedling may perform under sub-optimal conditions. Research has shown seed that was frozen during the grain filling stage or that had low falling numbers from pre-harvest sprouting may lack vigor and establish poorly. Freeze injured seed fails to develop normal coleoptile and will prevent the first leaf from reaching the soil surface.

PLANTING RATE To achieve maximum grain yield, it is important that the population is optimal. Small grains have the ability to tiller and produce several stems that can produce grain. Research has shown the main stem and the first tiller contribute the majority of the grain yield. It is important that the seeding rate is adjusted to produce a plant population which produces a main stem and one or two tillers. Another advantage a crop with few tillers has is that most stems will be in similar development stages. This narrow window for each crop stage improves the timing for crop inputs, such as herbicides or fungicides, especially for growth-stage sensitive inputs. Excessive seeding, however, can lead to lodging and poor root development. Having at least one tiller is needed for optimal root development.

The optimum population is a function of the production environment, the yield goal, and the planting date. In addition, varieties that produce few tillers may require higher seeding rates.

Table 5.2 Desired stand at harvest for the different small grains.

Crop	Plants per acre (times 1 million)	Plants per sq. ft.
Winter wheat	0.90 – 1.00	21 – 23
Spring wheat	1.30 – 1.40	30 – 32
Durum	1.30 – 1.40	30 – 32
Barley	1.25 – 1.30	28 – 30
Oats	1.25 – 1.30	28 – 30

If planting is delayed past the optimum seeding date for spring-planted small grains, seeding rates should be increased by about 1 percent for each day planting is delayed up to a maximum rate of 1.6 million seeds per acre. This increase in seeding rate will partially compensate for the decrease in grain yield and the reduction in tillering because the crop will go through its development faster as average temperatures increase during the growing season. For winter wheat, seeding rates should be increased if planting is delayed to compensate for a potential higher risk of winterkill.

Calculating the right amount of seed is an important first step toward maximizing yield. The seeding rate is a function of the number of kernels per pound of seed, the percent germination of the lot, the expected stand loss as a function of the quality of the seedbed, and the desired stand. An average optimum stand for hard red spring wheat, when planted early, is 28 to 30 plants per square foot or approximately 1.25 million plants per acre. This number should increase by 1 to 2 plants per square foot for every week planting is delayed past the early optimum seeding date. Expected stand loss, even under good seedbed conditions, is 10 percent to 20 percent and will increase with a poor seedbed or improper seed placement due to poor depth control. The general formula for calculating a seeding rate is:

$$\text{Seeding Rate (Pounds/Acre)} = \frac{\text{(Desired Stand in Plants/Acre) /(1 - Expected Stand Loss)}}{\text{[(Seeds/Pound) x (Percentage Germination)]}}$$

Calculate the seeding rate for each seed lot and calibrate the drill accordingly. An example for calculating the planting rate for wheat:

1. Desired population is 1,250,000 plants per acre at harvest
2. Historic field stand loss is 10 percent
3. Seed lot germination is 95 percent
4. Seed lot has a seed count of 15,000 seeds/pound

Then: 15,000 x 0.95 = 14,250 viable seeds per pound.
1,250,000 seeds x 110% = 1,375,000 viable seeds needed per acre.
1,375,000 seeds divided by 14,250 seeds/pound = 96.5 pounds per acre seeding rate, or 28 seeds per square foot.

The number of seeds per pound differs for each variety and can vary considerably between seed lots of the same variety. If the seeds per pound of a seed lot is not known, the most practical way to obtain this information is to count out one hundred seeds two or three times, weigh each sample and calculate the average weight per 100 kernels. Use this number to calculate the number of seeds per pound. The accuracy improves as more seeds are counted. Table 5.3 summarizes the pounds of seed needed for seed lots with different weight and for different seeding rates for a range of kernel weights and for different desired stand densities.

Table 5.3 Pounds of seed to be planted per acre assuming 15% stand loss and 95% germination.

Seeds/ pound	Desired stand (times 1 million)							
	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
	lbs/bu-							
10,000	96.8	108.9	121.1	133.2	145.3	157.4	169.5	181.6
10,500	92.2	103.8	115.3	126.8	138.3	149.9	161.4	172.9
11,000	88.0	99.0	110.0	121.1	132.1	143.1	154.1	165.1
11,500	84.2	94.7	105.3	115.8	126.3	136.8	147.4	157.9
12,000	80.7	90.8	100.9	111.0	121.1	131.1	141.2	151.3
12,500	77.5	87.2	96.8	106.5	116.2	125.9	135.6	145.3
13,000	74.5	83.8	93.1	102.4	111.7	121.1	130.4	139.7
13,500	71.7	80.7	89.7	98.6	107.6	116.6	125.5	134.5
14,000	69.2	77.8	86.5	95.1	103.8	112.4	121.1	129.7
14,500	66.8	75.1	83.5	91.8	100.2	108.5	116.9	125.2
15,000	64.6	72.6	80.7	88.8	96.8	104.9	113.0	121.1
15,500	62.5	70.3	78.1	85.9	93.7	101.5	109.3	117.1
16,000	60.5	68.1	75.7	83.2	90.8	98.4	105.9	113.5
16,500	58.7	66.0	73.4	80.7	88.0	95.4	102.7	110.0

Planting Depth Under most conditions the optimum seeding depth for small grains is 1.5 to 2 inches. The objective of seed placement is to place the seed in a zone with ample moisture, but shallow enough that the crop can emerge quickly. Adjusting and monitoring of your seeding depth are pivotal in reaching the above stated objective.

Cooler soil temperature at the depth of the seed increases emergence time. Deep seeding requires greater seedling vigor, reduces the number of seeds that emerge and may eliminate the emergence of the coleoptile tiller. The vigor of the stand is reduced, increasing the risk of seedling diseases and root rot to develop. Soil crusting, cold weather or other adverse conditions make deeper seeding risky. Unless conditions are favorable, yield losses occur due to deep seeding.

With the introduction of semi-dwarf varieties in wheat, depth control is more important because the coleoptile of semi-dwarf wheat tends to be shorter. The coleoptile is a leaf sheath that surrounds and protects the first true leaf as it grows from the seed towards the surface. If the coleoptile is shorter than the depth of planting, emergence will become difficult and the first-leaf may not reach the surface, ultimately dying, resulting in stand loss. There is a correlation between overall plant height and coleoptile length. Taller varieties tend to produce longer coleoptiles. In other words, if you are planting a taller wheat variety, you generally have more latitude with planting depth. When planting shorter semi-dwarfs, maintaining a shallower planting depth becomes crucial. Barley varieties tend to have shorter coleoptiles than wheat, demonstrating once again the need to carefully calibrate and monitor planting depth.

Replanting Decisions If the plant stand is less than optimum after emergence, carefully consider the potential of the existing crop, the cost associated with re-planting and the yield that is likely to be obtained with a late-seeded crop before deciding to replant. Carefully evaluate plant stand by walking the field and counting plants. Plant stands look much worse than they really are from a quick glance at a distance. If poor emergence or damage is not uniform, focus on those areas of the field that will likely need to be replanted. While maximum small grain yields are usually obtained from plant populations of 30-32 plants per square foot, reasonable yields can be obtained with populations as low as 14 plants per square foot. Replanting costs must be recovered from a later maturing crop that has a lower yield potential than the original seeding. Plus, replanting uses extra moisture as a function of soil disturbance.

Use the following guidelines to determine if replanting is worthwhile:

1. If reduced stand is uniform (no big skips or holes) keep stands of 15 plants per square foot.
2. If skips are large (3 to 6 ft.), or holes are 4 to 6 feet in diameter and the stand is 18 plants per square foot or less, then replant if moisture is adequate.
3. After June 1 in North Dakota and northern Minnesota, and May 15 in southern Minnesota, replant with a crop other than wheat or barley since yields are reduced by about 50 percent when planting after these dates compared with normal planting dates.

Planting Equipment Operation The double disc press wheel drill used by many growers provides best stands when traveling less than 4 mph and seeding less than 2 inches deep in a firm, optimum moisture seedbed. Faster speeds may cause extreme variation in seeding depth. Many air seeders and reduced tillage drills are designed to seed into high residue conditions. See Chapter 6, drill selections and openers for further discussion. Seeding unit design usually dictates seedbed preparation and pre-planting tillage needs.

Seeding unit settings and seed placement performance should be checked in each field. Performance should be checked frequently as seedbeds dry. Packing soil over and around seed is essential for uniform emergence and becomes critical for rough, cloddy, rapidly drying seedbeds and delayed planting. Reduced ground speeds enhance uniform seed covering and packing consistency.

Grain Drill Calibration The seeding rate tables found in your operator's manual or on the drill hopper cover are based on a standard weight per bushel for various crops. Wheat has a standard weight of 60 pounds per bushel. Due to differences in varieties and seed lots, the seed size and weight may vary from the standard. Seed metering systems are based on volume displacement. Therefore, if one lot of seed varies in size and weight from another, two different amounts of seed will be metered if the drill setting is not changed. For this reason, metering systems should be calibrated for a seed size to plant a particular population per acre.

A simple way to check calibration for gravity drop disc drills is to count the number of seeds dropped in a square foot or linear foot of drill row. To do this:

1. Operate your drill on a firm soil surface at your normal operating speed. A slow speed will drop more seed than a faster speed.
2. Count the seeds dropped in one foot of drill row.
3. Multiply the single row seed count by the following drill row adjustment factor:

Table 5.4 Adjustment Factor for different row spacing (in inches).

Row Spacing	Adjustment Factor
6"	2.0
7"	1.7
8"	1.5
10"	1.2
12"	1.0

4. Make several counts and compare the seeds counted with the values found in table 5.2. NOTE: The values listed in the table do NOT allow for reduced germination.
5. Make adjustments if necessary and repeat your calibration.

The most accurate method of determining seeding rate is to collect the seed metered from your drill over a measured distance.

The steps to follow are:

1. Measure out a distance for your drill width to equal 1/10 acre. This distance is listed in the following table.
2. Place bags under all drop tubes or place a tarp under a parked drill.
3. Operate the drill through the measured distance in the field at your normal operating speed. Or, if you prefer to do a stationary calibration, lift up the drill meter drive wheel, calculate the number of revolutions to cover 1/10 acre, engage the drill metering system and turn the drive wheel the number of revolutions to equal 1/10 acre for your drill width. To calculate the number of revolutions for your drill drive wheel, multiply the diameter of the drive wheel in inches times 3.14. This gives the distance around (circumference) your drive wheel in inches. Divide this number by 12 to give the circumference in feet. Example: 21 inch drive wheel x 3.14 = 65.9 inches; 65.9 / 12 = 5.5 feet.

4. Weigh the seed collected and multiply the weight by 10 as the amount collected was from 1/10 acre.
5. Compare this amount with the desired seeding rate. Make adjustments if necessary and repeat the calibration.

NOTE: This procedure can also be used to check the calibration of fertilizer applicators.

Table 5.5 Distance to complete 1/10 acre for different drill widths.

Drill Width Feet	Distance Feet
6	726
7	622
8	544
9	484
10	435
11	396
12	363
13	335
14	311

Air Seeder Calibration The air delivery system makes it difficult to collect seed at the openers with a tarp or in the bag. These units usually have a catch box directly under the seed bin designed for calibration and a hand crank to measure out the seed over a particular distance. They are usually designed to catch seed from 1/10 acre. Follow the instructions in the operator's manual for hand crank revolutions and make adjustments in the seeding rates.

Stand Counts Taking a stand count early in the season when the crop has emerged is a good practice. It allows for an evaluation whether seedbed preparation and planting went as planned, and whether the intended stand can be achieved. The easiest time to do a stand count is when the crop is in the two- to three-leaf stage because tillers are not yet visible.

To do a stand count, use one of the following two methods:

1. Count the number of plants in a foot of row at several locations in the field. Take an average and convert to plants per acre using Table 5.6.
2. Use a hula-hoop, let it fall, and count the number of plants inside the hoop. Repeat this at random several times across the field and calculate an average. Use Table 5.7 to convert the count to an approximate population per square foot or acre.

Table 5.6 Average number of plants per foot of row for different row spacing and plant densities per acre.

Row Width	Plants per acre (times 1 million)							
	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
6"	9.2	10.3	11.5	12.6	13.8	14.9	16.1	17.2
7"	10.7	12.1	13.4	14.7	16.1	17.4	18.7	20.1
10"	15.3	17.2	19.1	21.0	23.0	24.9	26.8	28.7
12"	18.4	20.7	23.0	25.3	27.5	29.8	32.1	34.4

Table 5.7 Adjustment factors to multiply the number of plants inside a hoop and convert the number to number of plants per acre.

Hoop Diameter	Multiply by
30"	8,900
32"	7,800
34"	6,900
36"	6,200
38"	5,500

Authors: Jochum Wiersma, Joel Ransom and Vern Hofman

CHAPTER 6: NO-TILL PRODUCTION

No-till is not just a drill. It is also a production system without primary or secondary tillage prior to, during, or after crop establishment. Herbicides are used primarily for weed control. Low-disturbance direct seeding is the same as the traditional no-till, zero-till or slot-till. Single discs or narrow knifes are used to disturb only a narrow strip of soil by the openers retaining nearly all of the residue on the surface between rows.

Improvements in equipment and crop management during the past two decades, along with cropping flexibility under USDA farm programs has increased the success of no-till production systems. In addition, the NRCS provides incentive payments to producers to implement no-till production systems through the EQIP program.

The use of no-till practices to produce small grain crops has gained wide acceptance among farmers in southwestern North Dakota with nearly 50 percent of the acres seeded using these practices (Table 6.1).

Table 6.1 No-till practices adoption rate for spring seeded small grains in North Dakota by cropping District (source CTIC).

Cropping district	1989	1994	2004
		%	
Northeast	0.2	1.9	0.2
East central	2.5	4.9	3.9
Southeast	3.6	6.3	21.5
Central	1.4	1.4	13.3
North central	2.6	4.2	3.2
Northwest	1.0	4.3	17.2
West central	0.7	4.0	26.2
South central	0.5	1.4	25.6
Southwest	3.7	20.3	47.3
North Dakota	1.7	4.8	17.2
Minnesota	0.8	1.6	0.8

The primary reasons to adopt no-till practices are: 1) Labor and fuel savings by reducing the number of passes across a field; 2) Equipment cost savings, since tillage equipment is no longer needed; and 3) Yield increases. In western North Dakota, research has demonstrated that spring wheat yields increased on average 47 percent with no-till (Table 6.2).

Table 6.2. Tillage effect on hard red spring wheat yields at Dickinson, ND. CT = conventional-till (< 15% residue); RT = reduced-till (30% residue); NT = no-till (> 80% residue remaining after seeding). (Carr, PM, 2004).

Tillage system	2000	2001	2002	2003	2004	5-yr Average
CT	33	46	28	29	20	31.2
RT	38	47	30	30	24	33.8
NT	48	56	39	49	32	44.8

In addition to the yield benefit, no-till practices reduce runoff, soil erosion, improves soil quality, reduces weed pressure, decreases the movement of pesticides and fertilizers to ground and surface water, increases wildlife numbers, and has the potential to sequester more carbon than conventional tillage systems.

Residue Management The previous crop's residue is a resource to conserve and use, not a nemesis that must be destroyed and buried with tillage. The previous crop's residue limits evaporation from the soil surface and maintains humidity levels in undisturbed soils between 90 percent and 100 percent, which is ideal for germinating wheat seed. Even with excellent soil seed contact, at least 85 percent of the water is imbibed by the seed in the form of vapor. In dry conditions, no-till planting systems preserve moisture in the seedbed allowing uniform germination and plant establishment to occur. Residue also provides a food source for beneficial fungi and bacteria as well as insect and weed seed predators. Managed properly, the beneficial aspects of residue will outweigh any negative aspects the previous crop's residue will have on this year's crop.

Crop residues should be spread during the harvest operation. Uniform distribution of crop residue will allow the drill to place seed uniformly at planting time. Windrowing residues and then expecting to spread them after harvest is difficult and ineffective. Harrows are a poor substitute for a combine with a good straw spreader or chopper. Furthermore, harrows incorporate weed seed and shattered grain into the soil thereby increasing the longevity of viable seed. During harvesting, the combine with the straw spreader or chopper operating, should be continuously moving through the field until all straw is cleared from the combine. Stopping before all the straw and chaff has cleared can result in piles in the field that are difficult to deal with at planting time. A forage chopper or a flail mower with the top removed on a windy day will work, but this will add an operation and increasing expenses. If disc openers are used for seeding, the combine header should be set as high as it can, yet gather all of the grain. Stripper headers in combination with a straw spreader or chopper improve combine efficiency and provide uniform distribution of crop residue. Leaving the majority of the straw intact connected to the soil and even distribution of the residue will reduce "hairpinning" at seeding time. If shank or narrow hoe type openers are used, then the combine header should be set low enough to cut the straw to lengths that are no longer than the width between the openers. This will allow straw to flow around shanks and reduce but not eliminate plugging from residue buildup on the drill. In any case, residue must be managed in a no-till planting system to ensure that the drill is capable of effectively handling it to the best advantage. Crop rotations also can be used to effectively manage crop residue. Low residue-producing crops such as pea, soybean, lentil, flax, safflower and sunflower can be alternated with high residue producing crops such as wheat.

Drill Selection Improvements in no-till planting equipment in the last two decades have improved seed placement as well as the microenvironment for seed germination, emergence, and growth. Selecting a drill for any particular planting system must successfully meet the following five criteria.

1) Precisely meter and place a wide variety of crop seeds at a uniform and intended depth and maintain the soil environment for successful seed germination and seedling emergence.
2) Seed on a soil surface which has crop residues from previous crops without destroying this residue and leaving it in an optimum configuration for soil, water, and crop protection.
3) Simultaneously place fertilizer in a parallel band with the seed row to provide the most efficient use of fertilizer by the seedling and growing plant while minimizing utilization by weeds.
4) Possess good mechanical durability to maintain the precise seeding performance throughout a long economic life without significant wear and maintenance.
5) Have a viable economical purchase cost relative to the drill's capability, durability and annual lifetime usage.

Openers Sweeps and wide hoes on air drills (Figure 1) are used in high-disturbance one-pass operations and are not suitable for low-disturbance no-till seeding. Hoe openers and sweeps move soil. Narrower points cause less disturbance than sweeps. Some of these narrow point openers (Figure 2) can place anhydrous ammonia below the seed in a separate band during the seeding operation. This system works well when soils are moist and ammonia concentrations are low, but fertilizer burn is more likely to occur in dry soils. One disc of the offset double disc opener (Figure 3) is positioned slightly forward of the other disc so the leading disc will cut or deflect residue. However, these double disc openers require more down force than the single disc opener (Figure 4) to penetrate soils to seeding depth. Note the concrete block used for weight on the back of the drill in Figure 3. In wet soil conditions, double disc openers can cause compaction and smearing of the soil. Disc openers will "hairpin" straw into the seed furrow particularly when straw is moist and flexible. Residue managers are used in row crop production planters to eliminate "hairpinning" and to allow the sun to warm the soil. The inverted –T or Cross-Slot opener (Figure 5) design virtually eliminates "hairpinning" of straw in the horizontal seed slot and places liquid or dry fertilizer in a separate band away from the seed. The opener is designed for one-pass low-disturbance seeding. The Cross-Slot opener uses parallel linkage so the opener follows the irregularities of the soil surface found in no-till conditions. A 22-inch vertical scalloped coulter cuts through crop residue. A blade on each side of the coulter cuts a horizontal slot. Seed is placed in the horizontal slot created by the left blade and fertilizer is placed in the horizontal slot created by the right blade. A scraper behind each blade on the opener prevents sticky soil and seed from being thrown up onto the surface by the coulter. The two semi-pneumatic wheels on each opener control the depth of penetration as well as pressing the soil and residue back into place thus closing the slot. The horizontal slot created by the blades plus the vertical slot created by the coulter give the opener its name.

The drill selected will determine residue management strategies and seed placement. Seeding depth in low-disturbance, no-till systems may be shallower than in conventional-

till or high-disturbance seeding if adequate residue remains in place after seeding. Double disc openers and hoe openers will need to place seed at the depth of tilled seeding.

Figure 6 is an example of a winter wheat seeding planted with a low-disturbance, no-till drill. Seed and fertilizer were placed in separate bands, but the previous crop's residue was left nearly undisturbed. The crown of the developing plant was protected from extreme temperatures, inhibiting evaporation of water from the soil, and capturing more snow. Uniform placement at intended depth will assure uniform germination and emergence (Figure 7).

The trend is toward low-disturbance drills that leave surface residues intact, preserve soil moisture, and improve soil quality capable of producing high yields. Low-disturbance direct seeding systems also reduce weed seed levels in diverse intensive rotations.

Rotations Well-planned and managed rotations with a degree of flexibility can effectively control many diseases and weed problems found in wheat in low-disturbance, no-till systems. Mobile pest problems can equally affect tilled and no-till systems. The proper intensity and diversity of the rotation will depend on the field's particular location. Rotations in western North Dakota will need to be less intense than rotations in higher rainfall areas. However, if the rotation uses less water than received during the year, the possibility of developing saline seep increases. Additional information on planning crop rotations can be found in various NDSU and UM Extension Publications. A useful guide in developing long-term rotations can be found in the SDSU bulletin, "The Power Behind Crop Rotations." This publication can be found on the DakotaLakes.com web site and an Excel spreadsheet which assists the producer in calculating intensity and diversity indexes discussed in this publication can be found on the Dickinson Research Extension Center web site, www.ag.ndsu.nodak.edu/dickinso -- Click on "Agronomy" and then click on "Automated Intensity & Diversity Worksheet" to download the spreadsheet. Also the "Crop Sequence Calculator" developed at the Northern Great Plains Research Lab at Mandan, ND, is an interactive program for viewing crop sequencing information and calculating returns. They may be contacted at www.mandan.ars.usda.gov.

Weed Control Controlling weeds once was considered by many producers to be the most challenging aspect of a no-till production system. Producers who understand weed ecology can identify weeds, select the proper herbicide, timing, and herbicide application techniques will find that weeds in no-till systems can be effectively and economically controlled. Short rotations, such as winter wheat-canola or winter wheat-flax or continuous wheat, will increase weed density in a no-till production system. A combination of preplant incorporated herbicides and a short rotation cycle contribute to weed problems. Recent studies show that if a combination of diverse rotations and effective herbicides are used, the weed seed bank will be nearly exhausted in three years if weed seeds are left on the surface such as in low-disturbance, no-till production systems.

No-till does not permit the use of preplant incorporated herbicides since they require tillage to be activated. Tillage also incorporates weed seeds and increases the long-term viability of seed. In low-disturbance, direct-seeding systems, perennial weed problems may increase, but will be more localized than what is found in tilled or high-disturbance systems. Timely spot herbicide applications can be used to control these perennial weeds. Preplant and post-harvest applications of herbicide, usually glyphosate or glyphosate in combination with other herbicides, are used to control emerged weeds and volunteer grain. Eliminating weeds and volunteer grain at least two weeks prior to planting will reduce problems from wheat streak mosaic virus in areas known to have this disease and will reduce the host population for mites, insects, and soil-borne disease. After several rotation cycles and effective weed control, some producers have eliminated some or all in-crop post emergent herbicides but maintain the glyphosate application to control emerged weeds preplant.

Since weed control is dependent on herbicide, equipment must function correctly and application techniques must be accurate. Applications should not be made when the ground is too wet. Wait a day or two for the soil to dry so the ground will support the spraying equipment and not leave ruts. In cold weather wait two to three days after freezing temperatures to allow weeds to resume active growth prior to herbicide application.

Fertilization Soil testing to determine beginning nutrient levels is suggested for no-till production. Initially, wheat producers should consider adding 30 pounds of additional nitrogen fertilizer per acre over what soil tests indicate to overcome any tie-up residue may have on applied nitrogen. After a few years, this may be discontinued and the soils lab recommendation followed. In the drier malting barley production areas of western North Dakota, leaching of nitrogen is less likely to occur, so lower application rates of 1.1 to 1.2 pounds of N per bushel of expected yield minus the soil nitrate level should be applied.

Since tillage is not an option for fertilizer placement, fertilizer source and placement may be more of a challenge. Nitrogen source and application techniques will have considerable affect on the efficiency of the nitrogen application. The potential for volatilization of urea broadcast on fields with high residue levels as found in no-till is greater than for urea that is banded or tilled into the soil. When adequate rainfall occurs within 24 hours of application volatilization is minor and urea can be used successfully. Light rainfall on heavy dews with windy conditions, can accelerate volatilization.

In low-disturbance, no-till, limited amounts of fertilizer can be placed with the seed. Too much fertilizer with the seed will cause fertilizer "burn," adversely affecting germination and establishment of the wheat crop. Some drills have the capability to place all fertilizer in a separate band away from the seed thus avoiding fertilizer burn while positioning fertilizer so it is available to the growing plant. These drills are ideal for true one-pass low-disturbance seeding.

Author: Roger Ashley

CHAPTER 7: WINTER WHEAT PRODUCTION

The acreage of winter wheat has historically been relatively small compared with spring wheat in the northern Great Plains and varies considerably from year to year. For the period 1999 to 2004, the area planted to winter wheat varied from 15,000 to 60,000 acres in Minnesota and 60,000 to 260,000 acres in North Dakota. The main constraint to winter wheat production in the northern Great Plains is winter kill. Newer varieties and production practices can reduce this risk, making winter wheat a more viable option in the cropping systems in the region. The benefits of growing winter wheat include:

1. Higher yield potential.
2. Greater profitability because it often requires less inputs than other cereals grains.
3. Reduces labor bottlenecks because it is planted and harvested during periods of few competing activities.
4. Provides cover to reduce wind and water erosion.
5. Provides cover for wildlife at key times of the year.

Characteristics of Winter Wheat Winter wheat differs from spring wheat because it requires a vernalization period before it will flower. The vernalization requirement can vary considerable from variety to variety, but generally seedlings or germinated seeds must be subject to cold temperatures (near freezing) for several weeks.

Ideally, winter wheat germinates and establishes a seedling with several leaves and perhaps a tiller before freeze-up in the fall. Winter wheat seedlings with reasonable development in the fall can withstand temperatures as low as minus 15°F if they are properly hardened (Table 7.1).

Table 7.1 Maximum number of days winter wheat can survive at different soil temperatures.

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

Growth resumes in the spring when temperatures at the crown are above freezing. Winter wheat is especially sensitive to winterkill after it breaks dormancy in the spring. Winter wheat generally produces more tillers than spring wheat and matures one or two weeks earlier. Winter wheat tends to have lower protein than spring wheat. Currently most winter wheat varieties grown in North Dakota and Minnesota are hard red winter (HRWW), though hard white winter varieties developed in Montana and South Dakota also are available.

Rotations and Planting into Residue Direct-seeding winter wheat into standing stubble is recommended in order to retain snow during the winter. Snow acts as an effective insulation and can protect the crown of the winter wheat plant from the potentially lethal low temperatures that are common during the winter in North Dakota and Minnesota (Table 7.2). Standing stubble maintains a cooler soil environment so the plant doesn't break dormancy as early as plants grown on bare soil.

Table 7.2 Predicted daily minimum temperatures at crown depth relative to two daily minimum air temperatures for differing snow depth.

Snow depth	-22°F	-44°F
	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

Three inches of snow is sufficient protection during most winters, but 4 to 6 inches of snow will further reduce winterkill. Winter wheat can be no-till seeded directly into a wide range of standing crop residues, though best results are obtained when winter wheat is direct-seeded into the standing stubble of an early maturing crop, such as barley or canola. Seeding into wheat or durum stubble will increase the risk of residue-born diseases, but even this practice is often preferred to seeding into clean-tilled fields for moisture conservation and reduction of winter kill. Winter wheat can successfully be produced after a low residue crops such as soybeans. However, only the most winter hardy varieties of winter wheat should be planted in these types of fields.

For fields tilled and not planted in the spring, a flax "residue" crop can be established in early August to facilitate snow catch. Flax can be established as a lightly seeded solid stand, in wide rows (i.e. 3-4 feet spacing) or as strips. Strips of flax 3 to 5 feet wide and 15 feet apart have been found to effectively trap snow while minimally depleting soil moisture. When seeding flax in strips or in wide row spacings, the drill should be set at a high seeding rate (40-60 pounds per acre) and drill spouts should be taped shut to obtain the desired spacing. Strips of flax more than 20 feet apart increase the risk of winter kill because they do not catch sufficient snow in most years. Flax should be seeded on or about Aug. 1 and no later than Aug. 15.

Seeding Dates -- The recommended seeding dates for winter wheat are Sept. 10 to Sept. 30 in the southern half of Minnesota and North Dakota and Sept. 1 to Sept. 15 in northern regions. Planting after the recommended dates will reduce winter hardiness and increase the potential for winter kill. Maturity the next spring is also delayed. Planting prior to the recommended date unnecessarily depletes soil moisture reserves, increases the risks of disease and winter kill. In winter wheat plantings after soybeans (or other crops that are harvested in the late fall), the earliest soybean varieties that are adapted to the area should

be grown, with winter wheat planted immediately after harvest.

Seeding Rate and Depth Winter wheat should be seeded at a rate of 900,000 viable seeds per acre (about 70 pounds per acre). Higher seeding rates are suggested for late seeding or for poor seedbed conditions. Winter wheat should be planted at 1-1½ inches deep to facilitate rapid emergence. Seeding less than 1 inch will cause the crowns of the plants to be closer to the surface of the soil than is optimum, predisposing the crop to winter kill.

Stands of winter wheat are often reduced by winter kill. Don't be hasty to destroy winter wheat stands in the spring. It may be mid-April or later before the degree of recovery is evident. Research has shown that stands of about 17 plants per square foot are required to produce maximum winter wheat yields, but stands as low as 11 plants per square foot can still produce yields of 40 bushels per acre. If only portions of the field are severely injured, stands of five to eight plants per square foot in the damaged areas can still produce satisfactory yields. This is particularly true in western North Dakota where yield potential may be lower than 40 bushels per acre.

Varieties There are numerous varieties of winter wheat that are well adapted to Minnesota and North Dakota. The most winter hardy varieties should be planted in the more northern regions and if planted into little or no residue. Currently the most winter hardy varieties are those that have been released by NDSU or Canada. Varieties from South Dakota and Montana tend to be intermediate in their winter hardiness, while those from Nebraska and Kansas tend to be the least winter hardy.

Soil Fertility Fertilizer rate recommendations for winter wheat are the same as those for spring wheat and can be found elsewhere in this book. Though broadcast applications of nitrogen can be made in the fall, winter and spring, spring applications are recommended because there is less potential for loss. Recent data indicate that early spring applications (before the 6-leaf stage) are more effective than later applications. Nitrogen applications on snow are not recommended. Snow compaction under wheel tracks destroys snow insulation properties and increases the risk of winterkill beneath the track. Movement of N offsite also is a problem on deeply frozen soils when snow melts in the spring.

Phosphorus aids winter survival by stimulating root growth and fall tillering. Where soil test results indicate phosphorus is low, phosphorous should be applied before or at the time of planting. When placing fertilizer with the seed, the combined amount of nitrogen and potassium should not exceed 10 lb/acre unless an air seeder with appropriate openers is used.

Weed Control Well established winter wheat is more competitive with summer annual weeds than spring cereal grains. The top growth of a healthy stand of winter wheat has good ground cover, which shades the soil and prevents weed germination. Annual grasses, such as wild oats and green or yellow foxtail, are rarely a problem in vigorous winter wheat fields.

The primary weed problems in winter wheat are winter annual weeds, and weeds that have the same life cycle as winter wheat. Winter annual weeds that could be problematic in Minnesota and North Dakota include horseweed, prickly lettuce, biennial wormwood, field pennycress, tansy mustard, flaxweed, shepherd's purse and several other mustard species.

Fall burn-down applications with herbicides prior to planting effectively controls emerged downy brome (cheat grass), Japanese brome, volunteer crops, and emerged annual weeds. If winter annual broadleaf weeds escape control in the fall, they can be controlled in early spring. Herbicide applications should be made when the weeds are in the rosette stage. Winter annual weeds are most sensitive to herbicides at this stage rather than later after plants have bolted (elongation of the flower stalk). Apply herbicides within the recommended growth stage of winter wheat. Application earlier or later than recommended will result in an increased risk of crop injury.

Disease Control Winter wheat is subject to the same diseases as spring wheat. Tan spot and leaf rust are of particular importance in winter wheat production.

The tan spot fungus survives on wheat stubble and straw. Tan spot is more severe and begins earlier where winter wheat has been planted into wheat stubble or straw. The fungus can cause infections in the fall and increase winter kill. Planting winter wheat into the standing stubble or straw of any other crop, including barley or oats, avoids this early build-up of tan spot. None of the currently recommended varieties are resistant to tan spot.

Leaf rust is another common fungus disease of winter wheat. Each year the rust spores blow in from the major winter wheat producing areas farther south. Currently available winter wheat varieties tend to be more susceptible to leaf rust than spring wheat varieties. A few varieties of winter wheat are susceptible to stem rust and should not be planted in Minnesota and eastern North Dakota.

Fusarium Head Blight is not as severe in winter wheat as in spring wheat because winter wheat flowers earlier, during a relatively dry period, and escapes infection. However, winter wheat varieties available for production in North Dakota and Minnesota are very susceptible to scab and could become infected if favorable weather coincides with flowering.

Fungicides can be used to help control tan spot and leaf rust as well as a number of other fungal pathogens. Additional information about disease control options can be found elsewhere in this book.

Wheat streak mosaic is a very serious disease of winter wheat in most of the region. All winter hardy varieties commercially grown are susceptible to the wheat streak mosaic virus. Affected plants develop yellow streaks on the leaves and often are stunted. An affected field may be uneven in height due to the stunting of infected plants. Wheat streak mosaic can cause moderate to severe yield reductions of winter and spring wheats and occasionally may cause complete crop failure in areas of a field. Wheat streak mosaic is a virus disease that is transmitted by the wheat curl mite, which is so tiny that it can't be seen without magnification. This mite is wind-borne from field to field. Wheat streak mosaic often spreads from volunteer wheat or other grasses (including corn) that are still green when winter wheat is planted.

Wheat streak mosaic can be controlled or reduced by the destruction of all volunteer wheat and grassy weeds at least two weeks before planting winter wheat. When possible, seed no closer than 1/8 mile to corn or fields with volunteer wheat. Planting winter wheat after

September 20th in southwest North Dakota reduces the chances of fall infections, which are extremely damaging. Earlier seeding of winter wheat often results in fall infection and build-up of the mite and virus before fall freeze-up.

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SECTION II: CROP GROWTH & SCOUTING

CHAPTER 1 - GROWTH AND DEVELOPMENT

CROP PHYSIOLOGY Wheat, barley, and oats are cool-season annuals in the grass family. Crop physiology and biochemical processes allow the crop to grow and develop. A basic understanding of these processes will result in improved crop and management decisions. The biochemical processes consist of several reactions controlled by specific enzymes. The role of enzymes is to catalyze the chemical reactions. The biochemical process that converts light energy into chemical energy is called photosynthesis and takes place in the chloroplasts. These chloroplasts contain the chlorophyll, which gives the plant its green color. Most enzymes are temperature sensitive and thus the chemical reactions have a minimum, a maximum, and an optimum temperature range. Developmental processes also are driven by temperature. Because of this, small grain growth and development only occurs within a certain range of temperatures. These temperatures are listed in Table 1.1.

Table 1.1 The minimum, optimum, and maximum growth temperatures for small grains.

	Growth Temperature		
Crop	Minimum, °F	Optimum, °F	Maximum, °F
Wheat	37-39	75-77	86-90
Barley	37-39	68-70	82-86
Oat	37-39	68-70	82-86

Photosynthesis is the conversion of light energy into chemical energy. The process consists of two chemical reactions, the **light reaction** and the **dark reaction**, which both take place in the chloroplast. The light reaction is the absorption of light energy by green plant pigments called chlorophyll, and its transformation into temporary energy-storing compounds. The process uses water and breaks it down into oxygen and hydrogen ions. The oxygen diffuses from the plant while the hydrogen ions are used to produce temporary high-energy compounds (NADPH and ATP).

The dark reaction utilizes the NADPH and the ATP to produce ribulose 1, 5 biphosphate (RUBP) that reacts with carbon dioxide to form 3-phosphoglyceric acid. The reaction that follows recycles the RUBP and produces various sugars. The enzyme that catalyzes the dark reaction, RUBP, not only can react with carbon dioxide (CO_2), but also with oxygen (O_2).

When reacting with oxygen, it produces glycolate and carbon dioxide wasting energy from the light reaction. This reduction of efficiency is called **photo-respiration** and occurs when the concentration of oxygen in the leaves is higher than the concentration of carbon dioxide. These conditions occur at high light intensities, and/or hot weather. Moisture stress also increases photo-respiration because the plants will close the stomata in the leaves to reduce transpiration, consequently reducing the exchange of oxygen and carbon dioxide from the

leaf tissue. Cool-season crops like wheat are most efficient with their photosynthesis under cooler temperatures and low light conditions.

Respiration, on the other hand, is the reduction of the sugars produced during photosynthesis into carbon dioxide (CO_2) and usable energy needed for the plant to maintain itself and grow. Respiration takes place in another cell organ called the mitochondria. Respiration is a continuous process that occurs day or night. This is in contrast to photosynthesis that only takes place during the daytime. For a plant to grow, the net result of photosynthesis minus respiration and the losses due to photo-respiration has to be positive.

Water plays a critical part in the growth of the plant. Water is needed in photosynthesis and other cellular functions. The majority of the water is used to cool the plant. **Transpiration** accounts for more than 95 percent of the water that is absorbed. Transpiration occurs as water evaporates from the above ground plant parts, especially the leaves. The ratio of total water absorbed to total dry matter produced by the plant is called the water requirement. A wheat crop of about 50 bushels per acre has a water requirement equivalent to about 10 inches. Because water also evaporates from the soil surface, the actual amount of water needed to produce a crop is higher. Under Minnesota and North Dakota conditions, small grains will need 14 to 16 inches of soil moisture per season, depending on climactic conditions, production system and the length of the growing season.

GROWTH & DEVELOPMENT OF WHEAT, BARLEY AND OATS Growth describes the increase in size and dry mater of the plant while development describes the differentiation of the plant into tissues and organs. Growth rate is determined by temperature, cultivar, availability of water and nutrients, and light intensity while development is dependant primarily on temperature and photoperiod. Thermal time as measured by growing degree days more accurately predicts development than calendar days.

Wheat can have a winter or spring growth habit based on a cold temperature requirement before flowering. Germinating seeds or emerged seedlings of winter wheat varieties need to be exposed to 4 to 8 weeks of temperatures below 38°F before they will flower. Such types are usually planted in the fall, which exposes the seedlings to cold temperatures during late fall and winter. Spring wheat varieties, however, do not require exposure to cold temperatures for normal development and can be planted in spring. The description of wheat development provided here applies primarily to spring wheat, although the basic development patterns for winter wheat, barley, and oats are similar. Figure 1.1 on page 53 shows major developmental stages in spring wheat and the approximate time intervals between them in Minnesota and North Dakota. Differences in maturity do exist among varieties. The growth cycle of wheat has the following divisions: germination, seedling establishment and leaf production, tillering and head differentiation, stem and head growth, head emergence and flowering, and grain filling and maturity.

GERMINATION, SEEDLING ESTABLISHMENT, AND LEAF PRODUCTION When a kernel is sown into moisture, the germination process begins. The radicle and seminal roots first extend, followed by the coleoptile. Roots can be initiated from several positions on the seedling, at the level of the seed and at the crown. The crown is usually separated from the seed by a sub-crown internode. The length of this internode is greater as the depth of planting increases. As the coleoptile emerges from the soil, its growth stops and the first true leaf pushes through the tip. After seedling emergence, leaves are produced at a rate of about one every 4 to 5 days. A total of eight or nine leaves are usually produced; later maturing varieties have the larger number. Emergence of the last leaf (termed the flag leaf) is an important stage for timing the application of certain plant growth regulators. For the first 3 to 4 weeks after germination, increases in root mass occurs at about half the rate of the increases in the above ground portion of the plant and rooting depth is shallow. Most roots are less than 6 inches deep until 40 days after germination. Crown roots, which eventually will be the major avenue for water and nutrient uptake by the plant, are associated with tillers and is one reason why at least some tillering is desirable. Drought stress during this early stage of development is not common, as the leaf area is limited and water use is minimal. Nevertheless, stress during this stage can reduce the number of tillers and root mass. Small grains are quite tolerant to frost during vegetative growth as the growing point is below the surface of the soil.

Tillering and head differentiation Tillering is an important development stage that allows plants to compensate for low plant populations or take advantage of good growing conditions. Tiller appearance is closely coordinated with the appearance of leaves on the main shoot. Tillers can form at the points of attachment of the coleoptile, and the lower leaves on the main shoot. The number of tillers formed depends on the variety and growing conditions. Under usual field conditions, a plant may produce a total of three tillers in addition to the main shoot, although not all will necessarily produce grain. The capability also exists to produce tillers from tillers (termed secondary tillers) if the plant is not crowded or is heavily fertilized. Tillers that appear at the time that the fourth, fifth, and sixth leaves emerge on the main shoot are most likely to complete development and form grain. Tillers formed later are likely to abort without producing grain. Tillers that produce more than three leaves and initiate their own root system are most likely to survive. The proportion of initiated tillers that abort differs with the variety, and can increase if the crop encounters stress conditions.

During the time that tillering occurs, another less obvious but extremely important event occurs with the initiation of heads on the main shoot and tillers. Although the head at this time is microscopic, the parts that will become the floral structures and kernels already are being formed. When head formation is complete, the stem begins elongating. This corresponds to the "jointing" stage. A plant usually has about five leaves at this time. Most of the yield components are fixed during the period between head initiation (4 leaf stage) and anthesis. To the extent possible, plant stresses during this period should be minimized. Cool weather during this early phase of development favors more uniform tillering and larger spikes. Drought and heat stress during the pre-jointing phase can cause tillers to abort and developing spikes to have fewer potential spikelets.

Stem and head growth Lower stem internodes on the plant remain short throughout development. The fourth internode is usually the first to elongate in a plant with nine total leaves. This is followed in sequence by the internodes above it. Each stem internode up the plant becomes progressively longer, and the last stem segment to elongate, the peduncle, accounts for a considerable proportion of the total stem length.

Stem elongation coincides with the period of rapid head growth in which the individual florets become prepared to pollinate and be fertilized. Throughout the pre-heading period, differences in the duration of the various developmental phases among shoots on the same plant help synchronize development. This means a difference of several weeks between emergence of the main shoot and a tiller is reduced to a difference of only a few days by the time the heads emerge from the flag leaf sheaths. The "boot" stage is just prior to head emergence, when the flag leaf sheath encloses the growing head. Stress during this stage of development can cause tiller death. Florets per spike is the yield component most affected by stress at this stage. Frost while the spikes are in the boot stage can cause serious yield losses because the developing florets are sensitive to freezing temperatures.

Head emergence and flowering As the stem continues to elongate, the head is pushed out of the flag leaf sheath, a stage referred to as "heading." Within a few days after heading, flowering (pollination) begins in the head, starting first with the florets in the central spikelets. Within the next few days flowering progresses up and down the spike. Flowering usually is noted by extrusion of the anthers from each floret, although this can change depending on the variety and weather conditions. If the anthers within a floret are yellow or gray, rather than green, it is reasonably certain that pollination of the floret has occurred. The period of pollination within a single head is about four days. The young kernels within a head vary considerably in size at pollination and maintain this size variation throughout grain filling to maturity. Post-flowering stress can cause floret abortion and reduction in grain weight. Small grains are extremely sensitive to high temperatures and freeze injury during flowering.

Kernel growth and maturity Growth progresses under usual conditions in three distinct phases spanning about four weeks. In the first phase, the "watery ripe" and "milk" stages, the number of cells in the endosperm (the major starch and protein storage portion of the kernel) is established. Not much weight is accumulated during this phase. Then, one to two weeks after pollination, the kernel begins accumulating starch and protein rapidly and its dry weight increases in a nearly linear manner. This is when most of the final weight of the kernel is accumulated. The kernel consistency is "soft dough" during this time. Finally, growth of the kernel declines about three weeks into grain filling and its weight approaches a maximum attained at physiological maturity. As the kernel approaches maturity, its consistency becomes "hard dough."

Growth Staging A number of staging systems have evolved for describing the development of cereal crops such as wheat, barley, and oats. The Zadoks system is becoming the most universally accepted and is described here. It is applicable to any small grain, and its stages are easy to identify in the field. The Zadoks system is a two-digit code where the first digit refers to the principal stage of development beginning with germination and ending with kernel ripening. Table 1.2 gives the nine principal growth stages. The second digit (also between 0 and 9) subdivides each principal growth stage. A second digit value of 5 usually indicates the midpoint of that stage. For example, a 75 refers to the medium milk stage of kernel development. In seedling growth (principal growth stage 1) the second digit refers to the number of emerged leaves. To be counted, a leaf must be at least 50 percent emerged. A code of 13 indicates that three leaves on the main shoot are at least 50 percent emerged. Tiller leaves are not counted. For tillering (principal stage 2), the second digit indicates the number of emerged tillers present on the plant. Since stages may overlap, it is possible to combine Zadoks indexes to provide a more complete description of a plant's appearance. For example, either or both of the Zadoks stages 13 and 21 could describe a plant with one tiller and three leaves. To time herbicide applications, the seedling stage (stage 1) identifying the leaf numbers is useful. As the plant matures, the Zadoks stages describing kernel development usually are used alone.

The Haun system is mainly concerned with the leaf production stages of development. The length of each emerging leaf is expressed as a fraction of the length of the preceding fully emerged leaf; a 3.2 indicates that three leaves are fully emerged, and a fourth leaf has emerged two-tenths of the length of the third. Although this system can be modified, it is not as useful where decisions are made using developmental indicators other than leaf numbers. Yet, agronomists and weed scientists concerned with seedling development staging, and particularly leaf numbers, may find the system useful.

The Feekes system has been widely used. It numerically identifies stages such as tillering, jointing, and ripening, but lacks the more detailed attributes of the Zadoks and Haun systems.

When determining the growth stage of the crop, use the following rules. This will result in more precise and consistent results.

1. Avoid the headland and field borders. Walk at least 100 feet into the field and avoid areas that are obviously stressed.
2. Examine at least 10 plants across the whole field.
3. The average growth stage of the field is the average growth stage of the plants that were evaluated. If two growth stages are equally represented, bias toward the conservative, cautious side, depending on the crop input being considered.
4. Use the following approach to determine the growth stage of an individual plant:
    a. Pull up the plant.
    b. Locate the first leaf. The first leaf is the lowest leaf and has a blunt tip. The leaf may be dead or missing, but the leaf sheath remnants generally are present. This leaf sheath encloses all other leaves and tillers except for coleoptile tillers.
    c. Hold the plant so the first leaf points to your left and carefully fan out the leaves and tillers.
    d. Locate the main stem. The main stem is usually the tallest and has the most leaves.
    e. Count the leaves on the main stem including dead or missing leaves. Generally, the leaf sheaths are still present. Do not count the leaves of the coleoptile tiller or other tillers.
    f. Count the total number of tillers present.
    g. Count the nodes. The nodes can easily be felt by holding the main stem between your thumb and index finger and more upwards from the crown. The nodes will be felt as hard tissue, while the internodes are softer and more pliable.
    h. Determine whether the flag leaf is present. The flag leaf emerges after at least three nodes are present above the soil surface. The developing head will be present in the leaf sheet of the emerging flag leaf.
    i. Determine whether the collar of the flag leaf has emerged. This is the start of the boot stage.
    j. Determine whether the first awns or the main stem have become visible. This is the start of heading.
    k. Determine whether the anthers within a floret have turned from pale green to yellow. This is the start of the anthesis or pollen shed. In wheat and barley, the flowering starts in the middle of the spikelet and moves up and down. In oats, the top of the panicle will flower first. The presence of anthers outside the floret are an obvious sign that flowering has started. Most barley varieties flower prior to heading while still in the boot stage.

Table 1.2 ***Small grains development stages by Zadoks, Feekes and Haun.***

Zadocks	Feekes	Haun	Description	Zadoks	Feekes	Haun	Description
			Germination				**Booting**
00			Dry Seed	40			--
01			Start of Imbibition	41		8-9	Flag leaf sheath extending
03			Imbibition complete	45	10	9-2	Boots just swollen
05			Radicle emerged from seed	47			Flag leaf sheath opening
07			Coleoptile emerged from seed	49		10.1	First awns visible
09		0.0	Leaf just at coleoptile tip				Inflorescence Emergence
			Seedling Growth	50	10.1	10.2	First spikelet of inflorescence visible
10	1		First leaf through coleoptile	53	10.2		1/4 of inflorescence emerged
11		1.+	First leaf unfolded	55	10.3	10.5	1/2 of inflorescence emerged
12		1.+	2 leaves unfolded	57	10.4	10.7	3/4 of inflorescence emerged
13		2.+	3 leaves unfolded	59	10.5	11.0	Emergence of inflorescence completed
14		3.+	4 leaves unfolded				**Anthesis**
15		4.+	5 leaves unfolded	60	10.51	11.4	Beginning of anthesis
16		5.+	6 leaves unfolded	65		11.5	Anthesis half-way
17		6.+	7 leaves unfolded	69		11.6	Anthesis complete
18		7.+	8 leaves unfolded				Milk Development
19			9 or more leaves unfolded	70			--
			Tillering	71	10.54	12.1	Kernel watery ripe
20			Main shoot only	73		13.0	Early milk
21	2		Main shoot and 1 tiller	75	11.1		Medium milk
22			Main shoot and 2 tillers	77			Late milk
23			Main shoot and 3 tillers				Dough Development
24			Main shoot and 4 tillers	80			--
25			Main shoot and 5 tillers	83		14.0	Early dough
26	3		Main shoot and 6 tillers	85	11.2		Soft dough
27			Main shoot and 7 tillers	87		15.0	Hard dough
28			Main shoot and 8 tillers				Ripening
29			Main shoot and 9 or more tillers	90			--
			Stem elongation	91	11.3		Kernel hard (difficult to divide by thumbnail)
30	4-5		Pseudo stem erection	92	11.4	16.0	Kernel hard (can no longer be dented by thumbnail
31	6		1st node detectable	93			Kernel lossening in daytime
32	7		2nd node detectable	94			Overripe, straw dead & collapsing
33			3rd node detectable	95			Seed dormant
34			4th node detectable	96			Viable seed giving 50% germination
35			5th node detectable	97			Seed not dormant
36			6th node detectable	98			Secondary dormancy induced
37	8		Flag leaf just visible	99			Second dormancy lost
39	9		Flag leaf ligule/collor just visible				

Growing Degree Days Predicting crop growth and development has obvious advantages in crop production because it allows producers to anticipate upcoming management decisions. This may help in scheduling activities as well as optimizing the timing of the inputs. One of the simplest approaches relates plant development to air temperature. In this method, the minimum and maximum air temperature are used to calculate the daily growing degree days or GDD.

Practical implementations of GDD models, however, have been limited. The most limiting factor is the availability of accurate, field-specific weather information. In addition, most applications have used only recorded weather information rather than a combination of recorded and forecasted weather information. The ability to forecast temperatures greatly enhances the usefulness of the GDD model by predicting when the next growth stage will be reached. Subsequently, this allows producers to truly take advantage of the model as a decision support system in planning activities. Several commercially available systems have been developed in recent years that provide this service.

Researchers at the USDA-ARS, and NDSU, developed a Growing Degree Days (GDD) model for spring wheat. The GDD is derived from air temperature and calculated by summation of accumulated thermal units in a 24-hour interval from midnight to midnight using the following formula:

$$T_n = \frac{(T_{max} + T_{min}) - T_b}{2}$$

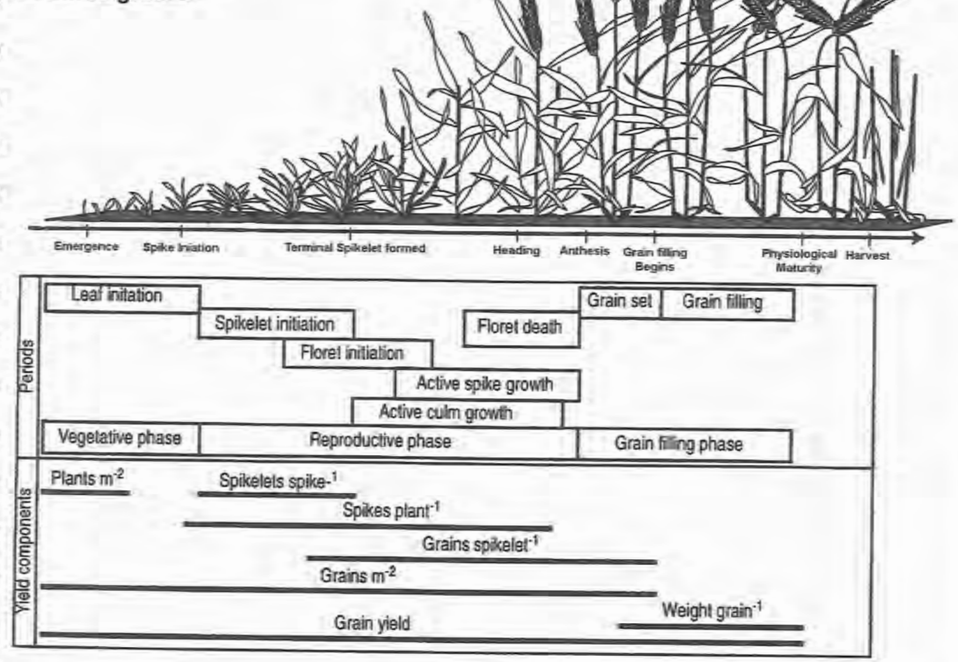
Where T_n is equal to the accumulated thermal units for that 24-hour period, T_{max} and T_{min} are equal to the maximum and minimum air temperature at 6 feet above the soil surface in that same 24-hour interval, and T_b is the base temperature for the model. For spring wheat, T_b = 32 °F. In addition, based on empirical evidence, T_{max} and T_{min} have an upper or lower limit, respectively. The upper limit for T_{max} equals 70°F, up to Zadok's growth stage 13, and 95°F afterwards. The lower limit for T_{min} equals 32°F.

The developed model has the capacity to predict growth stages from emergence through physiological maturity. It takes approximately 130 to 145 GDD to produce each successive leaf depending on the relative maturity of the wheat variety. In Table 1.3, the average number of GDD are listed for several important growth stages. Under normal conditions it takes approximately 180 GDD for wheat to emerge. Therefore, to correlate GDD with the planting date, an additional 180 GDD need to be added to the number in Table 1.3. Some highly day-length sensitive varieties require a minimum day length to trigger flower initiation. After floral initiation, however, day length sensitive variety development becomes more dependent on temperature.

Table 1.3 Growth stages and corresponding accumulated GDD.

	Description	Zadoks	Growing Degree Days
1.	Emergence	10	0
2.	First Leaf Unfolded	11	72
3.	2nd Leaf Unfolded	12	144
4.	3rd Leaf Unfolded	13	358
5.	4th Leaf Unfolded	14	501
6.	Pseudo Stem Elongation	30	644
7.	1st Node Detectable	31	715
8.	2nd Node Detectable	32	895
9.	Flag Leaf Just Visible	37	1075
10.	Flag Leaf Collar Visible	39	1217
11.	Boot Just Swollen	45	1359
12.	First Awns Visible	49	1430
13.	Inflorescence Complete	59	1500
14.	Beginning of Anthesis	60	1590
15.	Hard Dough	87	2070

Figure 1.1 Growth and development of small grains.



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CHAPTER 2 – SCOUTING AND DIAGNOSING PROBLEMS

INTRODUCTION

Closely monitoring fields during the growing season allows growers to find and identify problems that impact yield, learn of the effect of previously applied management practices and accurately predict potential problems. Scouting is a term that describes the more formal process of monitoring fields and is an important component of making informed crop management decisions. Growers often complain that scouting is time consuming and expensive. However, failing to scout can cost the grower through yield losses or application of unnecessary pesticides. By knowing the kind, number, and location of insects, weeds, and diseases within a field, the producer can make sound decisions about inputs and crop management that will nearly always more than cover the cost of scouting. Scouting is a cornerstone of Integrated Pest Management (IPM), a system designed not only to decrease pest damage, but also to maximize margins and decrease the potential for the development of pesticide resistance. One of the principles of IPM is that no chemical treatment should be applied unless the presence of damaging or potentially damaging pest populations has been determined. IPM systems recommend management decisions based on the level of damage expected from a particular pest, the value of the crop, and the cost of treatment. In this way, informed and economical pest management decisions are made. However, the role of scouting in IPM is not the only reason sampling and monitoring programs should be initiated. Many pests, such as plant diseases, only can be treated if caught early. Likewise, many insects are much more susceptible to management tactics when they are in the younger stages. Detecting pests early before populations build is, therefore, desirable for a number of reasons. Scouting programs are designed around the pest's life history and the crop's phenology and should provide an accurate representation of pest populations before damage is done to the crop. To properly scout for pests, you must know where they live, what they look like, and how to find and count them. Information on pest life cycles, and the timing of damage inflicted to the crop is essential.

Frequency of Scouting Scouting should be conducted throughout the growing season. The frequency of sampling depends on the nature of the pest threat. Scouting for most pests is ideally done weekly, but sample periods can be lengthened in cooler weather or shortened in higher temperatures. This obviously requires a significant amount of time. That is another reason to develop simple and fast scouting methods. To properly scout a field for any problem, you should plan on about an hour for every 80 acres. Planning your scouting efforts can drastically decrease the amount of time you spend in fields. By looking for weeds, insects, and diseases at the same time, you create efficiencies and reduce overall scouting time. There are 6 major periods for scouting small grain fields (Table 2.1).

Table 2.1 Growth stage scouting activities.

Growth Stage	Scouting Activities			
	Agronomic	Weeds	Insects	Diseases
2 Leaf	Stand count	Scout for weeds	-	Scout for tan spot
4 – 5 Leaves	Estimate yield (if jointing has started), nutrient deficiencies	Scout for weeds	Scout for aphids & grasshoppers	Scout for leaf diseases
Flag Leaf		Effectiveness of weed control, resistant weeds	Scout for aphids & other insects (armyworms)	Scout for leaf diseases
Flowering	Estimate yield	-	Scout for OWBM	Evaluate need for FHB treatment
Physiological Maturity		Evaluate need for pre-harvest herbicide program		-

Commercial scouts are an excellent source for much of this information. However, there are certain small grain pests that are linked to time sensitive treatments or must be scouted for under specific conditions. For example, growers may want to augment professional monitoring by scouting themselves for insects such as orange wheat blossom midge or aphids.

Scouting Equipment and Supplies Although scouting methods differ for different pests, some basic equipment/supplies are useful for most situations. A good pocketknife, a hand lens, and reference materials, such as this field guide, are essential in the field. A good sweep net is essential to scout for insect pests. A standard sweep net has a 15-inch opening. We recommend a sweep net with an aluminum handle. Sweep nets with hardwood handles are satisfactory, but tend to be heavier and slower.

Recordkeeping is vital and custom-printed data sheets are a good idea. Data sheets should contain all information that will be needed to later make management decisions. If cost/benefit decision equations are available for the crop and pest, the formula should be included on the sheet. One aspect that frequently is forgotten is location. Historic patterns of pest infestation may, in the long run, help concentrate future sampling efforts in those locations where infestation is heaviest. Recordkeeping can be assisted by having data sheets not only printed, but bound, to keep the season's data together for future reference (we find spiral binding works best).

Clear plastic zip-lock bags or screw-top vials, alcohol, and forceps or tweezers often are useful for collecting insects for later identification. In addition, a reference collection can make future identifications much easier. Any specimens collected in alcohol should be labeled with pencil on a slip of paper. Ink and computer printed labels will run or the letters will lift off of the label. Trowels and sieves for sampling soil, and paper bags for sampling plant material also are useful

Number & Location of Sample Sites There should be a sufficient number of samples taken to accurately reflect the population of the pest within the field. When sampling for aphids in small grains, for example, approximately 100 samples may be taken and should accurately reflect the entire field population. For other insects, such as grasshoppers, populations are often concentrated on the edges of fields and sampling efforts should first be concentrated there. Scouting location and pattern will depend on the within-field distribution of the pest being monitored. Obviously, other factors such as field size, shape, and access also will influence how and from where samples are taken.

There are three general scouting patterns:

1. If the pest is evenly distributed throughout the entire field, such as aphids, root maggots, and most armyworms, a transect in a circular, "W" or adapted "Z" pattern should be used (Figure 2.1). These patterns have been designed to ensure that the entire insect population has an equal opportunity to be sampled.

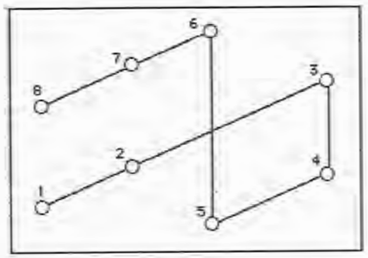


Photo 2.1 Adapted "Z" sample pattern used with evenly distributed insect pests. (From Hutchinson, 1993).

2. Some pests are associated with particular field conditions, such as low/high elevation, wet/dry, or low/high organic content. Sample effort must, therefore, be concentrated in these areas.
3. Certain insects (e.g. grasshoppers) generally concentrate on the edges of fields, but may get into the field as well. Scouting the margins of fields first will provide a good indication whether sampling within the field is required. Be aware that most of these species have different action thresholds within the field than they do at the edges.

Sampling at a wrong location could lead to low population estimates, resulting in potential crop loss from under-treatment. The same problem can result from under-sampling, reinforcing the necessity for sufficient samples to represent the insect pest population throughout the field.

SAMPLING METHODS

There are a number of standard techniques to sample pests. Selection depends on the type of pests being sampled and what resources are available.

Visual Inspection Probably the most common, the simplest, and the fastest method of scouting pests is to simply look for them. This technique generally involves selecting a number of plants, leaves, stems, or roots and examining them for the presence of the pest or the damage it caused. This may require the dissection of plant material or simply walking

through the sample area. Visual inspections can be quantitative or presence/absence depending on the species being monitored. Generally; presence/absence techniques are used where thresholds are very low, or numbers are very high, and actual counts would not be possible. In either case, careful examination of the material is necessary.

Sweeping Sweeping is done by one of two methods: the pendulum sweep, or the 180 degree sweep. In the pendulum sweep, the net is swung from side to side, perpendicular to the ground (one direction is one sweep, back and forth is two sweeps). Keep the rim of the net as close to the ground as possible or, in high canopies, such that the upper edge of the net is just out of the canopy. Be careful not to bump the net on the ground (or kick it) as this will effectively empty the net. A quick and steady walking pace should be maintained. 180 degree sweeps are conducted in much the same way. The net is held more out in front of the sweeper, the arc through which the net traverses is wider, and the net is swung so that the upper third of the net rim is above the top of the canopy. Sweep net sampling is an excellent method for determining exactly what species are in a field. Once a certain set number of sweeps are obtained, close the bag by flicking the end over the upper edge of the net ring. Emptying the bag carefully into a zip-lock plastic bag is very helpful. It allows you to examine the contents and identify species. The method does not provide a quantitative estimate. Nonetheless, sweeping is particularly useful when sampling very mobile insects such as grasshoppers.

Trapping Many insect pests, such as aphids, are attracted to certain colors or chemicals. This enables us to utilize these responses in trapping. Yellow-sticky traps can be used for early detection of aphids or orange wheat blossom midge, but are not very useful in determining economic thresholds. Emergence traps can monitor several insects that develop in the soil.

When encountering an unknown problem in a field, or when you suspect damage, it is good to consider the following set of questions to narrow down the potential causes.

1. Determine the obvious symptoms and create a list of causes that potentially could have these symptoms. There are several diseases, fertility and/or environmental effects that display similar symptoms.

2. Are the symptoms in any special or obvious pattern? Look at the directions of tillage and planting, and evaluate the topography of the field. Do the symptoms coincide with certain soil types in the field, or with the topography of the field? Nutrient deficiencies will often show such a pattern, while herbicide damage or diseases are much more likely to be distributed more evenly. Are there any obvious skips in weed control as evidenced by the presence or absence of specific weeds? If spray drift is suspected, inspect the windbreaks, ditches, and neighboring fields for similar symptoms.

3. Dig up whole plants and evaluate symptoms. Look at the leaves, stems, and roots. Determine if there are large (>0.5 inch) differences in planting depth between contrasting parts of the field. Deeper seeding not only will result in delayed emergence, and subsequent delay in development, but also may predispose the plant to more disease problems, especially root rots.

4. Determine if the symptoms only are on new growth or on old growth. This determination can be used to establish a timeline as to when the injury most likely occurred. Using a leaf count and using the growing degree day models combined with recorded weather data, will allow you to calculate a timeline.

If you have difficulty determining a plausible explanation, or are unsure of your evaluation, contact your local Extension office or submit a plant sample with a detailed description of the situation to the Extension Service of the University of Minnesota or North Dakota State University. Follow the instructions below to submit plant samples for evaluation.

INSTRUCTIONS FOR SUBMITTING PLANT SAMPLES

Sample Collection

1. Collect several examples of all symptoms exhibited by affected plants. Include examples of normal plants. Send the entire plant, not just affected parts.
2. Samples should have intact roots, seeds, heads when available. Include the soil surrounding the roots. Always dig plants -- do not pull them from the soil.
3. Disease specimens
   a. Collect early and late stages of leaf infection
   b. Collect fresh specimens of fleshy plant part with early symptom development.
4. Fertility-induced problems: Collect soil and/or plant tissue samples and send to the University of Minnesota Soil Testing Laboratory or a private soil analysis laboratory.

Sample Submission

1. Wrap roots and soil in moist paper towel. Cover the towel, not the entire plant, with a plastic bag and tie the bag at the top. Make certain that leaves are flattened on cardboard. Fleshy plant parts should be wrapped separately in dry paper.
2. Label healthy and unhealthy plants.
3. If samples from several fields are sent together, label each sample with a field identification code which corresponds to the Field ID on the Plant Pest Diagnosis Form. Fields may be identified to suit your needs.
4. Wrap the entire plant in dry newspaper or paper toweling. Include a Plant Pest Diagnosis Form with each sample. Keep one copy for your files.
5. Place prepared samples in a crush-proof container and label "Plant Material -- Perishable."
6. Send samples to:
   1. Plant Disease Clinic
105 Stakeman Hall
1519 Gortner Ave.
St. Paul, MN 55108
   2. NDSU Plant Diagnostic Lab
306 Walster Hall
Box 5012
Fargo, ND 58105
   3. Directly to the appropriate state specialist

Completing the Plant Diagnosis Form

1. Complete Section I identifying the grower, field, date, and crop information.
2. Check off the appropriate boxes in Section II, completely describing the nature of the injury. Each category can have one or more responses.
   a. Fruit refers to pods, kernels, grain, heads, ears, or fleshy parts.

   b. After evaluating the specific plant parts, make a judgment on the symptoms on a whole plant basis and the severity of the injury throughout the field.
3. Ignore those parts of the section that are not pertinent to your situation. In many cases, chemicals should be identified, while other information about the chemicals may not be relevant.
4. Additional Comments section should be used to elaborate on conditions that are not adequately covered above.

Authors: Ian MacRae and Jochum Wiersma

PLANT PEST DIAGNOSIS FORM

Grower Name________________ County________
Submitted by________________ Date Collected________
Field I.D.________________
Crop or Plant________________ Variety________
Source of Seed or Propagation Material________________

NATURE OF INJURY

A. ROOTS
__ Normal __ Rotted __ External Discoloration __ Internal Discoloration __ Galls or Swelling __ Poor Development __ Clubbed Ends __ Short & Stubby __ Proliferation

B. LEAVES
__ Normal __ Wilting __ Galls or Swelling __ Abnormal Growth __ Chewing Damage __ Spotted
__ Yellowing or Mottling __ Stunting __ Crinkling or Crippling __ Necrotic __ Falling Prematurely

C. STEMS
__ Epinasty __ Galls or Swelling __ External Discoloration __ Internal Discoloration __ Spotted
__ Rotted __ Canker

D. FRUIT OR FLOWERS __ Normal __ Poor Seed Set __ Spotted or Blighted __ Mottled

E. ENTIRE PLANT __ Stunted __ Discolored __ Abnormal Growth __ Wilted __ Lodged

F. SYMPTOM APPEARANCE IN LAST NUMBER OF ____ days ____ weeks

G. DEGREE OF INJURY TO ENTIRE PLANTING __ Severe __ Moderate __ Light

H. HAVE SYMPTOMS SPREAD SINCE FIRST NOTICED? __ Yes __ No

FIELD CONDITIONS

A. PATTERN OF SYMPTOMS
__ Entire Field __ Localized Area __ Scattered Plants __ Low Areas __ Slopes
__ Damage in Adjacent Field __ No Association with Terrain

B. SOIL INFORMATION (TEXTURE)
__ Sand __ Loamy Sand __ Sandy Loam __ Loam __ Silt Loam __ Silty Clay Loam
__ Clay Loam __ Clay __ Peat __ Muck __ % Organic Matter __ pH __ Depth of Topsoil in Inches

C. WEATHER CONDITION PRIOR TO SYMPTOMS
__ Hail __ Frost __ Blowing Soil

D. CHEMICAL HISTORY
Fertilizer________________
Time of Application **Rate** N____ lb/A P____ lb/A K____ lb/A
__ Fall __ Spring __ Post planting **Method** __ band __ broadcast

Herbicides________________ **Herbicides**________________
Method __ ppi __ pre __ post Rate: ____ lb/A **Method** __ ppi __ pre __ post Rate: ____ lb/A
Formulation: __ liquid __ powder __ granule **Formulation** __ liquid __ powder __ granule
Carrier __ water __ fertilizer **Carrier** __ water __ fertilizer

Herbicides (previous year)________________ Rate: _____ lb/A Method: __ ppi __ pre __ post

Insecticides________________
Method __ ppi __ pre __ post Rate: ______ lb/A
Formulation __ liquid __ powder __ granule

Fungicides________________
Method __ ppi __ pre __ post Rate: ______ lb/A
Formulation __ liquid __ powder __ granule

E. CROP LAST YEAR________________
F. ADDITIONAL COMMENTS________________

SECTION III: FERTILITY MANAGEMENT

CHAPTER 1 - FERTILITY MANAGEMENT OF WHEAT

NITROGEN -- Two procedures are used in North Dakota and Minnesota to formulate N recommendations. In eastern Minnesota (Figure 1.1), a soil test for residual nitrate is not used. N recommendations are based on the previous crop, organic matter level and yield goal (Table 1.1).

Table 1.1 Nitrogen recommendations for spring/winter wheat in eastern Minnesota where the soil nitrate test is not used.

Crop grown last year	Organic[1] Matter level	Yield Goal (bu/acre)					
		<40	40-49	50-59	60-69	70-79	80+
Alfalfa (4+plants/ft²), Non-harvested sweet clover	low	0	0	30	55	80	95
	medium/high	0	0	0	35	60	75
Soybeans	low	15	40	65	90	115	130
	medium/high	0	20	45	70	95	110
Edible beans, field peas, harvested sweet clover	low	15	40	65	90	115	130
	medium	0	20	45	70	95	110
Any crop in Table 2, Group 1	low	0	30	55	80	105	120
	medium	0	0	35	60	85	110
Any crop in Table 2, Group 2	low	55	80	105	130	155	170
	medium	35	60	85	110	135	150
Organic soil	———	0	0	0	30	35	50

[1]low=less than 3%; medium and high = 3% or more.

Table 1.2 Previous crop groups used to formulate wheat N recommendations in eastern Minnesota.

Crops in Group 1	Crops in Group 2	
Alfalfa (2-3 plants/ft²)	Alfalfa (0-1 plants/ft²)	Oats
Alsike clover	Barley	Potatoes
Barley	Buckwheat	Rye
Birdsfoot trefoil	Canola	Sorghum-sudan
Fallow	Corn	Sugar beets
Grass-legume hay	Flax	Sunflowers
Oats	Grass-hay	Sweet corn
Potatoes	Grass-pasture	Triticale
	Mustard	Wheat

In western Minnesota and the entire state of North Dakota, a soil test taken at a depth of 0-2 feet is recommended to help formulate N recommendations. The formula for N recommendations using a soil test is:

$$N_{Rec} = (YG \times 2.5) - STN - NPC$$

Where N_{Rec} is the recommended N to use, YG is the yield goal in bu/acre, STN is the soil test nitrate at the 0-2 foot depth in lb/acre, and NPC (or PCC in North Dakota recommendation tables) is the nitrogen credit expected after certain crops that do not appear on a fall or early spring nitrate soil test.

Nitrogen credits from various crops are given in Table 1.3.

Table 1.3. Nitrogen credits from previous crops.

Previous crop	Credit, lb N/acre
Soybean	40
Edible bean	40
Pea and lentil	40
Chickpea	40
Sweet clover, harvested	40
Alfalfa harvested and unharvested sweet clover	
>5 plants/sq.ft.	150
3-4 plants/sq.ft.	100
1-2 plants/sq.ft.	50
< 1 plant/sq.ft.	0
Sugar beets	
Yellow leaves at harvest	0
Yellow-green leaves	30
Dark green leaves	80

NITROGEN MANAGEMENT Nitrogen for spring wheat is best applied preplant or at seeding. A fall application of anhydrous ammonia and urea is usually effective in North Dakota and northwestern Minnesota, but urea is not recommended as a fall fertilizer in central and southern Minnesota. Application of nearly any plant-usable N fertilizer is effective as a spring application. Application at seeding is often used. Rates applied with the seed of urea and other dry and liquid materials are shown in Table 1.4. Higher rates are possible if seed and fertilizer separation of at least 1 inch is achieved with specially designed seeder attachments. Anhydrous application at seeding can be accomplished if the seed and ammonia band is separated by at least three inches of lateral distance.

Figure 1.1 Reference map for nitrogen recommendations

Top-dressing should not be used as a primary source of N on spring wheat due to the short window of opportunity for making such an application and because research has seldom shown an advantage to split applications except under irrigation. Top-dressing could be considered as a supplementary source of N in years when the yield goal was underestimated and favorable soil moisture and cool temperatures point to an opportunity for higher yield potential.

These top-dress applications should be made with streamer bars or stream nozzles to prevent burn. At least ½ inch of rain should fall to make these top-dress applications successful before the critical jointing stage of growth is reached. Application of top-dressed or foliar-applied N also has been shown to be useful in increasing protein levels in spring wheat if applied at or before the watery-ripe stage of wheat growth and there is sufficient rainfall thereafter to move it into the root zone.

Table 1.4 Maximum urea-N fertilizer rates recommended with small grain seed at planting based on planter spacing, type and seed spread. Assumes a coarse soil texture for the lower end of each range and heavier texture for the upper end of each range of urea-N values. For more detail, see NDSU Ext. Cir. EB-62.

Planter Type	Seed Spread (inches)	Planter Spacing, inches: 6	7.5	10	12
		lb urea-N/acre			
Double disc	1	20-30	19-28	17-23	15-20
Hoe opener	2	32-44	27-38	23-31	20-27
	3	44-58	37-48	30-40	26-34
Air seeder	4	56-72	46-58	37-48	32-42
	5	68-86	56-68	44-57	38-49
	6	80-100	66-79	51-55	44-56
	7		76-90	58-74	50-64
	8			66-83	56-71
	9			73-92	62-78
	10			80-100	68-86
	11				74-93
	12				80-100

Phosphorus and Potash Recommendations for phosphate (P_2O_5) and potash (K_2O) are based on yield goal and soil test. These recommendations are listed in Table 1.5. Broadcast rates of P and K are listed. Rates for low and very low soil test categories contain extra P and K that may result in increasing soil test levels over time. If the fertilizer is banded, and only one-year results needed, P and K rates can be reduced by 1/3 (North Dakota) or up to ½ (Minnesota). It is impractical to broadcast low rates (10-15 lb/acre) of P_2O_5 or K_2O. For these fields, the best plan would be to apply the amount needed with the seed or double the recommended rate on alternate years.

Table 1.5 Phosphate and potash fertilizer suggestions for wheat in Minnesota and North Dakota.

Yield goal bu/a		Soil Test Phosphorus, ppm: VL	L	M	H	VH	Soil Test Potassium, ppm: VL	L	M	H	VH
	Bray	0-5	6-10	11-15	16-20	21+	0-40	41-80	81-120	121-160	161+
	Olsen	0-3	4-7	8-11	12-15	16+					
		lb P_2O_5/acre					lb K_2O/acre				
20		19	17	9	3	0	47	34	20	7	0
40		39	35	17	7	0	95	68	40	13	0
60		58	52	26	10	0	142	101	60	20	0
80		78	69	35	13	0	190	135	80	26	0

Suggested use of other nutrients Major emphasis in spring wheat fertility needs should be directed towards efficient and effective management of N, P and K fertilizers. Sulfur (S) Chloride (Cl) and copper (CU) can be important in limited situations. These special cases are described in the following paragraphs.

Sulfur Sulfur fertilizer can increase spring wheat yields when the crop is grown on sandy soils. Research trials have shown there is no need to add S to a fertilizer program when wheat is grown on fine-textured soils in Minnesota and North Dakota. A broadcast rate of 25 lb S/acre in the sulfate form will be adequate for growing wheat on sandy soils. For more efficient application, 10-15 lb S/acre applied with the drill at seeding is suggested. Fall application of sulfate fertilizers is not recommended. Elemental sulfur formulations have not been nearly as effective as sulfate-based fertilizers.

Chloride Chloride is seldom a problem in Minnesota. However, in North Dakota, where chloride levels lower than 40 lb/acre 2 feet are common outside the Red River Valley, an application of chloride can increase wheat yield between 3-6 bu/acre about half the time. There are interactions between variety and chloride response, but they tend to be inconsistent in studies. The lower the chloride test, the higher the probability of response. Rates as low as 10 lb Cl/acre band applied have been sufficient to increase yields.

Copper Minnesota has significant cultivated organic soils. Copper is commonly deficient in these soils. Table 1.6 contains recommendations for these soils, using the dilute HCl extraction method.

Table 1.6 Suggestions for use of copper in wheat grown on organic soils.

Copper HCl soil test, ppm	Method of Application — Broadcast: Copper	Broadcast: Copper sulfate	Foliar: Copper	Foliar: Copper sulfate
	lb/acre			
0-2.5 (low)	6-12	24-48	0.3	1.3
2.6-5.0 (marginal)	Trial only	Trial only	0.3	1.0
Greater than 5.0 (adequate)	0	0	0	0

In North Dakota, copper responses have been seen in low organic matter sandy soils. The responses have been inconsistent, so copper application at rates of about 5 lb actual Cu/acre as copper sulfate should be considered site-specific to the appropriate soils at best.

Whole field applications, which include non-responsive higher organic matter heavier soils, is not recommended. Foliar applications of copper chelates have not been effective in North Dakota studies.

Other nutrients Research from Minnesota and North Dakota has shown that magnesium, calcium, iron, boron, zinc and manganese are not needed in fertilizer programs. Most soils supply ample amounts of these nutrients and wheat extracts them regardless of soil test levels.

Durum wheat, North Dakota Recommendations for durum wheat in North Dakota are the same as spring wheat. Yield expectations for durum usually are lower than for spring wheat, so formulate the recommendations appropriately.

Winter wheat, North Dakota Recommendations for winter wheat in North Dakota are the same as spring wheat. An application of N is often made in the fall, however, the application also could be made in early spring before significant growth. Spring application of top-dressed N is sometimes hampered by poor soil conditions during thaw and spring rain. Frozen subsoil, combined with saturated surface soil, can make application difficult and may contribute to significant N runoff under some conditions. Use of tramlines during seeding can make spring application more practical. Studies have not indicated a reason to split spring applications. Phosphate and potash applications should be made in the fall at seeding.

Authors: George Rehm and Dave Franzen

CHAPTER 2 - FERTILITY MANAGEMENT OF BARLEY

Nitrogen The amount of N applied to barley is important for yield and is an important quality producing factor. As opposed to the goal of high protein in spring wheat and an aggressive N fertilization strategy, the goal of malting barley production is low protein. High protein disqualifies barley for the malting industry. For that reason, early seeding and any other management strategy that results in increased yield without increasing N rate is useful in decreasing harvest protein.

There are two approaches for formulating N recommendations for barley. In eastern Minnesota, soil testing for residual soil nitrate is not used. N recommendations are based on the previous crop, organic matter level and yield goal. Nitrogen recommendations for eastern Minnesota are shown in Table 2.1.

Table 2.1 Nitrogen recommendations for barley in eastern Minnesota where the soil nitrate test is not used.

Crop grown last year	Organic[1] Matter level	Yield Goal (bu/acre)						
		<50	50-59	60-69	70-79	80-89	90-99	100+
Alfalfa (4+plants/ft²), Non-harvested sweet clover	low	0	0	10	25	40	55	70
	medium/high	0	0	0	0	20	35	50
Soybeans	low	10	30	45	60	75	90	105
	medium/high	0	10	25	40	55	70	85
Edible beans, field peas, harvested sweet clover	low	10	30	45	60	75	90	105
	medium	0	10	25	40	55	70	85
Any crop in Table 2, Group 1	low	0	20	35	50	65	80	95
	medium	0	0	15	30	45	60	75
Any crop in Table 2, Group 2	low	50	70	85	100	115	130	145
	medium	30	50	65	80	95	110	125
Organic soil	------------	0	0	0	0	30	40	50

1low=less than 3%; medium and high = 3% or more.

In western Minnesota (Figure 1.1 on page 61) and the entire state of North Dakota, soil testing at the 0-2 foot depth is recommended to help formulate N recommendations. For malting barley, the use of an additional 2-4 foot depth increment is suggested where practical to screen fields for excessive deep soil N that may increase grain protein.

The formula for N recommendations in malting barley is:

$$N_{Rec} = (1.5 \text{ X } YG)\text{-}STN\text{-} NPC$$

Where N_{Rec} is the N recommended, YG is yield goal in bu/acre, STN is soil test nitrate to 2 feet in depth, and NPC is the N provided after certain crops (see Table 3.)

The formula for N recommendations for feed-grade barley is:

$$N_{Rec} = (1.7 \text{ X } YG)\text{-}STN\text{-} NPC$$

Phosphate and Potash Recommendations for phosphate (P_2O_5) and potash (K_2O) are based on yield goal and soil test levels. These recommendations are provided in Table 8. Rates for broadcast are given, but these rates can be reduced by half in Minnesota or a third in North Dakota if band applied near or with the seed because of the increased efficiency of banded applications. Limits of fertilizer rates that can be applied with barley seed at planting are the same as those for wheat (Table 1.4 on page 62).

Table 2.2 Phosphate and potassium recommendations for malting or feed-grade barley in Minnesota and North Dakota.

		Soil Test Phosphorus, ppm					Soil Test Potassium, ppm				
		VL	L	M	H	VH	VL	L	M	H	VH
Yield	Bray	0-5	6-10	11-15	16-20	21+	0-40	41-80	81-120	121-160	161+
goal	Olsen	0-3	4-7	8-11	12-15	16+					
bu/a		lb P2O5/acre					lb K2O/acre				
40		28	20	12	4	0	45	31	17	3	0
60		43	31	19	7	0	67	47	26	5	0
80		57	41	25	9	0	89	62	35	7	0
100		71	51	31	11	0	112	78	44	8	0

Suggested use of other nutrients Major emphasis in barley production should be directed towards efficient and effective management of N, P, and K fertilizers. Sulfur (S), chloride (Cl) and copper (Cu) may be important in limited situations.

Sulfur Sulfur can increase barley yields on low organic matter, sandy soils. Research has seldom seen yield increases on heavier textured soils with medium or higher organic matter. A broadcast application of 25 lb S/acre in the sulfate form, or 10-15 lb S/acre as sulfate in a band has provided adequate nutrition in deficient soils.

Chloride If soil chloride levels are below 40 lb/acre in the 0-2 foot depth, application of chloride can increase barley yields from 3 to 7 bu/acre about half the time. Application rates of as little as 10 lb Cl/acre in a band at seeding has been sufficient to overcome deficiencies.

Copper Copper may be required when barley is grown on organic soils. The recommendations for Cu on barley are the same as those for wheat (Table 1.6 on page 63).

CHAPTER 3 - FERTILITY MANAGEMENT OF OATS

Nitrogen Nitrogen recommendations are formulated in two different ways depending on geography. In eastern Minnesota, soil testing is not used to formulate an N recommendation (Table 3.1). In western Minnesota and the entire state of North Dakota, soil testing for nitrate is recommended to determine N application rates.

Table 3.1 Nitrogen recommendations for oats in eastern Minnesota where the soil nitrate test is not used.

Crop grown last year	Organic[1] Matter level	40-60	61-80	81-100	101-120	121+
Alfalfa (4+plants/ft²), Non-harvested sweet clover	low	0	0	0	0	0
	medium/high	0	0	0	0	0
Soybeans	low	0	20	40	60	80
	medium/high	0	10	30	50	70
Edible beans, field peas, harvested sweet clover	low	0	20	40	60	80
	medium	0	25	40	55	70
Any crop in Table 2, Group 1	low	0	0	0	25	45
	medium	0	0	0	15	35
Any crop in Table 2, Group 2	low	40	60	80	100	120
	medium	30	50	70	90	110

[1]low=less than 3%; medium and high = 3% or more.

Phosphate and Potash Recommendations for phosphate (P_2O_5) and potash (K_2O) are based on yield goal and soil test levels. These recommendations are provided in Table 8. Rates for broadcast are given, but these rates can be reduced by half in Minnesota or a third in North Dakota if band applied near or with the seed because of the increased efficiency of banded applications. Limits of fertilizer rates that can be applied with oats at planting are the same as those for wheat (Table 1.4 on page 62).

Table 3.2 Phosphate and potassium recommendations or oats in Minnesota and North Dakota.

		Soil Test Phosphorus, ppm					Soil Test Potassium, ppm				
		VL	L	M	H	VH	VL	L	M	H	VH
Yield	Bray	0-5	6-10	11-15	16-20	21+	0-40	41-80	81-120	121-160	161+
goal	Olsen	0-3	4-7	8-11	12-15	16+					
bu/a		lb P2O5/acre					lb K2O/acre				
50		29	21	13	5	0	55	38	21	4	0
70		41	29	18	7	0	77	53	29	5	0
90		52	38	23	8	0	100	69	38	7	0
110		64	46	28	10	0	122	84	46	8	0

Suggested use of other nutrients The work done in North Dakota with nutrients other than N, P and K suggest that their application is not generally important in achieving acceptable oat yield. Emphasis should be given to efficient and effective management of N, P, and K in the production of high yield, high quality oats.

Authors: George Rehm and Dave Franzen

NO-TILL PRODUCTION

Air seeder equipped with wide sweeps are suitable for high-disturbance one-pass operations.

Narrow point opener.

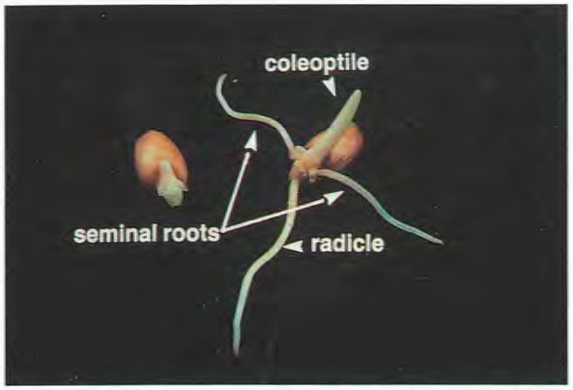
Single disc opener.

Offset double disc opener.

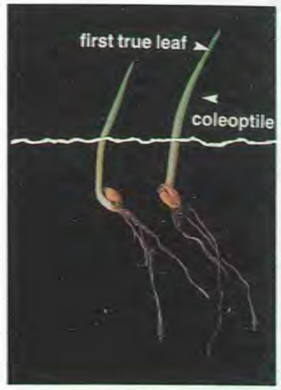
Inverted T or cross slot opener.

Winter wheat planted with a low-disturbance no-till drill.

Uniform germination and emergence as a result of uniform placement and proper depth control.



Germinating wheat kernels showing radicle, seminal roots and celeoptile. Kernel on left is at Zadoks stage 4 and kernel on right is at stage 7.



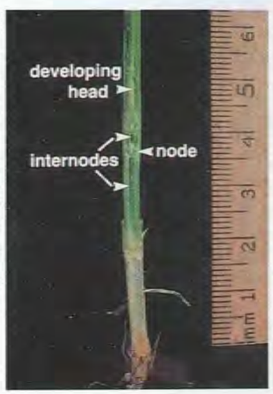
Wheat seedling at Zadoks stage 10. Note first leaf emerging from tip of coleoptile.

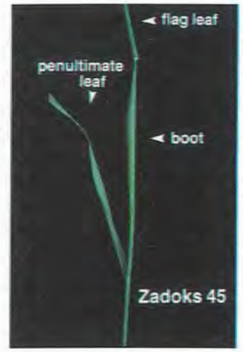
Seedling at two-leaf stage

The lower half of a barley plant at early tillering showing a tiller emerging from the axil of the first leaf.

Wheat plant just after jointing.

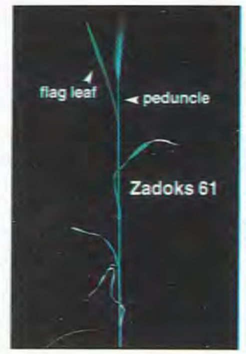
Base of wheat plant during early stem elongation. Individual stem internodes are elongating in sequence. Note the developing head.





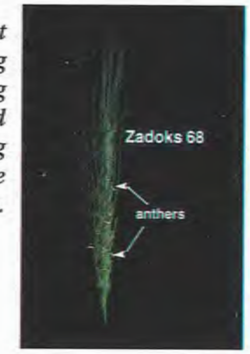
The upper half of a barley plant at boot stage. Note swelling sheath indicating the position of the developing head.

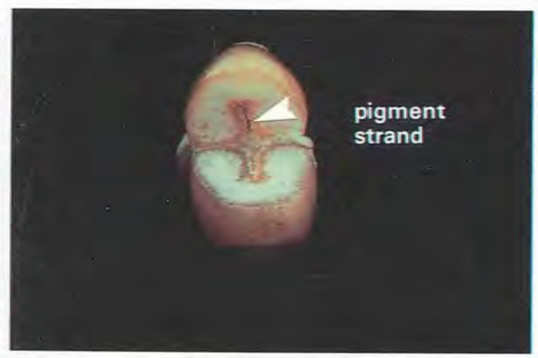
Wheat plant fully headed.



Wheat at the beginning of anthesis. The first anthers will become visible in the middle of the head within hours.

Head at flowering showing extruded anthers along most of the head's length.





Wheat kernel at physiological maturity. Note the presence of the pigment strand.

Head at approximately physiological maturity when the kernels have attained maximum dry weight. Note the green color is gone from the peduncle and head parts.

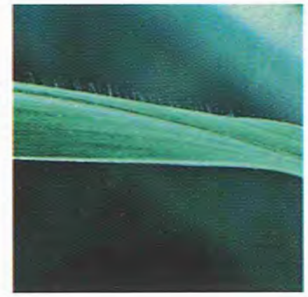
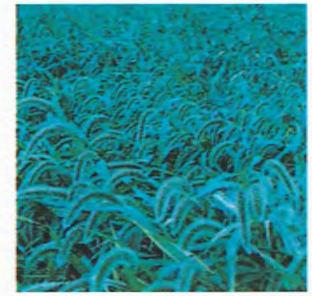

Barnyardgrass


Buckwheat, wild


Cocklebur, common


Crabgrass, large

Foxtail, giant

Foxtail, green


Foxtail, yellow


Kochia


SMALL GRAINS WEEDS


Lambsquarters, common


Marshelder


Mustard, wild


Nightshade, black

SMALL GRAINS WEEDS

Nutsedge, yellow


Oats, wild


Pigweed


Proso millet, wild



Quackgrass


Ragweed, common


Ragweed, giant


Smartweed, Pennsylvania

Sowthistle, perennial


Sunflower, wild


Thistle, Canada


Thistle, Russian


Imidazolinones or sulfonylureas can cause yellowing or stunting of small grain. Injury is generally temporary.

Roundup injury on spring wheat. Youngest leaves near growing point slowly become chlorotic and die.

Roundup drift injury on spring wheat.

Elongated rachis, twisted awns, missing spikelets, and heads not emerging from the flag leaf caused by 2,4-D applied to spring wheat before tillering.

Heads not emerged from the twisted flag leaf and shortened peduncles can be caused by late application of a growth regulator herbicide.

Sterile florets and head tips caused by a late application of dicamba to spring wheat.

High rates of the pyridine herbicide can cause prostrate growth, yellowing, and stunting of spring wheat and barley.

Diclofop can cause barley injury when applied at high rates and during cool temperatures. Note leaf yellowing, browning, and stunting.

Fenoxaprop injury to barley. Note the leaf yellowing.

Fenoxaprop injury to barley. Not the leaf stunting.

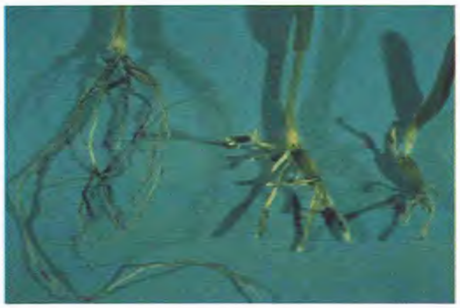
Bromoxynil injury to spring wheat. Note the necrotic leaf spot. Injury is temporary, and small grains quickly recover.

Far-Go injury to spring wheat. Note the uneven emergence and stunting.

HERBICIDE INJURY

Far-Go can cause shoot tips to fail to unroll from the celeoptiles, giving the plant a buggy-whip appearance.

Wheat leaves emerging through the side of the soleoptile caused by a high application rate of Far-Go.



Trifluralin injury to wheat. Note the shortened, swollen root tips.

Avenge can cause leaf burn and leaf necrosis under hot, dry conditions. This injury is usually temporary and disappears as new leaves emerge.

Avenge can only be applied to labeled varieties of spring wheat. An application of Avenge to sensitive varieties will result in severe injury or death.

Stampede causes leaf burn, yellowing, and stunting. Injury is usually temporary and will disappear as new leaves emerge (10-14 days).

CULTURAL PRACTICES

Deep-planted small grains take longer to emerge and can result in uneven stands. Elongated internodes appear in plants on the right. Plants on the left show seedling growth when planted at correct depth.

Soil crusting can result in delayed emergence, emerged shoots that are bent over, and twisted, kinked leaves.

Lighter colored areas in photo show the result of wheel track compaction made by postharvest tillage.

ENVIRONMENTAL FACTORS

Coleoptiles of small grain seedlings exposed to fluctuating temperatures at the soil line exhibit yellow and green color bands. Injury is temporary.

Cold, wet soils cause poor soil aeration that in turn reduces oxygen levels needed for normal root growth.

Leaves injured by spring frost appear at first water-soaked, then dark green. These injured leaves dry out and quickly turn brown. Frost injured plants quickly recover if the growing point was not exposed to freezing temperatures.

ENVIRONMENTAL FACTORS

Hot weather that occurs during the conversion from vegetative to reproductive stages can cause small grain plants to fall behind in their ability to carry out respiration and supply materials for the new growth of leaves, florets and spikelets. High temperatures during flowering can result in head sterility.

Blowing sand from strong winds can injure small grain leaves resulting in leaf abrasions.

Wheat plants lacking in nitrogen first become light green, then yellow.

Under drought conditions, small grain plants suffer from cell dehydration. This results in cessation of cell division, reduced biochemical activity, and slowed photosynthesis. Plants suffering under these conditions will appear stunted and yellow or bronze in color.

Hail injury occurring on small grains in the preboot stage can cause the grain head to curl up inside the sheath, resulting in twisted heads that are partially exposed and hanging upside down. The effects of hail injury can also be similar to injury from Dicamba applied too late.

SMALL GRAINS DISEASES

Common root rot of wheat.

Seedling disease.

Pythium brown rot of wheat.

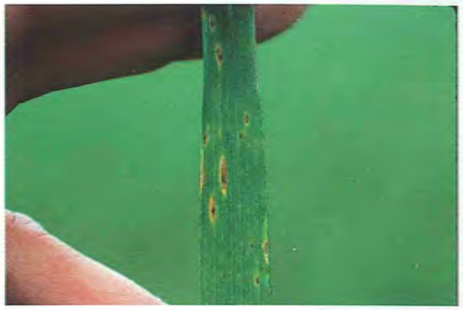
Take-all symptoms on wheat crowns.

Powdery mildew of wheat..

Overwintering stage of tan spot fungus on residue.

SMALL GRAINS DISEASES

Early season tan spot on wheat.



Tan spot on wheat.

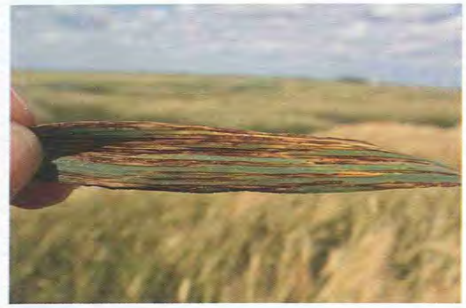
Septoria leaf blotch on wheat.

Speckled leaf blotch on wheat.

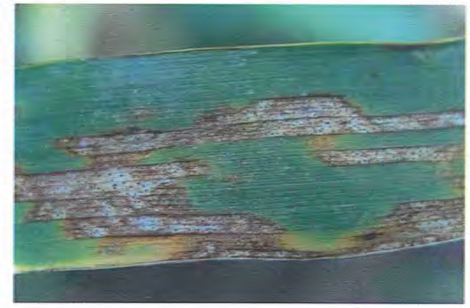
Spot blotch on wheat.

Xanthomonas leaf streak on wheat leaves

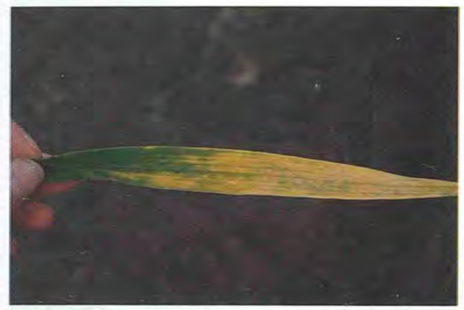
SMALL GRAINS DISEASES



Net blotch on barley.



Speckled leaf blotch on barley.



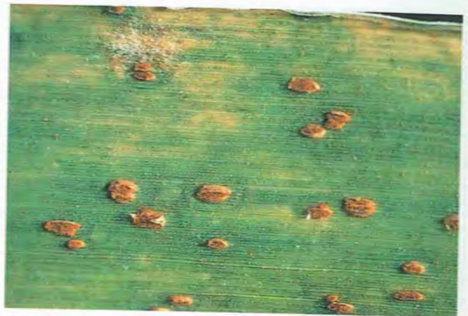
Barley yellow dwarf symptoms on a leaf.

Barley yellow dwarf virus on spring wheat.

Wheat streak mosaic virus.

Moderately resistant reaction of leaf rust on wheat.

Susceptible reaction of leaf rust on wheat.



Close-up of leaf rust pustules on wheat.

Stripe rust on winter wheat.

Stem rust on barley.

Crown rust on oats.

Black chaff on wheat.

Loose smut on wheat.

Ergot sclerotia on wheat head.

Glume blotch infections on durum wheat.

Fusarium Head Blight on wheat.

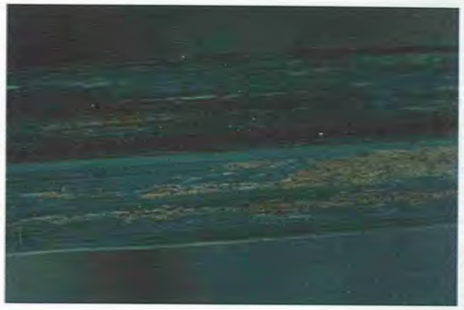
Fusarium damaged wheat seed.

Fusarium head blight on barley (healthy head on the left).

Aphids in grain head.

Armyworm larvae.

Bird-oat cherry aphids, mothers and daughters.



Damage from barley thrips.

Barley thrip adult greatly enlarged; cigar-shaped with feathery wings.

Wheat infected with barley yellow dwarf. Note discoloration and stunting.

Wheat infected with barley yellow dwarf. Note localized patches of plants with yellow flag leaves.

Cutworm larvae. Note "C" shape. Larvae curl when disturbed.

Hessian fly adult.

Hessian fly larvae inside stem. Larval feeding can result in lodging.

Grasshopper damage typically first seen at the edge of fields.

Orange Wheat Blossom Midge larvae (left) and adult (right).

SMALL GRAINS INSECTS

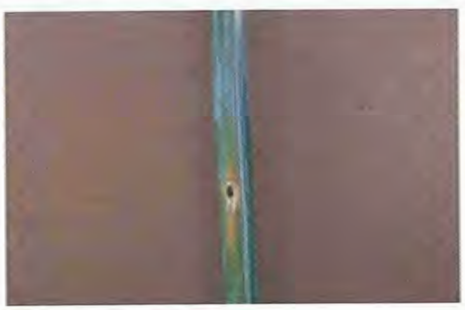
Ladybug larvae (larger inset in photo). One of the most important natural aphid controls.

Ladybug pupae; adults will emerge from these immobile forms. Note larva on right is almost ready to pupate.

Ladybug adult; found in large numbers after heading.

Tiny parasitic wasp; another important control of aphids. Female wasps lay their eggs in aphids and the hatching larvae eat the aphid from the inside. They only attack/ sting other insects.

A parasitized aphid, called a "mumy." Note the hole in the aphid's abdomen. This is where the parasitic wasp exited after it finished developing.



Exit hole of a stalk borer.

Stalk borer caterpillar still in wheat stem.

CHAPTER 1 – SAFE HANDLING AND STORAGE OF PESTICIDES

PESTICIDES For more complete information about pesticides, pesticide laws and regulations, safe handling of pesticides, and protecting applicators, the public, and the environment, see the ***Private Pesticide Applicator Training*** manual available at your local Extension Service office. "Pesticide" is a broad term that represents many types of chemicals used for pest control. The legal definition of a pesticide, according to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is:

> "...any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating insects, rodents, nematodes, fungi, or weeds, or any other forms of life declared to be pests; and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant."

Not all pesticides are designed to kill target organisms. Some pesticides interact with the site that pests inhabit. Other pesticides target the host plant or animal. There are several ways pesticides are classified. The most common methods of classification are target, mode of action, application method or formulation. Definitions of the different classifications are given below.

CLASSIFICATION BASED ON MODE OF ACTION A common way that pesticides may be grouped or classified is by their mode of action in controlling the target pest organism. Generally, pesticides within a chemical class have the same mode of action on specific types of pests. They also may have similar characteristics, such as chemical structure, persistence in the environment, and types of formulations. There are a number of pesticide families. For more information about herbicide mode of action see the publication:

> **Herbicide Mode of Action and Injury Symptoms**
> BU-3832-GO
> University of Minnesota Extension Service
> North Central Regional Extension Publication No. 377

CLASSIFICATION BASED ON FUNCTION The term "pest control" refers to a pesticide's function, such as preventing, destroying, repelling, or controlling pests. A description of the most common pesticides is given in Table 1.1.

Table 1.1 Pesticide classification based on pesticides function.

Pesticide classification	Function
Biocide	Microbial organisms
Fungicide	Fungi
Insecticide	Insects & other related animals
Herbicide	Weeds
Miticide	Mites
Nematocide	Nematodes
Rodenticide	Rodents
Avicide	Birds
Ovicide	Eggs of organisms
Predacide	Vertebrates
Growth regulator	Modifies plant or insect development
Defoliant	Removes plant foliage
Desiccant	Dries plant foliage
Repellent	Diverts a pest
Attractant	Lures a pest
Pheromone	May attract pests or disrupt behavior
Sterilant	Renders pest unable to reproduce

Table 1.2 Pesticide classification based on type of application.

Type of Application	Description
Aerial	Spraying a field from the air to provide better coverage than ground applications.
Band	Placing the pesticide in a strip or band over a row or on the soil next to the row (before or after crop or weed emerges).
Broadcast	Covering an entire field or area with the pesticide (before or after plants emerge).
Pre-plant	Applied onto the soil before planting.
Pre-emergence	Applied on to the soil before or after crop planting, but before crops or weeds emerge from the ground.
Post emergence	Applied after weeds or crops emerge from the ground.
Soil applied	Applied directly to the soil.
Incorporated	Soil applied pesticides that are mixed into the soil after or during application.

Pesticides Classified by Formulations A pesticide product consists of two parts: active and inert ingredients. Active ingredients are chemicals that actually control the pest. Inert ingredients are all other materials in a pesticide product. An active ingredient usually must be "formulated" with inert ingredients in a manner that increases pesticide effectiveness in the field, improves safety features, and enhances handling qualities. Formulations are classified as solids or liquids on the basis of their physical state in the container at the time of purchase.

Table 1.3 Pesticide classification based on formulation.

Liquid Formulations	Description
Emulsifiable concentrates (EC or E)	A concentrate containing a liquid active ingredient, one or more petroleum-based solvents, and an agent that allows the formulation to be mixed with water to form an emulsion.
Solutions (S)	Pesticides that readily dissolve in water or a petroleum-based solvent to form a solution.
Ready-to-use (RTU) solution	Products that contain the correct amount of solvent when purchased, requiring no further dilution before application.
Concentrate solutions (C or LC)	Solutions sold as concentrates, which must be further diluted with a liquid solvent before application.
Ultra-low-volume (ULV)	Concentrates that may approach 100 percent active ingredient and designed to be used as is or to be diluted with only small quantities of specified solvents.
Flowables (F or L)	Insoluble finely ground active ingredients mixed with a liquid, along with inert ingredients, to form a suspension. Flowables are mixed with water for application.
Aerosols (A)	Active ingredients mixed with a solvent and applied directly under pressure as fine droplets.
Invert emulsions	Water-soluble pesticide dispersed in an oil carrier.
Dry Formulations	**Description**
Dusts (D)	Usually low percentage of active ingredient plus a very fine, dry, inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash and applied dry.
Baits (B)	An active ingredient mixed with food or another attractive substance to attract the pests or is placed where the pests will find it.
Granules (G)	Dusts but with larger and heavier particles made from an absorptive material such as clay, corncobs, or walnut shells.
Wettable powders (WP or W)	Dry, finely ground formulations that look like dusts. Usually they must be mixed with water for application as a spray.
Soluble powders (SP or WSP)	Look like wettable powders but when mixed with water dissolve readily and form a true solution.
Water-soluble packets (WSP)	Measured amounts of pesticide formulation are packaged in bags that dissolve when they are put into water. Not a specific formulation - rather a package for wettable powders, soluble powders, and gels.
Microencapsulated pesticides (M)	Microencapsulated formulations are particles of pesticides (liquid or dry) surrounded by a plastic coating. The formulated product is mixed with water and applied as a spray.
Water-dispersible granules (dry flowables) (WDG or DF)	Like wettable powder formulations, except that the active ingredient is prepared as granule-sized particles and, when mixed in water, the granules break apart into fine powder.

Adjuvants An adjuvant is a chemical added to help increase the effectiveness of the active ingredient. Some of the most common adjuvants are surfactants -- "surface active ingredients" -- that alter the dispersing, spreading, and wetting properties of spray droplets. Common adjuvants include:

Table 1.4 Common adjuvants.

Common adjuvants	Description
Wetting agents	Allow wettable powders to mix with water.
Emulsifiers	Allow petroleum-based pesticides (ECs) to mix with water.
Invert emulsifiers	Allow water-based pesticides to mix with a petroleum carrier.
Spreaders	Allow pesticides to form a uniform coating layer over the treated surface.
Stickers	Allow pesticides to stay on the treated surface.
Penetrants	Allow the pesticide to get through the outer surface to the inside of the treated area.
Foaming agents	Reduce drift or can be used for marking treated sections of the target site.
Thickeners	Reduce drift by increasing droplet size.
Safeners	Reduce the toxicity of a pesticide formulation to the pesticide handler or to the treated surface.
Compatibility agents	Aid in combining pesticides (and fertilizers) effectively.
Buffers	Allow pesticides to be mixed with adjuvants or other pesticides of different acidity or alkalinity.
Anti-foaming agents	Reduce foaming of spray mixtures that require vigorous agitation.

Reading Pesticide Labels Pesticide product labeling is the main method pesticide manufacturers use to communicate with users. Pesticide labeling also is the United States Environmental Agency's primary tool for regulating all aspects of pesticide use. The information printed on or attached to the pesticide container is the label. Labeling includes the label itself, plus all other information you receive from the manufacturer about the product. Pesticide users are required by law to comply with all the instructions and directions on the label.

Always Read and Follow the Label Directions
Label Directions Are Legal Requirements

Types of Registration Always check the label for registration information. All pesticides sold in the United States must be registered with the EPA. All pesticides sold in Minnesota also must be registered with the Minnesota Department of Agriculture. All pesticides must list the EPA registration and the EPA establishment numbers. You also may encounter three types of registration:

1. Full Registration ('Section 3')
2. Emergency Exemption Registration ('Section 18')
3. Special Local Needs or SLN Registration ('Section 24C')

Supplemental labeling must be provided for each SLN registration. Applicators must have a copy of the SLN labeling in their possession in order to apply the pesticide for that purpose. Emergency registration exemptions are used when an emergency pest situation arises for which no pesticide is registered. Known as, "Section 18 exemptions," these registrations

are handled by the highest governing official involved, which usually is a state governor or federal agency head.

Information on the Label Pesticide labels contain basic information that helps users clearly identify the product. Some of these items will be on the front panel of every label by EPA requirements. Figure 1.1 details the items that are required to be stated on a label.

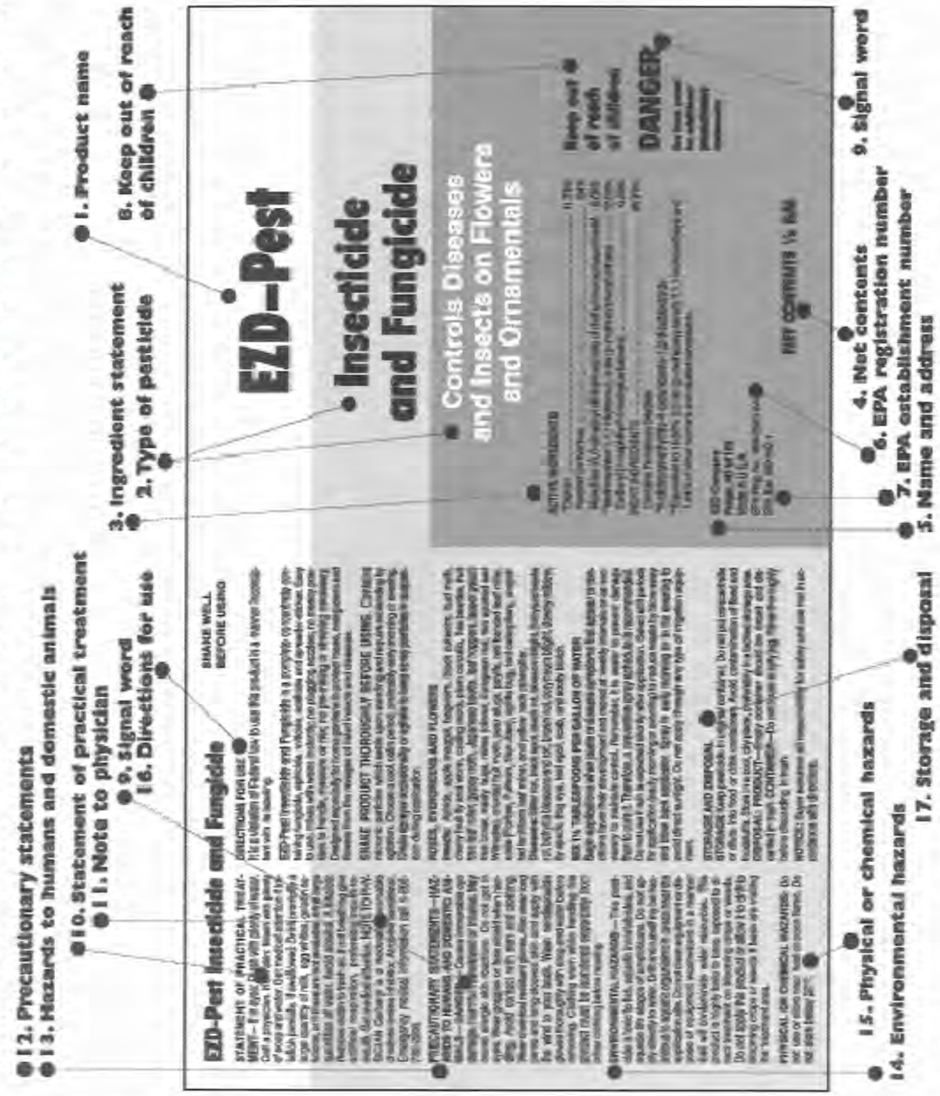


Figure 1.1 The warnings and instructions for use that are found on any registered pesticide.

The signal words used on a label are either caution, warning, danger, or poison. Each of these four words has clearly defined meanings and relate to the toxicity of the product. Table 1.5 lists the definitions and the toxicity for each of the four signal words.

Table 1.5 Signal words and the respective definitions and toxicity ratings as found on pesticide labels.

Toxicity	Oral LD50 (mg/Kg)	Dermal LD50 (mg/Kg)	Inhalant LC50 (mg/L)	Warning Words
Highly	0-50	0-200	0-2000	DANGER, POISON, ☠
Moderately	51-500	201-2000	2001-20,000	WARNING
Slightly	500-5000	2001-20,000		CAUTION
Relatively Nontoxic	5000+	20,000+		NO SIGNAL WORDS

DANGER, POISON, ☠ – with a skull and crossbones means the product is highly hazardous -- just a taste to a teaspoonful taken by mouth can kill.

DANGER – means the product is a severe skin or eye irritant or corrosive.

WARNING – means the product is moderately hazardous -- as little as a teaspoonful to a tablespoonful by mouth could kill an average-sized adult.

CAUTION – means the product is slightly hazardous to relatively nontoxic -- an ounce to more than a pint taken by mouth could kill an adult.

Protecting the Applicator There are four main routes that pesticides can enter your body:

1. Dermal exposure (when you get a pesticide on your skin)
2. Oral exposure (when you swallow a pesticide)
3. Inhalation exposure (when you breathe in pesticide vapors or dusts)
4. Eye exposure

The highest risk of pesticide exposure resulting in a pesticide poisoning occurs when mixing and loading undiluted pesticide products.

Some pesticides are more toxic than others, but toxicity is not the only factor that creates a poisoning risk. The risk of pesticide poisoning depends on the following conditions:

1. The class of pesticide and the chemical make-up of the pesticide. Some chemical compounds in pesticides are more dangerous to humans than others.
2. The dosage of pesticide that enters the body. With some pesticides, a very small dose could cause permanent harm or even death.
3. The amount of time the body is exposed to the pesticide. In general, the longer the exposure the more harm the poison can do.
4. The route of entry (the way the pesticide enters the body). For example, one pesticide may be less harmful if it gets on the skin than if it is swallowed.

Handling a toxic pesticide safely reduces exposure and risk of poisoning. A simple formula to keep in mind is:

Risk = Exposure x Toxicity

It is not always easy to tell if an illness is due to pesticide poisoning. Some illnesses (such as heat exhaustion, asthma, the flu or food poisoning) may show the same symptoms as pesticide poisoning. When someone who handles pesticides becomes ill, however, be aware that pesticide poisoning may be the cause. If you feel ill, think about whether the symptoms occurred before or after you used pesticides. If you need to see a doctor, be sure to mention any pesticides you have used.

What to Do if Someone Is Poisoned Be prepared! If an accident happens, you need to know exactly what to do. Don't wait for an emergency to find out what to do. Any delay could lead to death. Keep the pesticide label on hand at all times. Have a first aid kit ready. Learn CPR. Post emergency phone numbers next to all telephones. Contact the regional poison control center immediately. They provide information on all types of poisoning and can be reached 24 hours a day.

IN MINNESOTA AND NORTH DAKOTA

Minnesota Poison Control System
Hennepin County Medical Center
701 Park Avenue
Minneapolis, MN 55415
Emergence Phone: 1-800-222-1222

Personal Protective Equipment (PPE) Wearing protective clothing and equipment when applying pesticides can reduce the risk of pesticide poisoning because it reduces the chance of exposure. If specific clothing such as goggles or a full protective suit is not listed on the label, use the signal words, precautionary statements, and the product formulation as guidelines. The minimum PPE requirements for anyone handling or applying pesticides (pesticide labels often require additional PPE) are:

1. Always wear work clothing with long pants and sleeves.
2. Wear unlined, liquid-proof, chemical-resistant gloves; unlined neoprene or rubber boots; and a wide-brimmed hat.
3. At the very least, in addition to the above, wear a chemical-resistant apron over cloth coveralls when mixing, loading, or handling undiluted pesticides.
4. Wear liquid-proof, chemical-resistant coveralls or suit with a hood, or wide-brimmed hat if there is any chance of becoming wet with spray.
5. Wear a respirator whenever there is a risk of inhaling pesticide vapors, fumes, or dust.
6. Wear eye or face shields whenever there is a risk of pesticide coming in contact with the eyes.

Clothing worn while applying pesticides should be washed every day:

1. Wear waterproof gloves when handling clothing with pesticides on it.
2. Wash gloves, boots, aprons, suits, goggles, and respirators with detergent and water. Hang or store away from other clothing. When handling pesticides, rinse gloves before removing from hands.
3. Empty pesticide granules from cuffs and pockets before washing.
4. Pre-rinse or pre-soak the clothing.
5. Wash items separate from family laundry.
6. Wash only a few items at a time. Use the highest water level and longest wash time available on your machine.
7. Wash items soiled with hard-to-remove pesticides two or three times. This is especially important when clothing is soiled with highly toxic pesticides.
8. Do small loads with a high water level. Run a second cycle with washers that use less water (such as a front-loading washer).
9. Use hot water for washing (146 degrees F).
10. Use heavy-duty detergents and liquid detergents.
11. Clean the washing machine by running a complete cycle with detergent.
12. Line dry clothing. Sunlight helps break down some pesticides.
13. If undiluted emulsifiable concentrates have spilled on clothing, discard it because washing will not remove enough of the pesticide.

Storing Pesticides Read the label to see if any special steps should be taken before storing the pesticide. Legal requirements for pesticide storage areas may change and the storage of bulk pesticides have additional requirements. Contact the Minnesota Department of Agriculture (1-800-967-2474) or the North Dakota Department of Agriculture (1-800-242-7535) for current storage regulations.

Never keep pesticides where children or unqualified adults can reach them

Store pesticides only in their original containers with the labels intact. The storage area should be a locked room or cabinet where children, unauthorized persons and animals cannot enter. The storage area should have a concrete floor which is impermeable (that is, it will not let fluids pass through) and easy to wash. One of the best ways to reduce the need for storage is to only buy the amount needed for immediate use.

For complete information about pesticide storage, see ***The Private Pesticide Applicator Training Manual*** from the University of Minnesota or North Dakota State University Extension Service.

Disposing of Pesticide Wastes Pesticide users are responsible for properly disposing of empty pesticide containers, excess usable pesticides, and waste material that contain pesticides or their residues. Improper disposal of pesticide wastes can create serious hazards for humans and the environment. It is illegal to bury or burn any type of pesticide container.

The Minnesota and North Dakota Departments of Agriculture sponsor Waste Pesticide Collection Programs and Pesticide Container Recycling Programs. For more information, contact your local county Extension office or call the Department of Agriculture.

Be sure to triple or pressure rinse all pesticide containers at the time of use.

Report pesticide spills According to state law, you must immediately report incidents involving pesticides, even ones that you may consider minor. This includes leaking containers, spills, exposure, poisoning, motor vehicle accidents, tornadoes, fires, and floods. Emergency notification must include this information:

1. Name of chemical.
2. Indication of the acute and chronic health risks of the substance.
3. Estimate of the quantity of the chemical released.
4. Location of the release.
5. Time and duration of the release.
6. Environmental medium into which the release occurred (air, water, soil, etc.).
7. Indication of whether the substance is extremely hazardous.
8. Proper precautions (for example, is evacuation necessary?)
9. Name and telephone number of the contact person.

To report pesticide spills call 911 and the state's emergency management:

IN MINNESOTA
Minnesota Department of Public Safety - Division of Emergency Management
1-800-422-0798

IN NORTH DAKOTA
North Dakota Division of Emergency Management
1-800-472-2121

Here is a list of things to do if a spill occurs.

1. Act quickly. If a spill occurs, it must be taken care of immediately. Any delay could cause serious contamination.
2. Notify the authorities. In addition to the DEM, alert state, county, or local police using 911 if the spill occurs on a public road.
3. Protect yourself. Do not expose yourself to the chemical. Wear protective clothing and equipment as required by the pesticide label.
4. Control the spill. Stop the leak or spill if it is possible to do so safely. If a small container is leaking, put it into a larger container to contain the pesticide.
5. Contain the spill. Prevent the spill from spreading if it can be done safely. Keep it in as small an area as possible. Keep it from getting into any body of water, such as storm sewers and tile lines. Do not hose down the area.
6. Guard the site. Isolate the contaminated area to keep people away. Rope it off if possible.

7. Clean up the spill. The Minnesota Department of Agriculture will give you guidance and assistance on cleaning up a spill and handling contaminated materials.

Protecting the Environment It is important for applicators to understand what happens to pesticides in the environment and how pesticides pollute the water, soil, and air and may affect non-target organisms. Responsible pesticide users know and follow good practices that achieve effective pest management with little risk of environmental damage. Labeling statements may alert you to particular environmental concerns that a pesticide product poses.

Pesticides move in several ways:

1. In air; through wind or indoors through air currents generated by ventilation systems
2. In water; through runoff to surface waters or leaching to ground water
3. In or on objects, plants, or animals (including humans) that move or are moved off-site

Pesticide drift is the movement by air of pesticides to areas other than the target area of application. Drift can be in the form of a spray, dust, or vapor. Large droplets are less likely to drift than small droplets. Droplets with diameters smaller than 50 microns are likely to drift under normal conditions. The following table shows how drift varies with droplet size.

Table 1.6 Distance water droplets drift while falling 10 feet in a 3 mph wind.

Droplet diameter (in microns*)	Classification*	Drift (in feet)
30	Cloud	500
100	Mist	50
200	Drizzle	16
500	Light Rain*	7

* 1 micron = 1/25,000 inch

Lower pressure and coarse nozzles produce larger droplets with less drift potential. Droplets that are released closer to the ground are less likely to drift, since they are in the air for less time.

How to Reduce Drift The type of pesticide, the application equipment, and the weather all have an effect on pesticide drift and the damage it causes. Whenever you apply pesticides, think about how you can control drift. Pay attention to each of the factors affecting pesticide drift listed above:

1. Use low-volatility formulations
2. Use the proper size nozzle for the job, preferably the largest practical nozzle
3. Operate at the lower end of the rated pressure range of the nozzle
4. Release spray near the crop or soil surface
5. Avoid spraying at high temperatures

6. Spray when the wind is low and blowing away from sensitive crops or areas

Pesticides and soils have certain characteristics that affect leaching into the ground water and runoff into surface waters. A combination of characteristics determines whether a particular pesticide will leach or run off on a particular soil:

1. Characteristics of the pesticide
2. Characteristics of the site and soils
3. The applicator's management practices

Here are some ways to protect water quality:

1. First and foremost, the applicator has a responsibility to follow label directions and all Minnesota regulations for handling and applying pesticides.
2. Use Integrated Pest Management practices to avoid unnecessary pesticide use.
3. Choose pesticides that have less potential for leaching or for surface runoff, particularly in vulnerable areas.
4. Spot spray or band pesticides when possible.
5. Keep all pesticide preparation areas, supply tanks, and storage areas at least 150 feet from any water well.
6. Use a rinse pad facility or mix, load, and clean application equipment in the field.
7. Prevent back-siphoning into wells by installing backflow prevention devices.
8. Plant vegetative covers as buffer zones around surface water.
9. Report all spills or back-siphonages.
10. Determine the soil characteristics at the application site. Soil texture and organic matter content influence chemical movement.

Reducing Spray Drift Several new drift reducing spray nozzles are available. The best reducing nozzles induct air into the spray drop with a venturi. Larger drops are produced, which limit their use mainly to systemic pesticides. If excellent coverage is needed for contact herbicides, fungicides and insecticides, a finer drop is usually needed or a higher application rate is needed to compensate for the larger drops.

Other drift reducing nozzles, such as extended range or pressure reducing chamber nozzles, help reduce fine drops. They reduce fine drops over standard flat fan nozzles, but not to the extent of the air inducing types. Operating extended range nozzles down to 15 to 20 psi will reduce fine drops while maintaining a good spray pattern. Standard flat fan nozzles should not be operated below 30 psi.

Shielded spray booms are another excellent way of reducing spray drift. Research studies show that driftable fine drops are reduced by 50 percent to 70 percent over unshielded spray booms. Incorporating drift reducing nozzles along with shielded booms can drastically reduce spray drift, but will not reduce spray drift down to zero. Caution must be used when spraying upwind of sensitive crops or near housing developments.

Pesticides and Your Responsibility Not only pesticide applicators have a responsibility for using pesticides safely. Farmers who hire others to apply pesticides on their crops share the responsibility for good management of the pesticides used on their farm. It is farmers who need to make sure the choice to use a pesticide is part of a sound Integrated Pest Management program. Farmers need to make sure adequate measures are taken to protect water and non-target organisms, pesticides are handled and stored in ways to prevent children and others from exposure, and to understand the public's concern over the use of pesticides in the production of their food.

Authors: Dean Herzfeld and Andrew Thostenson.

CHAPTER 2 – SPRAYER EQUIPMENT OPERATIONS

PESTICIDE APPLICATION EQUIPMENT

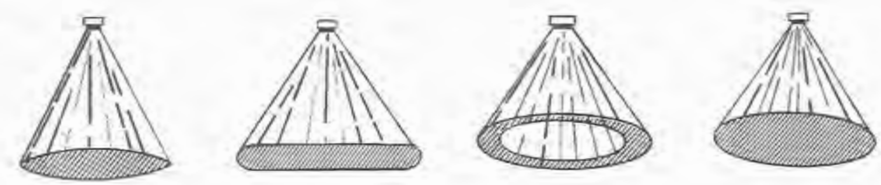
When choosing a nozzle, think about:

1. The size of droplets needed
2. The spray pattern wanted
3. The rate of application

The label may recommend a droplet size and spray pattern. Select nozzles that meet those requirements and also provide the rate of application required by the label. Nozzle charts, found in nozzle manuals available from dealers, show the application rate at certain pressures and ground speeds.

Flat spray nozzles produce medium-sized droplets in a fan-shaped pattern. There are three kinds of flat spray nozzles: regular flat fan spray, even spray, and off-set spray.

Regular flat fan spray nozzles give uniform coverage when overlapped in a boom sprayer. Even spray nozzles are used for band applications. Off-set or off-center spray nozzles are used in clusters for boomless broadcast applications.

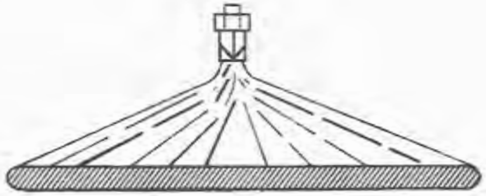


Regular Flat Fan **Even Flat Fan** **Hollow Cone** **Solid cone**

Cone nozzles produce smaller droplets in a round pattern. They are used in directed sprays to apply fungicides and insecticides because they produce the smaller droplets needed for these applications. They do not provide even coverage in a row when mounted on a boom.

Flooding spray nozzles produce large droplets in a wide pattern. They are used close to the ground and at low pressures. They can be mounted on a boom to provide even coverage.

Because they are used close to the ground and produce large droplets, they are excellent for preventing drift.



Sprayer Calibration The procedure for calibrating a sprayer is not difficult. Calibration involves measuring the volume delivered by the sprayer to a specific area and then calculating how much would be delivered to an entire acre.

The first thing in any calibration procedure is to check the flow rate of all nozzles on the sprayer. All nozzles should discharge the same amount within plus or minus 5 percent of each other and produce a good pattern. Check this by collecting the flow from individual nozzles in a measuring cup for a period of time. Thirty seconds works well. A special spray calibrator also works well to give flow rates in gallons per minute and gallons per acre. If any nozzles show abnormal flow (either high or low), they should be replaced if they are not plugged with dirt.

Several methods for calibrating sprayers are available. The following method is simple and accurate. Included is a chart listing the seconds to drive various distances converted to speed in miles per hour (MPH). This also allows you to check the accuracy of your tractor or pickup speedometer.

Sprayer Calibration Methods A sprayer can be calibrated by determining the time required for a sprayer to travel a measured distance and determining the delivery rate of the nozzles during that time. The following chart lists the travel distance required for a single nozzle or group of nozzles spraying one row to spray 1/128 acre. When a nozzle treats 1/128 acre, one ounce of spray collected equals one gallon per acre applied.

Table 2.1 Sprayer Calibration Chart.

Nozzle or Row Spacing (inches)	Travel Distance to equal 1/128 acre (feet)
40	102
30	136
22	185
20	204
10	408

Instructions for use:

1. Use the chart for distance to drive in the field (use nozzle spacing for broadcast sprayers or row spacing for directed and band rigs). For example: You want to broadcast spray with a unit that has a nozzle spacing of 20 inches. You need to measure off a distance of 204 feet in a field.
2. Set the throttle for spraying and operate all equipment. Measure the seconds required to drive the measured distance. To check your travel speed in miles per hour, use the Speed Calibration Chart. (Table 2.2)
3. Catch spray for the noted time in step 2 with a measuring cup. If a boom sprayer is used, catch the spray from one nozzle for the noted time. On directed spray rigs, catch the spray from all nozzles per row for the noted time.

The amount collected from a nozzle or nozzle group output in ounces = gallons/acre actually applied.

Repeat for several nozzles to assure uniform application.

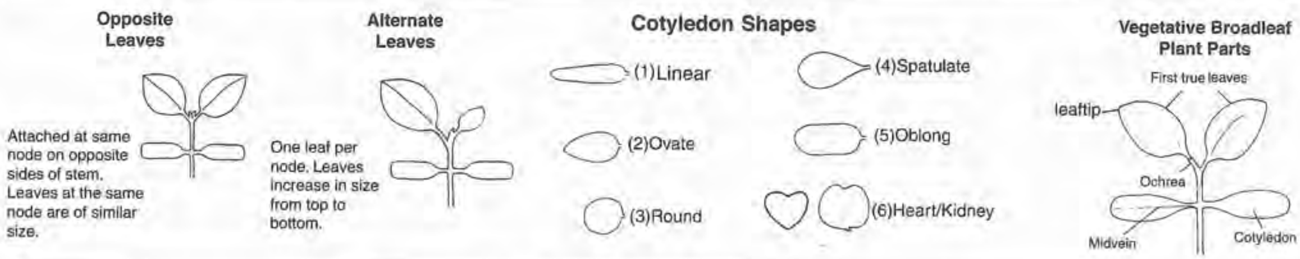
Table 2.2 Speed Calibration Chart.

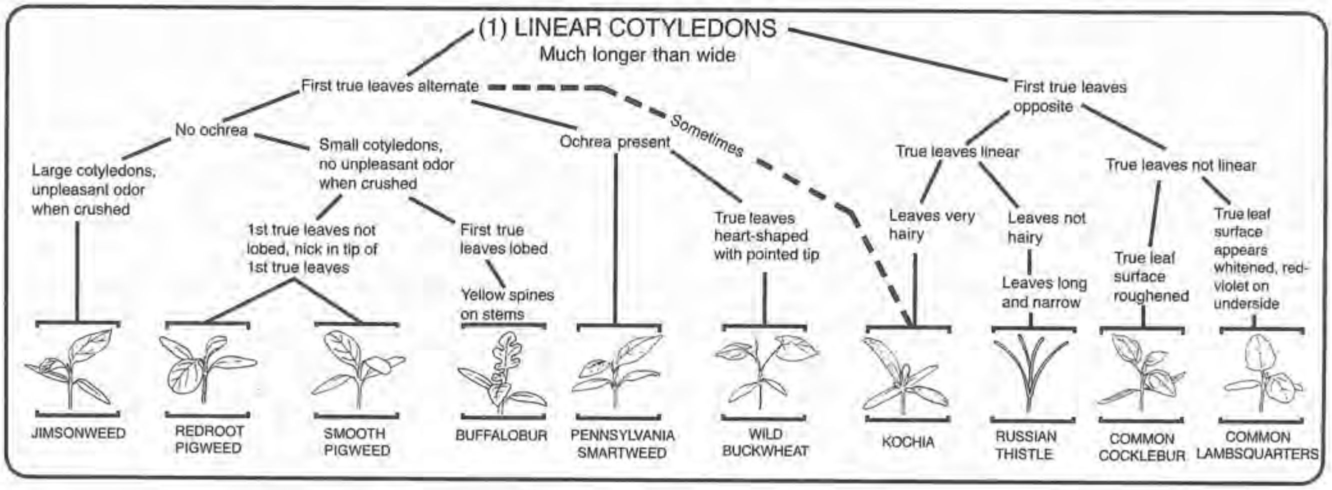
	Distances Traveled (feet)				
Speed (MPH)	102	136	185	204	408
	Time Periods (seconds)				
2.0	35	46	63	69	139
2.5	28	37	50	56	111
3.0	23	31	42	46	92
3.5	20	26	36	40	80
4.0	17	23	32	35	70
4.5	15	21	28	31	62
5.0	14	18	25	28	56
5.5	13	17	23	25	50
6.0	12	15	21	23	46
6.5	11	14	19	21	43
7.0	10	13	18	20	40
7.5	9	12	17	18	37
8.0	9	12	16	17	35
8.5	8	11	15	16	33
9.0	8	10	14	15	31
9.5	7	10	13	15	29
10.0	7	9	14	14	28

Example: If it takes 20 seconds to travel a distance of 204 feet, your travel speed is 7 MPH.

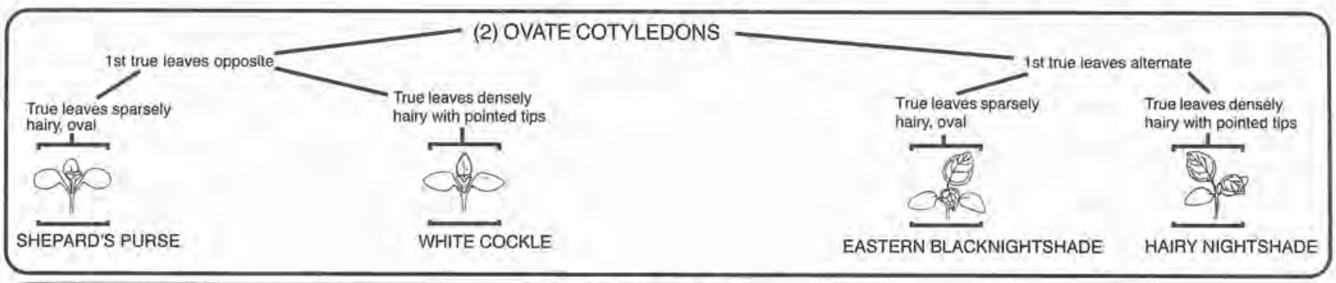
Author: Vern Hofman

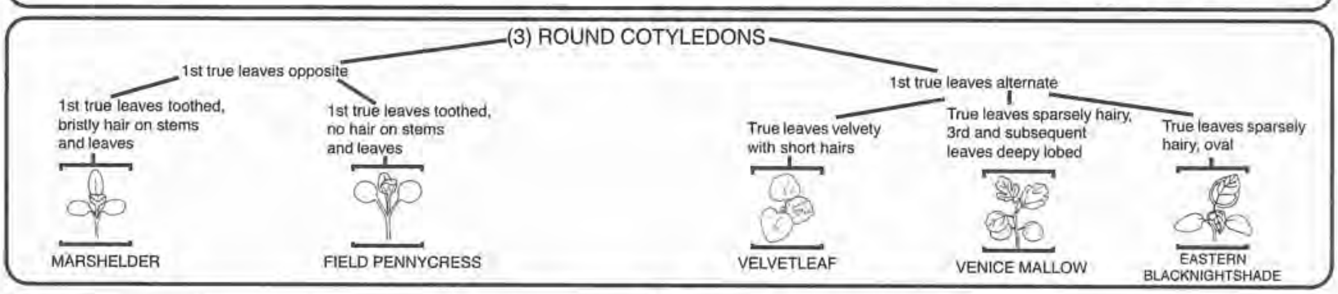
BROADLEAF SEEDLING IDENTIFICATION KEY
TERMINOLOGY

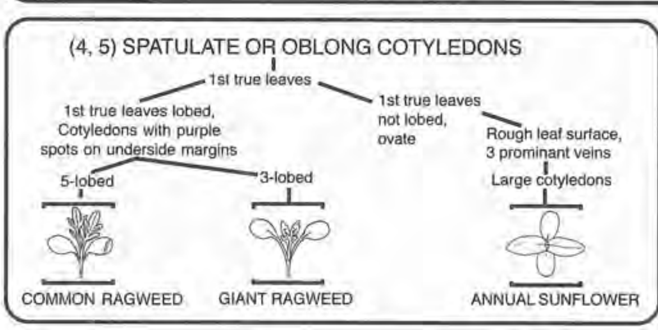


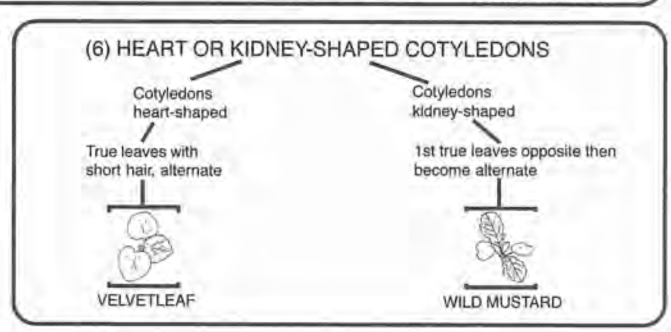


BROADLEAF SEEDLING IDENTIFICATION KEY (CONTINUED)

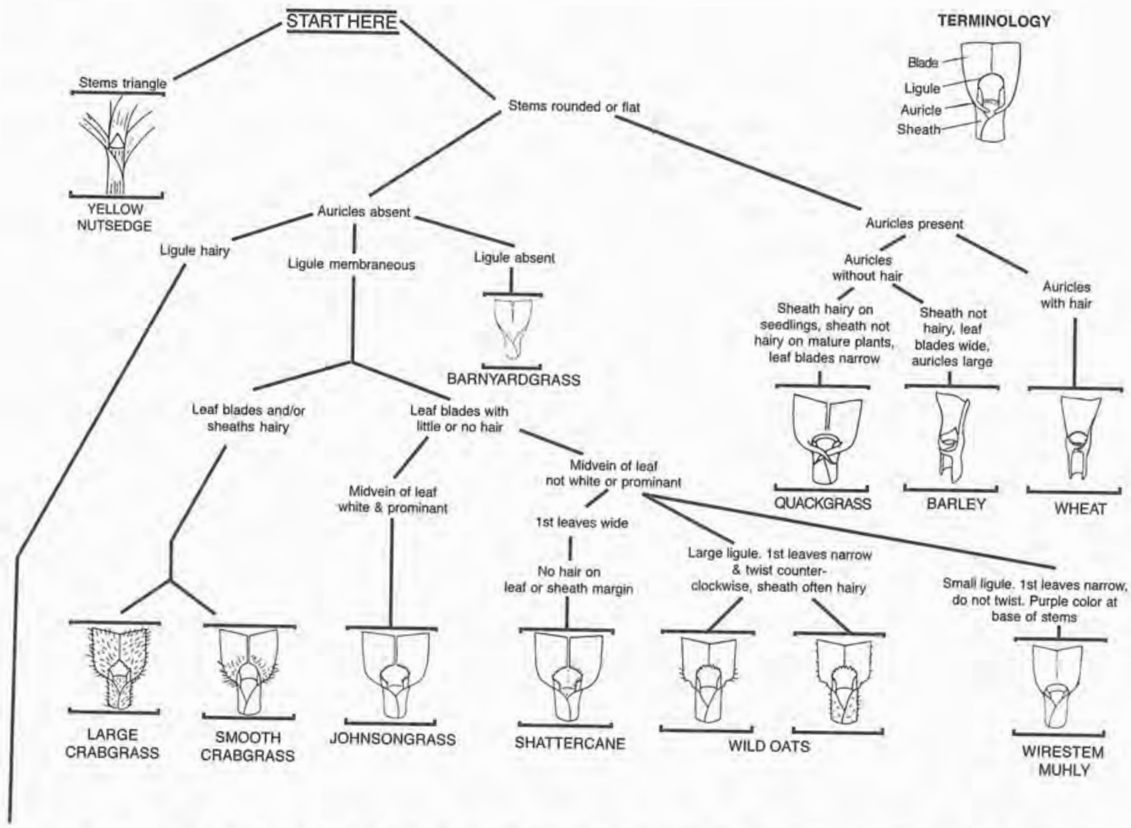




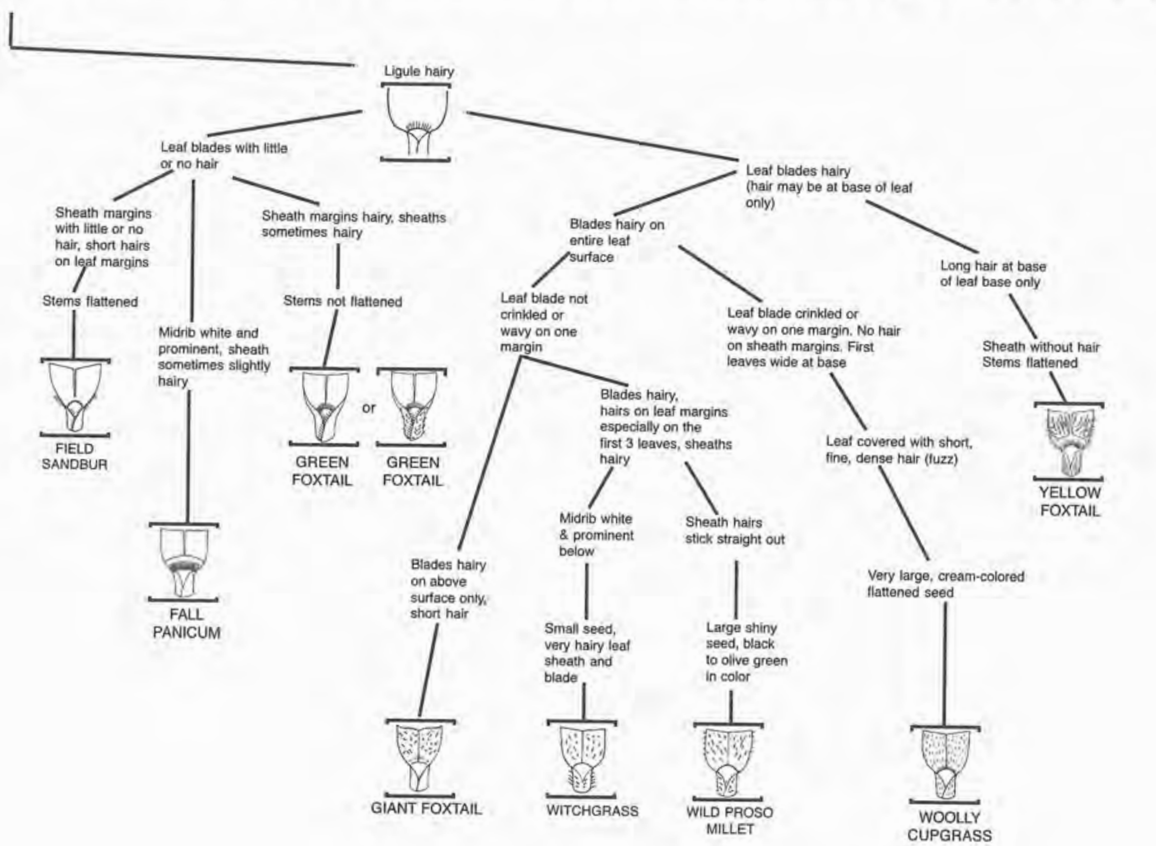




GRASSY WEED SEEDLING IDENTIFICATION KEY



GRASSY WEED SEEDLING IDENTIFICATION KEY (CONTINUED)



SECTION VI: WEED CONTROL

CHAPTER 1: WEED CONTROL IN SMALL GRAINS

Effective weed control usually results from a combination of cultural, mechanical, and chemical practices. The ideal combination for each field will depend on a number of considerations including: 1) the crop being grown, 2) the kinds of weeds, 3) the seriousness of the weed infestation, 4) the soil type, 5) the cropping system, and 6) the availability of time and labor.

Cultural practices that are optimum for crop growth should be followed. These practices include adequate fertility, optimum stands and row width, and proper seeding date. Tillage operations, if used, should be timed to destroy weeds. Tilling the soil immediately before planting will kill weeds that have germinated, thus giving the crop a competitive advantage and often improving weed control from chemicals that do not control weeds that have germinated.

Sowing clean seed at an adequate seeding rate will help reduce the weed population in small grains. Also, small grains must be seeded early so the cool season small grain crop can compete effectively with weeds. Early spring seeding reduces warm season annual grass weed problems such as foxtail (pigeongrass). However, early spring seeding does not help to reduce wild oat populations.

Perennial weeds, such as quackgrass, should be controlled prior to seeding small grains (preferably the year before). Most herbicides available for use in small grains will control many annual weeds, but will not adequately control established perennial weeds.

Rainfall shortly after application often reduces weed control from postemergence herbicides because the herbicide can be washed from the leaf surface. Herbicides vary in absorption rate and ease of being washed off the leaf. The rainfall effect also can vary depending on rainfall amount and intensity. The approximate time between application and rainfall needed to maximize weed control is given in the following table:

Table 1.1 Rain free period needed after herbicide application.

Herbicide	Time between herbicide application and rainfall
Achieve	1 hour
Aim	1 hour
Ally	4 hours
Assert	3 hours
Avenge	6 hours
Banvel/Clarity	1-6 hours
Buctril	1 hour
Bronate Advance	1 hour
Curtail	2 hour
Curtail M	2 hours
Discover	0.5 hours
Everest	1 hour
Express	4 hours
Harmony Extra	4 hours
Roundup	1-6 hours (depends on formulation)
Puma	1 hours
Silverado	4 hours
Starane	1-2 hours
Stampede	4 hours
2,4-D or MCPA amine	6-8 hours
2,4-D or MCPA ester	1-2 hour

Off target movement (drift) herbicide is a problem in Minnesota and North Dakota every year as herbicides move from target fields into nontarget fields containing crops susceptible to the herbicide. Herbicide drift can be a result of particle movement with the wind or vapor drift. Particle drift occurs at the time of herbicide application. Vapor drift can occur at the time of or after application. Particle drift is most likely to occur with small droplets and high winds speeds. All herbicides are subject to particle drift. Spraying large droplets at low wind speeds and when the wind direction is away from the susceptible crop can minimize particle drift.

Vapor drift occurs when volatile herbicides vaporize following application. Vapor drift is most likely to occur with volatile herbicides such as Banvel and the ester forms of 2,4-D and MCPA. Volatility increases as temperature increases, therefore the risk of vapor drift is greatest when volatile herbicides are applied during hot temperatures. Susceptible crops can be injured by vapor drift even if the herbicide was sprayed when the wind was blowing in the opposite direction. To minimize the risk of vapor drift injury, herbicides with high potential to form damaging vapors should not be used near susceptible crops.

GRANULAR VERSUS SPRAY FORMS OF HERBICIDE Several herbicides are available in formulations to be applied as dry granules or as sprays. With a few exceptions, approximately the same weed control can be expected from either form. The cost of granules is usually higher than the cost of an equal amount of the spray form. Distribution of chemicals with granule applicators is sometimes not as uniform as with sprayers, especially on rough ground. In some instances poor distribution has resulted in variable weed control. A wide, flat press wheel or similar attachment on the planter that leaves a level, fine surface is desirable for uniform granule application. Chemicals that cause irritation are less irritating in the granular form than in the spray form.

Herbicide Mixtures Herbicide mixtures are used to overcome limitations of single chemicals. Certain mixtures may (1) control more kinds of weeds, (2) give more consistent performance with variable soils and weather conditions, (3) lessen soil residue problems, (4) increase persistence enough to give full-season weed control, or (5) reduce crop injury.

Only those mixtures that have been field tested under local conditions should be used. Use of some mixtures may result in poor weed control or crop injury. Growers or applicators are responsible for chemical residues in crops, crop injury or lack of weed control resulting from the use of unlabeled mixtures.

Reducing Weed Control Costs There are many possibilities for reducing weed control costs while still attaining good weed control. Wise selection of weed control practices and herbicides to fit specific field situations is the key. Identify your weeds and develop an effective, low cost control program that is suitable for the crop you plan to grow. Reducing herbicide rates below those recommended increases the possibility of costly weed control failure. On the other hand, applying herbicides at greater than recommended rates adds unnecessarily to your weed control costs and may result in crop injury or herbicide carryover. Applying herbicides at the proper time and rate with a carefully calibrated applicator provides the best return on your herbicide investment.

Selecting Herbicides Selection of an appropriate chemical or combination of chemicals should be based on the following factors:

- Label approval for use
- Application timing
- Ground and surface water pollution concerns
- Use of the crop
- Crop and variety tolerance
- Potential for soil residues that may affect following crops
- Kinds of weeds
- Soil texture and pH
- Amount of organic matter in the soil
- Formulation of the chemical
- Application equipment available
- Potential for drift problems
- Tillage practices
- Herbicide performance
- Herbicide cost
- Herbicide resistant weeds

*Table 1.2 Crop tolerance and herbicide clearance.**

Herbicide	Barley	Oats	Rye	Durum Wheat	Spring Wheat	Winter Wheat
Achieve (tralkoxydim)	G/F	NL	NL	NL	NL	NL
Aim (carfentrazone)	F/G	F/G	NL	F/G	F/G	NL
Assert (imazamethabenz)	G	NL	NL	G	G	G
Banvel/Clarity (dicamba)	P	G	NL	F	F	F
Buctril (bromoxynil)	G	G	G	G	G	G
Bronate Advanced (bromoxynil + MCPA ester)	G	G	G	G	G	G
Curtail (clopyralid + 2,4-D amine)	G	NL	NL	G	G	G
Curtail M (clopyralid + MCPA ester)	G	G	G	G	G	G
Discover (clodinafop)	G	NL	NL	G	G	G
Everest (flucarbazone)	NL	NL	NL	G/F	G/F	G/F
Express (tribenuron) + 2,4-D (ester/amine)	NL	NL	NL	G/F	G/F	G/F
Far-Go (triallate)	G	NL	NL	G	G	G
Harmony GT (thifensulfuron)	G	G	NL	G	G	G
Harmony Extra (tribenuron + thifensulfuron)	G	G/F	NL	G	G	G
MCPA (amine or ester)	G	G	G	G	G	G
Puma (fenoxaprop + safener)	G	NL	NL	G	G	G
Silverado (mesosulfuron + safener)	NL	NL	NL	G/F	G/F	G/F
Stampede EDF (propanil)	G	G	NL	G	G	NL
Starane (fluroxypyr)	G	G	G	G	G	G
Stinger (clopyralid)	G	G	NL	G	G	G
Treflan (trifluralin)	F	NL	NL	F	F	F
2,4-D (amine and ester)	G	P	G	G	G	G
WideMatch (clopyralid + fluroxpyr)	G	G	NL	G	G	G

* P = Poor; F = Fair; G = Good; NL = Not labeled for use

Authors: Beverly Durgan and Richard Zollinger

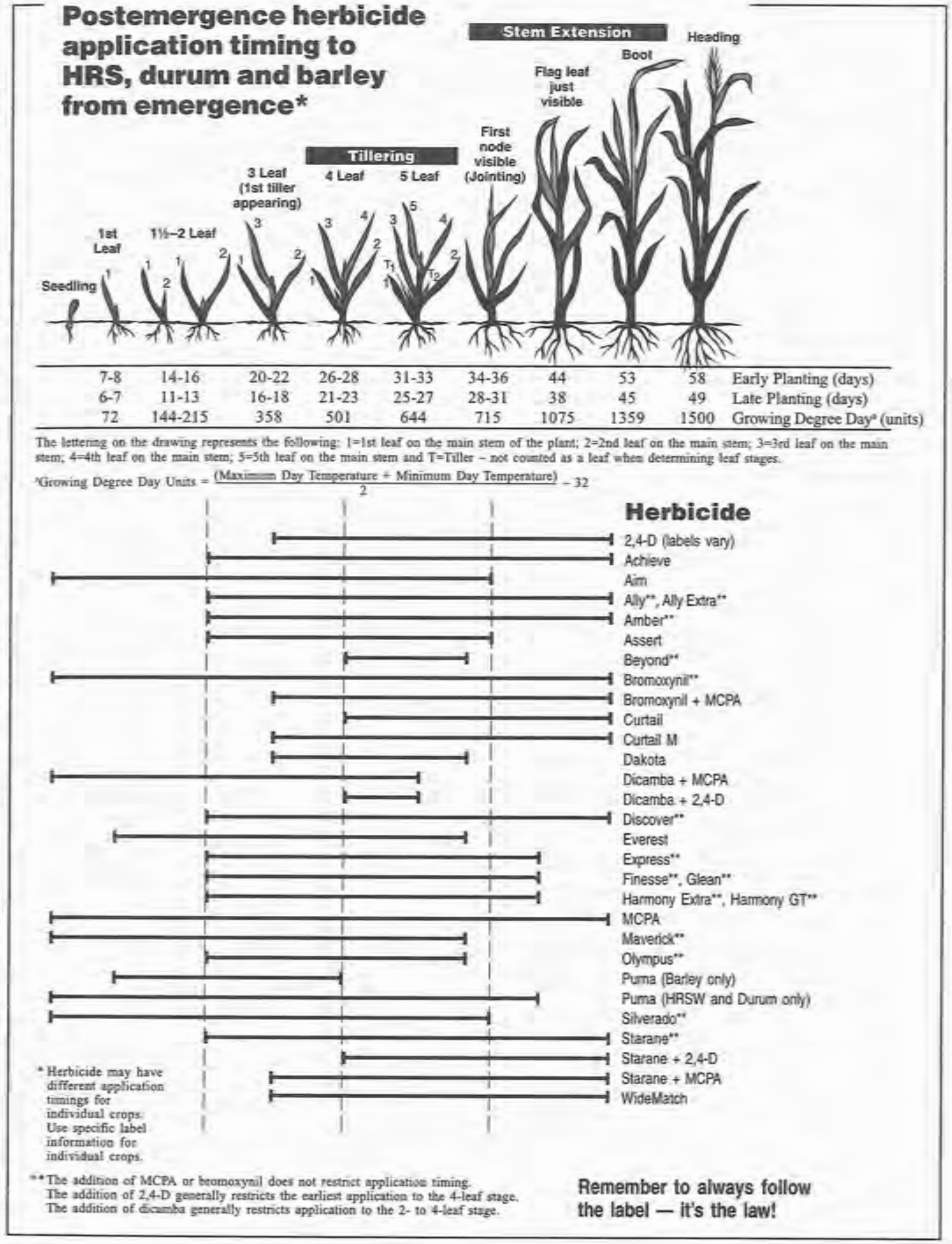
Table 1.3 Effectiveness of herbicides on major weeds in small grains.

Herbicides	Grasses: Barnyardgrass	Grasses: Green Foxtail	Grasses: Wild Oats	Grasses: Yellow Foxtail	Broadleaves: Cocklebur	Broadleaves: Common Ragweed	Broadleaves: Eastern Black Nightshade	Broadleaves: Giant Ragweed	Broadleaves: Kochia	Broadleaves: Common Lambsquarters	Broadleaves: Marshelder	Broadleaves: Pigweed spp.	Broadleaves: Russian Thistle	Broadleaves: Smartweeds (annual)	Broadleaves: Wild Sunflower	Broadleaves: Wild Buckwheat	Broadleaves: Wild Mustard	Perennials*: Canada Thistle	Perennials*: Field Bindweed	Perennials*: Perennial SowThistle
Preplant or Preemergence																				
Fargo (triallate)	N	N	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Treflan (trifluralin)	G	G	P	G	N	N	N	N	F	F	F	F	N	N	N	N	N	N	N	N
Postemergence																				
2,4-D, others (2,4-D)	N	N	N	N	F	G	G	G	F	G	G	G	F	P	G	P	G	F	F	F
Achieve (tralkoxydim)	G	G	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Aim (carfentrazone-ethyl)	N	N	N	N	P	P	G	P	G	G	F/G	N	G	F	F/G	F/G	P	N	N	F/G
Assert (imazamethabenz)	N	N	G	N	N	N	N	N	F	N	N	N	N	P	N	F	G	N	N	N
Avenge (difenzoquat)	N	N	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Banvel (dicamba)	N	N	N	N	G	G	G	G	G	G	G	G	F	G	G	G	P	G	G	G
Bison (bromoxynil & MCPA)	N	N	N	N	G	G	G	G	G	G	G	F/G	G	G	G	G	F	N	P	N
Bison Advanced (bromoxynil & MCPA)	N	N	N	N	G	G	G	G	G	G	G	G	G	G	G	G	G	P	P	P
Bronate Advanced (bromoxynil & MCPA)	N	N	N	N	G	G	G	G	G	G	G	G	G	G	G	G	G	P	P	P
Buctril (bromoxynil)	N	N	N	N	G	G	G	G	G	G	G	F/G	G	G	G	G	F	N	P	N
Clarity (dicamba)	N	N	N	N	G	G	G	G	G	G	G	G	F	G	G	G	P	G	G	G
Clopyr AG (clopyralid)	N	N	N	N	G	G	F	G	P	N	G	N	P	F	G	G	N	G	P	F
Curtail (clopyralid & 2,4-D)	N	N	N	N	G	G	G	G	F	G	G	G	F	F	G	G	G	G	F	F
Curtail M (clopyralid & MCPA)	N	N	N	N	G	G	G	G	F	G	G	G	F	F	G	F	G	G	F	G
Discover (clodinafop-propargyl)	G	G	G	F	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Everest (flucarbazone-sodium)	G	G	G	F	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Express (tribenuron)	N	N	N	N	F	G	F	G	G	G	G	F	G	F	F/G	F	G	G	P	F
Harmony Extra (thifensulfuron & tribenuron)	N	N	N	N	G	G	N	G	G	G	G	G	G	G	G	G	G	G	N	F
Harmony GT (thifensulfuron)	N	N	N	N	G	G	N	G	G	G	G	G	G	G	G	G	G	F	N	N
MCPA, others (MCPA)	N	N	N	N	G	G	G	G	G	G	G	G	N	P	F	P	G	F	G	F
Moxy (bromoxynil)	N	N	N	N	G	G	G	G	G	G	G	F/G	G	G	G	G	F	N	P	N
Puma (fenoxaprop)	G	G	G	G	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Silverado (mesosulfuron)	F	F	G	N	N	N	N	N	N	N	N	F	N	N	N	N	F	N	N	N
Stampede (propanil)	G	G	P	G	N	N	N	N	P	G	P	G	P	P	P	G	G	N	N	N
Starane (fluroxypyr)	N	N	N	N	G	G	G	G	G	N	G	P	F	N	G	F	N	P	G	N
Stinger (clopyralid)	N	N	N	N	G	G	F	G	P	N	G	N	P	F	G	G	N	G	P	F
WideMatch (clopyralid & fluroxypyr)	N	N	N	N	G	G	G	G	G	N	G	P	F	F	G	G	N	G	G	F

NOTE: G = Good; F= Fair; P = Poor; N = No control. Effectiveness ratings apply if herbicide is used according to label recommendations as to rate, time of application, etc., and favorable temperature and moisture conditions prevail.

* Only control of top, no control of roots.

*Table 1.4 Postemergence herbicide application timing to HRS, durum and barley from emergence.**



CHAPTER 2 – HERBICIDE RESISTANT WEEDS

Herbicide Resistant Weeds Several common weed species in small grains have developed herbicide resistance. These weed species and the herbicides against which they have developed resistance are shown in Table 2.1. These resistant weed species can no longer be controlled by these herbicides.

Table 2.1 Herbicide families used in small grains where resistant weed biotypes have developed.

Herbicide Family	Weed Biotypes
Dinitroaniline	Green foxtail
Arlyoxyphenoxypropionate	Wild Oat, green foxtail
Sulfonylurea	Kochia, Prickly Lettuce, Russian Thistle
Thiocarbamate	Wild Oat

Herbicide resistance develops through the selection of naturally occurring weed biotypes that have an inherent ability to tolerate the herbicides. The term "biotype" refers to plants within a species that have a slightly different genetic makeup from the general population. However, a resistant wild oat biotype can survive a herbicide rate several times higher than that needed to control susceptible biotypes. Resistance may arise due to the natural morphological or physiological characteristics of the species. It also is possible that resistance may develop in response to selection pressures due to farming practices or particular herbicide usage.

Herbicide resistance usually begins when a small number of resistant biotypes from a species survives an application from a particular herbicide. When a small grain field is sprayed with a herbicide, susceptible weeds die and resistant biotypes survive. The resistant biotype plants that mature and set seed become the source of future generations of resistant biotypes that eventually replace the susceptible weed species.

Three factors that intensify the selection process of resistant weed biotypes are herbicide efficacy, frequency of use, and duration. A highly effective herbicide acts like a screening process by removing the susceptible weeds and leaving the resistant weed biotypes. The greater the efficacy of a herbicide, the greater the selection intensity for selecting resistant weed biotypes. This intense selection pressure allows resistance weed biotypes to quickly establish themselves over a few growing seasons. Coupled closely with herbicide efficacy in this selection process is frequency of herbicide use. When herbicides with the same mode of action are applied over consecutive growing seasons to crops in rotation, pressure is placed on susceptible weed species and resistant weed biotypes are left.

Regardless of how resistance develops, it is important to know the herbicide mode of action to plan weed control programs that prevent the development and spread of resistant weeds. Weed control programs should incorporate a variety of strategies that emphasize prevention. Relying solely on a single strategy or one herbicide family for managing weeds increases the likelihood that herbicide resistance will develop.

Strategies for Preventing and Managing Herbicide Resistant Weed Problems:

- Scout fields to identify weed species present.
- Use herbicides only when necessary.
- Practice herbicide rotation using herbicides with different modes of action and herbicides from different chemical families.
- Use herbicide mixtures with different modes of action.
- Control weed escapes and sanitize equipment to prevent the spread of resistant weeds.
- Integrate mechanical, cultural, and chemical weed control methods.

See the ***"Herbicide Resistant Weeds"*** publication for more details. This publication can be ordered from the University of Minnesota Extension Service Distribution Center as FO-6077-C.

Authors: Beverly R. Durgan and Richard Zollinger

Section VII: Disease & Pest Management

CHAPTER 1 – PATHOLOGY

OVERVIEW

Small grain diseases limit profitability through reductions in yield and quality. Important steps involved in managing these losses include disease identification and application of timely and appropriate management strategies. This section is designed to aid readers in the recognition of economically significant small grain diseases and provide recommendations for management. A list of seed treatment and foliar fungicides registered for use on small grains in Minnesota and North Dakota during 2005 also is provided.

SEEDLING DISEASES

Seedling Blights. Cold, wet soils slow the growth of seedlings and provide a favorable environment that allows certain fungi to attack the seed or seedling. In addition, some fungi are seed-borne, which gives them the advantage of being on, or in, the seed after planting. Seed treatment fungicides may protect against seed-borne or soil-borne fungi as young roots become established. Different seed-treatment fungicides may be active against specific fungi, so it is important to select the correct product for the potential disease problem (see Fungicide Tables). Some seed treatment formulations are a combination of fungicide and insecticide. Avoid over-application with seed treatment products and apply products to quality seed with germination levels above 85 percent.

ROOT ROTS

Common Root Rot Plant infection often occurs early in the season during wet conditions, but plant damage is not generally evident until later, when the plant reaches the heading stage. If the weather turns hot and dry for an extended period, plants with disease are readily identifiable. Initially, heads and leaves appear bleached. Depending on weather conditions, the remaining plant tissue may die as well. Diseased plants produce fewer and smaller kernels. Root symptoms, most noticeable on the sub-crown internode, are expressed as chocolate-brown to reddish-brown lesions. Root and crown tissues may be discolored from severely diseased plants (See photos 'Common root rot of wheat and Seedling disease' in Section IV). Fungi that cause common root rot survive in soil and on crop debris. Crop rotation using a broadleaf crop can help reduce the level of inoculum in soil. Planting resistant varieties, managing soil nutrients, and applying fungicide seed treatments (see Fungicide Tables) are recommended.

Pythium Root Rot Multiple species of Pythium cause disease on small grains. The organisms produce structures that survive in the soil for years, which means dormant

structures can be widespread in fields. As a result, plant symptoms also tend to be widespread when environmental conditions promote disease development. Infected plants produce fewer tillers, are slow to fill kernels on smaller-than-normal heads, and are stunted and chlorotic. Diseased roots are generally light-brown in color. Root tips and fine feeder roots generally rot in the soil, reducing root mass (See photo 'Pythium brown rot of wheat' in Section IV). Pythium root rot is difficult to diagnose if only aboveground tissues are examined because similar problems are caused by other environmental stresses. Crop rotation with non-hosts helps to reduce inoculum in fields, and applying a seed treatment may prevent early root infection by the pathogen.

Rusts Leaf rust (See photos 'Close-up of leaf rust pustules on wheat' and 'Susceptible reaction of leaf rust on wheat' in Section IV), stripe rust (Photo 'Stripe rust on winter wheat'), and stem rust (See photo 'Stem rust on barley' in Section IV) diseases are common on hard red spring wheat and barley, while crown rust (See photo 'Crown rust on oats' in Section IV) is known as one of the most serious oat diseases. Many varieties of wheat are resistant to stem rust, but new races of the fungus that cause leaf rust require plant breeders to periodically release new varieties with unique genes for resistance. Fungal spores of leaf and stripe rust overwinter in southern states and are carried to Minnesota and North Dakota on winds early in the growing season. Fungicide application is recommended to manage leaf and stripe rusts if the diseases are established in the crop canopy and weather favors rust development prior to heading. Crown rust of oat over-winters locally on buckthorn shrubs and is difficult to control when wet spring weather favors early development of the overwintering spore stage. Many varieties of oat have moderate resistance to crown rust

LEAF SPOT DISEASES

Bacterial Blight (barley) and Bacterial Stripe (wheat) Diseased wheat and barley leaves exhibit small, linear, light-brown, water-soaked spots or streaks. Elongate lesions run parallel with the leaf veins and may coalesce and kill large areas of leaf tissues if weather promotes disease development (See photo 'Xanthomonas streak on wheat leaves' in Section IV). A milky-appearing, slimy exudate may be present on diseased leaves during periods of heavy dew or extended wet weather. Plant heads also can be attacked. Infected spikelets exhibit a dark staining of the veins. This symptom is referred to as black chaff (See photo 'Black chaff of wheat' in Section IV). Bacteria may be contained inside infested seed, and are known as seed-coat contaminants. The disease is spread during the growing season when healthy plant tissue comes into contact with the bacterial exudate that's produced on diseased tissues. Localized areas of diseased plants are often observed in fields. While some varieties may have more disease resistance than others, resistance levels have not been established. Avoid planting seed infested with the bacteria.

Net Blotch and Spot Blotch Both diseases are common throughout Minnesota and North Dakota barley production areas. Spot blotch can develop if wet conditions persist as the crop approaches maturity. The organism that causes spot blotch can also cause common root rot of wheat and barley (see Common root rot). Lesions of spot blotch are small, chocolate-brown, and oval in shape (See photo 'Spot blotch on wheat' in Section IV). Heads may also be attacked, resulting in kernel discoloration. While six-row malting barley varieties have resistance to spot blotch, many two-row varieties are susceptible. Lesions of net blotch are dark-brown, long, and narrow. As they mature, the lesions take on a design that looks like netting (See photo 'Net blotch on barley' in Section IV). The fungi that produce both diseases are seed-borne as well as residue-borne. Planting quality disease-free or fungicide-treated seed and crop rotation are recommended.

Powdery Mildew This disease is promoted by dense plant canopies and moderate summer temperatures (< 85°F). White, cottony mycelium forms on the upper leaf surfaces or stems of plants (See photo 'Powdery mildew of wheat' in Section IV). Mycelium is most noticeable in the lower canopy where humidity levels are more stable. If plants are infected early and disease development is favored, losses in yield and test weight can result. Fungicide applications at early growth stages (4-5 leaf stage) will limit injury; a later fungicide application (after flag-leaf stage) is not as effective. All varieties are susceptible to powdery mildew.

Tan Spot (Wheat) and Septoria Leaf blotches (Wheat and Barley) Several fungi cause leaf diseases of wheat, barley, and oats. Fungi that cause leaf spots often survive on infected crop residue, on grassy weeds, and sometimes on infected or contaminated seed. Most of these disease organisms require extended periods of dew or high humidities for plant infection. Tan spot, a major leaf spotting disease of wheat, produces tiny, black survival structures on wheat residue (See photo 'Overwintering stage of tan spot fungus on residue' in Section IV) that provide early-season inoculum. Tan spot and Septoria nodorum blotch lesions are similar. Both begin as oval- to diamond-shaped areas that often have a chlorotic perimeter and small dark spot in the center (See photo 'Tan spot of wheat' in Section IV). Other leaf spot diseases, such as Septoria tritici (wheat) and speckled leaf blotches (barley), cause vein-limited, elongate lesions that produce tiny, dark fungal bodies at maturity (See photos 'Septoria leaf blotch on wheat,' and 'Speckled leaf blotch of barley' in Section IV).

Planting resistant varieties and crop rotation are recommended to reduce inoculum in infested fields. Chemical control of leaf spot diseases is recommended if the crop has good yield potential, the weather promotes disease development, and the disease organism(s) is present.

HEAD DISEASES

Ergot The ergot fungus may infect wheat, barley and other grasses when extremely wet conditions persist through the flowering stage. Rye is particularly susceptible. The seed of infected florets is replaced by black ergot bodies (sclerotia) that protrude from individual spikelets (See photo 'Ergot sclerotia on wheat head in Section IV). Ergot sclerotia are poisonous to humans and animals. Often sclerotia can be removed with modern grain cleaning equipment, but sometimes the ergot bodies are similar in size to the wheat kernel and may be more difficult to remove. Crop rotation (minimum of 1 year) is recommended to reduce the potential for ergot development. Planting seed containing ergot is not advised. Mowing grasses around rock piles and from roadside ditches and headlands will help reduce grass sources of the fungus. Seed treatments are not effective.

Fusarium Head Blight (Scab) Certain species of the Fusarium fungus cause scab when humid, rainy weather occurs at flowering in wheat and at full head emergence in barley. The disease can continue to progress on the grain head up to grain maturation. Parts or all of the infected wheat heads have a bleached or white appearance. Damaged spikelets may exhibit a salmon-pink color at their base (See photo 'Fusarium head blight of wheat' in Section IV). In barley, infected kernels often have a brown, water-soaked appearance (See photo 'Fusarium head blight of barley' in Section IV). In wheat, damaged seeds are generally shriveled, chalky white, or occasionally pink in color (See photo 'Fusarium damaged wheat seed in Section IV). Scab severely reduces yield and test weight and scabby kernels may contain fungal toxins, including deoxynivalenol (DON). Among livestock, swine are the most susceptible to these Fusarium toxins. For a fee, the Veterinary Diagnostic Labs at the University of Minnesota and North Dakota State University will test scabby grain for the deoxynivalenol toxin.

Scab can be reduced using a multiple management approach: crop rotation with broad-leaf crops; tillage to bury crop residues; use of varieties with more tolerance to scab; use of good quality seed and seed treatment to prevent seedling blight from scab infection; and use of appropriate fungicides at flowering in wheat or early head emergence in barley. The severest scab often occurs when susceptible crops are planted on last year's corn ground, as corn stalks may harbor the Fusarium species causing scab. Varieties differ in their susceptibility to the Fusarium head blight fungi. Information is available on relative susceptibility of varieties in the N.D. and Minn. variety trial bulletins.

Propiconazole has a 24C state label in N.D. and Minn. for use on wheat at heading time to suppress scab, and both states have applied for Sec. 18 emergency exemptions for Folicur (tebuconazole) for scab suppression in wheat and barley, with application allowed up to 30 days prior to harvest (see Fungicide Tables).

Glume Blotch Fungi that cause Stagonospora (Septoria) leaf spots also may infect the grain heads, if wet weather persists during grain fill. The disease is called glume blotch because the fungus causes a grayish-brown discoloration of the glume tips, and often the discolored area contains small black fruiting structures of the fungus (See photo 'Glume blotch infections on durum wheat in Section IV).

Severe glume blotch causes reduced test weight and shriveled grain. Disease management recommendations are similar to those used to manage the leaf blotch phase - crop rotation, variety choice and use of foliar fungicides.

Loose Smut Loose smut of wheat or barley (See photo 'Loose smut of wheat' in Section IV) can be controlled with several systemic seed treatment fungicides (see fungicide tables). Some seed treatment products effective against loose smut are only registered on wheat. All currently grown varieties are susceptible to loose smut, but it is not a severe problem in most seed lots. The embryo test to detect loose smut in barley seed can't be reliably used to assess loose smut levels in wheat seed. Foundation seed and registered seed should always be treated for loose smut. Seed lots from fields with considerable loose smut also should be treated.

SYSTEMIC DISEASES

ASTER YELLOWS The unique bacteria-like organism that causes aster yellows of wheat, barley, and oats is inserted into its plant host tissues by a vector as it feeds. The aster leafhopper has been identified to be the primary source of transmission for the organism that causes aster yellows in Minnesota. Symptoms are similar to barley yellow dwarf with chlorotic leaf tissues gradually turning a red to purplish color before dying. Severely diseased plants are stunted and if heads are produced, the flowers may be sterile. Symptoms are more severe if plants are infected during early growth stages. Insect control isn't recommended because the insects are carried on winds from southern states and are deposited into fields at regular intervals during the growing season.

BARLEY YELLOW DWARF VIRUS Barley yellow dwarf virus (BYDV) may infect wheat, barley and oats. In oats, the disease is generally called oat red leaf, because of the characteristic symptom expressed in oats. The virus is transmitted by several species of grain aphids. Symptoms include stunting and chlorosis of the leaves (See photo 'Barley yellow dwarf symptoms on a leaf in Section IV). Symptoms are more severe if plants are infected in the early stages of development. Oat varieties vary in tolerance to BYDV, but little is known of differences in tolerance among wheat or barley cultivars - most are susceptible. Control of aphids should be based on the recommended thresholds for that insect (see Insect Management section).

WHEAT STREAK MOSAIC VIRUS Wheat streak mosaic virus (WSMV) may cause severe yield losses in winter wheat or spring wheat. The virus is carried from plant to plant by tiny, wind-blown wheat curl mites. The mite lives and reproduces on wheat and many other grass hosts. The mite and virus survive winters on seeded and volunteer winter wheat and on some perennial grasses. Symptoms of the disease include a mild to severe chlorosis running parallel to the leaf veins (See photo 'Wheat streak mosaic virus in Section IV).

Wheat streak is controlled with cultural management strategies – appropriate planting dates and control of volunteers and grassy weeds in the field to be planted. Volunteer wheat should be destroyed at least two weeks before planting the new crop. Control of volunteers may be with cultivation or "burn-down" herbicides. Winter wheat should not be planted too early, preferably not before Sept. 15 in most regions. In the spring, any volunteer winter wheat or infected, symptomatic winter wheat should be destroyed or they will be sources of infection for the nearby spring wheat crop. Early-planted spring wheat is at less risk of severe WSMV infection than late-planted spring wheat.

Note: Fungicide tables for disease control in small grains are based on the latest information available from the crop protection industry. This information conformed to federal and state registrations and regulations at the time of printing. Always follow label directions, making certain to check instructions on how to apply, when to apply, how long to wait prior to harvest, whether treated crops can be fed to livestock, and what safety precautions should be followed. Pathogen resistance to fungicides has been noted in the U.S. and abroad. Specifically, use practices that will minimize selection pressure for strobilurin-based fungicide products.

SEED TREATMENT

Chemical or Control Agent/ Product	Rate	Disease Control[1] Loose Smut	Seedling Blight	Common Root Rot	Pythium Root Rot	Remarks
Azoxystrobin						
Dynasty, 9.6%	0.153-0.382 fl oz/cwt	No	G-E	No	No	For wheat and barley
Carboxin + PCNB						
Vitavax-PCNB 17%,17%	3-4 fl oz/cwt	E	E	No	P	
Carboxin + Thiram						
Vitavax 200 Flowable 17%,17%	3-4 fl oz/cwt	E	E	No	No	
RTU-Vitavax-Thiram,10%,10%	5-6.8 fl oz/cwt	E	E	No	No	
Difenoconazole + Mefenoxam						
Dividend XL 16.5%,1.38%	1 fl oz/cwt 2 fl oz/cwt	G E	G-E G-E	F-G G	F-G G-E	Wheat only Wheat only
Dividend XL RTA 3.21%,0.2%	2.5 fl oz/cwt 5 fl oz/cwt 10 fl oz/cwt	G G G	G F-G G-E	No G-E G	No F-G G-E	Wheat only ND has state label (24 c) for barley
Dividend Extreme 7.73%:1.87%	1 fl oz/cwt 2 fl oz/cwt 4 fl oz/cwt	G G G	G F-G G-E	No G-E G	No F-G G-E	Wheat only ND has state label (24 c) for barley
Incentive RTA 3.12%:0.27%	2.5 fl oz/cwt 5 fl oz/cwt 10 fl oz/cwt	G G G	G F-G G-E	No G-E G	No F-G G-E	Wheat only Wheat only Wheat only
Fludioxonil						
Maxim 4FS 40.3%	0.8-0.16 fl oz/cwt	No	G-E	No	No	
Fludioxonil + Mefenoxam						
Maxim XL 21%,8.4%	0.167-0.334 fl oz/cwt	No	G-E	No	No	
Imazalil						
Agsco Double R II, 10%	0.8-1.5 fl oz/bu	No	No	G-E	No	Wheat and barley only
Nu-zone 10 ME 10%	0.8-1.5 fl oz/cwt	No	No	G-E	No	Wheat and barley only

Chemical or Control Agent/ Product	Rate	Disease Control[1] Loose Smut	Seedling Blight	Common Root Rot	Pythium Root Rot	Remarks
Mancozeb						
Dithane WSP 80%	1.3-2 oz/bu	No	G-E	No	No	
Manzate 75 DF 75%	1.3-2 oz/bu	No	G-E	No	No	
Penncozeb 75 DF, 75% and Penncozeb 80WP,80%	Consult label	No	G-E	No	No	
Maneb						
Agsco DB-Green L 25.6%	3 fl oz/bu	No	G-E	No	No	Contains 8.6% lindane
Seed Mate Maneb-Lindane 50%	2 oz/bu	No	G-E	No	No	Contains 18.75% lindane
Mefenoxam						
Apron XL-LS 32.3%	0.32-0.64 fl oz/cwt	No	No	No	G-E	
Metalaxyl						
Allegiance FL 28.35%	0.375-0.75 fl oz/cwt	No	No	No	G-E	
PCNB (Terraclor)						
PCNB Seed Coat 24%	2 fl oz/bu	No	G-E	No	No	
Thiram						
42-S Thiram 42%	2 fl oz/bu	No	G-E	No	No	Wheat and barley only
Tebuconazole + Metalaxyl						
Raxil MD, 0.48%,0.64%	5 fl oz/cwt	G-E	G-E	G-E	G-E	
Raxil XT 15.0%,20%	0.16oz/cwt or 1 pouch/50 cwt	E	G-E	G-E	G-E	
Raxil MD-W 0.46%,0.615%	5 fl oz/cwt	E	G-E	G-E	G-E	Contains 1.538% imidacloprid for wireworm suppression
Tebuconazole + Metalaxyl + Imazalil						
Raxil MD Extra, 0.34%:0.58%;1.0%	5 fl oz/cwt	G-E	G-E	E	G-E	For wheat and barley only
Tebuconazole + Thiram						
Raxil-Thiram 0.6%,20%	3.5-4.6 oz/cwt	E	G-E	G	No (only early season)w	
Triticonazole						
Charter, 2.4%	2-3.1 fl oz/cwt	E	G-E	G-E	No	For wheat and barley only

[1]P=Poor, F=Fair, G=Good, E=Excellent, No=No Control

FOLIAR SPRAYS

		Disease Control[1]				
Chemical/Product	Rate/A	Leaf Spots	Leaf Rust	Stem Rust	Powdery Mildew	Remarks
Azoxystrobin						
Quadris, 22.9%	6.2-10.6 fl oz	G-E	E	G-E	G-E	Wheat and barley
Azoxystrobin + Propiconazole						
Quilt, 7.0%:11.7%	7-14 fl oz/A	G-E	E	G-E	G-E	For wheat and barley.
Copper						
Champ DP, 57.6%; Champ Formula2, Flowable, 37.5%	1-1.33 lb/A	G	No	No	No	
Champ WP, 77%	1.5-2 lb/A	G	No	No	No	
Cuprofix Disperss, 36.9%	2.25 lb/A	G	No	No	No	
Kocide 2000 DF, 53.8%	1.25-1.5 lb/A	G	No	No	No	
Kocide 4.5 LF, 37.5%	1-1.33 pt/A	G	No	No	No	
Mancozeb						
Dithane DF 75%	2 lb	G-E	E	G-E	No	Do not make more than 3 applications of Mancozeb. Do not apply within 26 days of harvest.
Dithane F-45, 37%	1.6 qt	G-E	E	G-E	No	
Dithane M-45 or Dithane WSP 80%	2 lb	G-E	E	G-E	No	
Manex II,37%	1.6 qt	G-E	E	G-E	No	
Manzate75 DF, 75%	2 lb	G-E	E	G-E	No	
Penncozeb 80WP, 80%	2 lb	G-E	E	G-E	No	
Penncozeb DF, 75%	1-2 lb	G-E	E	G-E	No	
Propiconazole						
Tilt 3.6E 41.8%	2-4 fl oz/A	G-E	E	G-E	G-E	Apply at flag leaf emergence (Feekes growth stage 8). Make only one application. For wheat only, Section 2 ee label permits application of 2-4 oz/A before wheat exceeds the 5 leaf stage and allows 4 fl oz/A to be applied to wheat with heads emerged, up to flowering stage (Feekes growth stage 10.5).
PropiMax, EC, 41.8%	2-4 fl oz/A	G-E	E	G-E	G-E	
Bumper, 41.8%	2-4 fl oz/A	G-E	E	G-E	G-E	

		Disease Control[1]				
Chemical/Product	Rate/A	Leaf Spots	Leaf Rust	Stem Rust	Powdery Mildew	Remarks
Pyraclostrobin						
Headline, 23.6%	6-9 fl oz/A	G-E	E	G-E	G-E	Wheat and barley
Trifloxystrobin + Propiconazole						
Stratego, 11.4%:11.4%	10 fl oz/A	G-E	E	G-E	G-E	Wheat only. A 2(ee) label allows application of 4-10 fl oz/A to control early season tan spot.
Sulfur						
Sulfur DF 80%	6-15 lb	No	No	No	G	Do not apply when temperatures are high 80% (above 90 F). For powdery mildew only.

[1] P = Poor; F = Fair; G = Good; E = Excellent; No = No control.
[2] Leaf spots include tan spot, Septoria leaf blotches and spot blotch.

Note: The fungicide tables are based on the latest information available from the Minnesota Agricultural Experiment Station, North Dakota Agricultural Experiment Station, United States Department of Agriculture, Environmental Protection Agency, and the agricultural chemical industry. The information conformed to federal and state regulations at the time of printing. Always follow label directions, making certain to check instructions on how to apply, when to apply, how long to wait prior to harvest, whether the treated crops can be fed to livestock, and what safety precautions should be followed.

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CHAPTER 2 – ENTOMOLOGY

The following is a key that can be used for identifying insects in small grains:

1. **Insects feeding below ground on seed, seedlings, roots and underground parts.**
   a. ***Wireworms*** -- Smooth, slender, "hard shelled" yellow to brown worms (1/2" to 1-1/2" long), very young small larvae may be white. They feed on seeds and roots, and reduce stand. Usually greater problem following sod, legume grass mixture, or CRP. May be problem over several years.
   b. ***Cutworms*** -- Damage appears as plants are cut off at/below soil surface. Freshly planted seedlings sometimes present. Produce ragged feeding on leaf edge in larger plants. Caterpillars very light to black, 2" long. Usually curl when disturbed.
   c. ***White Grubs*** -- Plump, white, C-shaped grubs with distinct head, 3/4" long. Plants wilt without appearing to be cut off. Generally a greater problem after sod or CRP.
2. **Feeding in stem and on above ground plant parts.**
   a. ***Grasshoppers*** -- Ragged feeding injury on leaf edges. Damage first appears along field margins. Jumping, flying insects.
   b. ***Armyworm*** -- Dark green to light brownish worms, up to 2" long. Light stripe down center of back and one along each side. Hide under dirt lumps, in soil cracks or in lodged grain during day. Eggs laid on edge of field in grassy weeds and in rank and lodged grain.
   c. ***Greenbug*** -- Small, pale-green, soft-bodied, slow-moving insects. Piercing mouthparts, suck plant juice. Dark stripe down center of back. Generally found in clusters on plant and infected plants found in clusters. Slight discoloration on attacked plants causes light areas in field (aphid holes).
   d. ***Corn leaf aphid*** -- Small, soft-bodied, dark-green insects. Posterior margin darker with small black tubes sticking up. Antennae half the length of body. Found scattered on barley leaves. Prefer corn, but also found on barley, wheat and oats.
   e. ***Bird cherry-oat aphid*** -- Small, soft-bodied, purplish-black insects. Tubes on posterior of abdomen are black tipped. Found scattered over plant, may be more abundant on lower parts.
   f. ***English grain aphid*** -- Small, soft-bodied green insects. Antennae and tubes on abdomen black. Found in clusters in leaf axils and on heads.
   g. ***Wheat stem maggot*** -- Whitened heads in field, easily pulled from sheath. Whitish-green maggot may be observed at break point. Infestations rarely get above 5 percent white heads, can reach 20 percent to 40 percent in heavy infestations.
   h. ***Barley thrip*** -- Barley head not fully freed from sheath. Tiny, black, fringe winged, cigar-shaped insects found in leaf sheath. Plant tissue within sheath shows abrasion damage. May be abundant on spring wheat.

   i. ***Stalk borer*** -- Dark, saddle-backed caterpillar. First damage is a hole in the stem near the base of the stalk and surrounded by feces.
   j. ***Cereal leaf beetle*** -- Metallic blue-black beetle with orange middle. Immatures are soft, slug-like, hump-backed larvae covered with slime and feces. Both adults and immatures remove leaf tissue between veins. Prefer oats.
   k. ***Wheat stem sawfly*** -- Pale white or yellowish larva measures 1/2" long, with a well-defined head. The adult a slender wasp about 1/2" long with a black abdomen and yellow ringed markings. Tunnel in stems, causing lower protein content and often causing infested heads to fall to ground making them unharvestable.
   l. ***Hessian fly*** -- Small white maggots tunneling in stem girdle of the plant and causes localized lodging. The adults are small mosquito-like flies, mostly sooty black, but females have orange-red abdomens (related to and similar in appearance to orange wheat blossom midge, but midge are more pink in coloration). Prepupal cases appear like flax seeds and are evident at jointing of infested plant.
3. **Insects found in inflorescence.**
   a. ***Various aphid species*** -- Small, soft-bodied usually wingless insects, green to dark with black tubes on posterior margin of abdomen. Appear first on emerging head, behind blossom and developing berry. May also be present on stem and leaves.
   b. ***Orange wheat blossom midge*** -- Tiny grayish-white to salmon colored maggots found within glumes and between developing berries. Feeding damage causes darkening of plant near maggot and some berry deformation.

(Adapted from: Identification of Insect Pests in Minnesota Small Grains Author: Noetzel, 1994)

Sampling Insect Pests in Small Grains Although there are a number of insect pests on wheat, not all of them are problematic year. An exception, perhaps, are aphids and orange wheat blossom midge (OWBM). Both should be scouted for every year. Other occasional common insect pests in wheat include grasshoppers, thrips, wheat stem maggot, common stalk borer, wheat stem sawfly, and wireworms. Wheat is usually scouted visually or with traps. Most of the pests in wheat also can attack barley and other small grains. While thresholds may vary somewhat, sampling techniques for insect pests in small grains remains similar.

Correct identification of insect pests is important for scouting efforts to be successful. Given that over 99 percent of all animals are insects, it is easy to understand that many insect species may appear similar, but are not equal threats to crops. A good example is Lauxanid flies in wheat. They are a similar color to orange wheat blossom midge, are found within the wheat field in large numbers, but are not damaging to the crop. It also is important to identify those species that will potentially aid in pest control. Heavy populations of natural enemies, such as predators and parasitoids, can negate the necessity for chemical control. However, complete reliance on biological control may not be possible; environmental conditions may favor the biology of the pest species resulting in a pest outbreak. A good estimate of pest populations then becomes even more important.

There should be a sufficient number of samples taken to accurately reflect the population of the pest within the field. When sampling for aphids in small grains, for example, approximately 100 samples may be taken and these should accurately reflect the entire field population. In other insects, such as grasshoppers, populations are often concentrated on the edges of fields and sampling efforts should first be concentrated there. Scouting location and pattern obviously depends on the within field distribution of the insect being monitored. Obviously, other factors, such as field size, shape and access, also will influence how and from where samples are taken.

Incorrectly sampling at a wrong location could lead to low population estimates, resulting in potential crop loss from under-treatment. The same problem can result from undersampling, reinforcing the necessity for sufficient samples to represent the insect pest population throughout the field.

Aphids Aphid populations in this region result mostly from immigrating insects, which arrive on storm fronts from southern states. Although aphids are noticed mostly at heading, they are present in small grains much earlier. Prior to heading, aphids are found lower on the plant, on the underside of leaves or around leaf axils. Aphids move up the plant after heading where they are more easily noticed. Scouting should begin at tillering and continue through heading. Scouting for aphids in small grains is a simple matter of visually inspecting wheat tillers in the field. Aphids tend to be evenly distributed across fields; begin by utilizing one of the sampling plans used to sample an entire field (see below).

Table 2.1 Decision thresholds for sequential sampling program for aphids in small grains.

Number of tillers inspected	If the number of tillers with aphids is lower than this number, stop sampling and do not treat	If the number of tillers with aphids is in this range, pick another 5 tillers	If the number of tillers with aphids is above this number, stop sampling and treat
25	19	20 - 23	24
30	23	24 - 28	29
35	28	29 - 33	34
40	32	33 - 38	39
45	36	37 - 42	43
50	41	42 - 47	48
55	45	46 - 52	53
60	49	50 - 57	58
65	54	55 - 61	62
70	58	59 - 66	67
75	62	63 - 71	72
80	67	68 - 76	77
85	71	72 - 80	81
90	76	77 - 85	86
95	80	81 - 90	91
100	84	If >84 out of 100 tillers are infested, treat with insecticide	

While walking the transect through the field, randomly select tillers and carefully examine them for the presence of aphids. There are two sampling plans: a percent/total method, and a sequential sampling plan designed to save time and effort. The total/percent plan involves selecting 100 plants roughly evenly across the transect, if more than 83 percent of the stems have aphids present, a treatment is probably economically valid. Decisions for the sequential plan are presented in table 1. Feedback from growers indicates the sequential plan is perceived as cumbersome and confusing. If the sequential plan is used regularly, it becomes second nature and will save time. Consequently, it is probably more suitable for crop consultants or others doing frequent insect estimations in the field.

Orange Wheat Blossom Midge (OWBM) Insects develop according to the accumulation of heat units (i.e. degree-day). There are excellent degree day (dd) predictive models for the emergence of adult OWBM. Ten percent of males emerge at 1,100 dd (base 45^{o}F) with emergence continuing to approximately 1,600 dd. Females begin to emerge at approximately 1,300 dd. Female midge fly over the crop canopy at dusk, looking for suitable wheat plants on which to lay eggs. Temperatures must be above 59^{o} F and the wind below 6 mph for females to fly. To scout for OWBM, visually inspect wheat fields at dusk (9-10 p.m) on warm, relatively still evenings and watch for females flying over the top of the canopy. These are small, fragile insects and are not strong fliers. Their flight pattern will appear irregular and they will tend to flutter from plant to plant. Treatment thresholds (1 adult per 4-5 wheat heads) can be determined only by scouting for females in the field. Other monitoring methods, such as sticky traps, have not been proven to be effective estimators of OWBM populations. Small grains are most susceptible to OWBM at anthesis, so scouting should begin before flowering. OWBM problems will be greatest in wheat-on-wheat fields and these fields should be considered at higher risk and scouted first.

Grasshoppers Although there are more than 200 grasshopper species on the Great Plains, only a few species in Minnesota and North Dakota are likely to become economic pests in small grains. Grasshopper populations develop during dry springs following long, warm autumns. During years with moderate or high moisture, fungal diseases keep grasshopper populations in check. Grasshoppers prefer to lay their eggs in untilled soil, such as roadsides, ditches, etc. Eggs will hatch here and the young nymphs (immature grasshoppers) will start to feed here, moving out into neighboring croplands as food becomes scarce. Damage will likely first occur at the margin of fields. An exception is ground that was in soybeans or alfalfa the previous year. Certain grasshopper species will lay eggs in both cropping systems. Grasshopper nymphs look very much like adults but lack fully developed wings. Scouting for grasshoppers should start early in the growing season (late April, early May), because early detection is often instrumental in control. Early treatment of grasshopper production areas is sometimes essential to save crops in outbreak years. Scouting should start at field edges, fence rows, dirt roads, and ditches. Also, pay particular attention to any area that had high grasshopper populations the previous year; grasshopper populations do not "come out of nowhere," they build up over successive generations. Scout for grasshoppers visually, first at the edges of fields and then within the field. If grasshopper numbers are below thresholds at the edges of the fields, it is probably unnecessary to scout within the field (unless the field was in soybeans, CRP, or alfalfa the previous year – then grasshopper numbers could be higher within the field than at the edges). Grasshopper thresholds are calculated as the population per square yard. When sampling within the field, start at a corner, move across the field diagonally, then turn towards any side of the field and continue to the edge. While walking the line, visualize a 1ft² at a point ahead of you. When you reach the 1ft², count the number of grasshoppers moving or feeding within it (this is probably most easily accomplished by moving your foot over the area and counting the number of grasshoppers that hop away). Count a minimum of 20 of these 1ft² areas, calculate the mean number of grasshoppers per ft² and multiply by 9 to arrive at the population per yd². Action thresholds vary for adult and immature grasshoppers (called nymphs) and whether you are scouting the margin or inside the fields (Table 2.2).

Table 2.2. Action thresholds for adult and nymphal grasshoppers.

Rating	Nymphs / yd²		Adults / yd²	
	Margin	Field	Margin	Field
Light	25-35	15-25	10-20	3-7
Threat	50-75	30-45	21-40	8-14
Severe	100-150	60-90	41-80	15-28
Very Severe	200+	120+	80+	29+

Barley Thrips Barley thrips occasionally can become a problem in wheat. Barley thrips are minute, cylindrical insects, brownish to black in color. Their wings appear to be fringed, much like a feather. Immature thrips look just like adults, only smaller and without wings. They become established in small grains around the 5-leaf to boot stage. Newly arrived thrips will produce higher populations around flag and heading. The real damage is not from the thrips in the field at 5-leaf stage, but from their offspring. Later damage includes white heads, which are quite distinct in the green field and may lead to overestimates of damage. Treatment at this stage is not practical and is not recommended as the damage already has been done. Scout from the appearance of the second node to completion of the boot stage, looking for discolored striping (abrasions) on the leaves caused by feeding. If feeding damage is present, look for thrips on the top two leaf sheaths of stems collected randomly from a field.

Minnesota threshold recommendations have included sampling 100 tillers randomly from the field. Treatment is recommended if the average number of thrips per tiller exceeds 10. The threshold for treatment in North Dakota is when the number of thrips per stem are equal to greater than the number calculated by :

Threshold (thrips per stem) = (Cost of Control / Expected price per bushel) / 0.4

Armyworm Armyworm populations in this region are generally the result of immigrating insects from southern states. Armyworms do not overwinter well in Minnesota and storm fronts blow in adults in the late spring and early summer. The earlier the growing season, the earlier it is necessary to scout armyworms. These insects are dark green to light brown and have a light stripe down the center of their back. Adults lay eggs in grassy or weedy areas or in lodged grain. Armyworms, such as some cutworms, tend to feed at night and hide throughout the day. If feeding damage is found in the foliage and no other responsible insects pest can be found, scout for armyworms by parting the foliage on the plant and inspecting the plant and the soil below for small fecal pellets. If pellets are found (or if no other causative agent for plant damage can be found), then look for larvae under plant

trash, soil clods, or in soil cracks. If 4 to 5 worms or more are found per sq. foot, treatment is recommended.

Wheat Stem Maggot Only an occasional pest of small grains in this region, damage from the wheat stem maggot shows up as conspicuous white heads in wheat and barley. It is greenish-white and can be found inside the stem just above the top node. The adult is a small, yellowish-black fly. The damage caused by this insect is very noticeable, so if white wheat heads are found and cannot be connected with some other problem, collect stems and cut open just above the top node. Either the tunnel or the maggot will be noticeable. No chemical control is recommended.

Common Stalk Borer Stalk borers are relatively thin larvae, clearly marked with stripes, and do not curl up when handled. The common stalk borer is clearly marked with incomplete white and purple-brown stripes. A full grown stalk borer will leave the stalk, be about 1-1/2" in length, and be virtually impossible to distinguish from a full grown light-colored cutworm. They can be scouted by looking for a hole near the base of the stalk, surrounded by fecal pellets (similar to the entry holes of European corn borer on corn stalks). Dissect the stem to find this dark, saddle-backed insect.

Wheat Stem Sawfly Rarely a problem in this region but can reach damaging populations in drier areas. This is a small, black and yellow wasp-like insect that lays eggs in late June and early July. The larvae tunnel in the stems until full-grown, when they move down into base of the stem and girdle it from the inside. Infested stems usually break off leaving stubble, in which the sawfly overwinters. Next year's populations generally result from these overwintering sawflies. There is no valid chemical treatment for wheat stem sawfly, but, if they are found in the field, any grain planted in the area the following year should be of a resistant variety. Scout by looking for broken stalks and examining inside stubble for larvae. Swathing heavily infested fields (>6% of stems infected) at 30-35% grain moisture is recommended to reduce losses due to lodging.

Wireworms Wireworms are smooth, slender and have a relatively hard, yellow to brownish shell. They feed on roots and planted seeds. Feeding damage appears as gouging and furrowing in the root. Because many species take more than a year in the soil to mature, areas that were in non rotated or notilled cropping systems tend to have higher wireworm populations (e.g. CRP). The only treatment for wireworms is seed treatment incorporating Lindane. It may be advisable to scout for wireworms in areas coming out of CRP before planting to assess if seed treatment is necessary. Wireworms can be scouted by examining roots or by using a modified solar trap system. Scout for at least one week before planting. Wireworms are more likely to be near the soil surface as the soil temperature increases in the spring, so scouting close to planting will increase the likelihood of finding wireworms. Mix a 1:1 corn/wheat seed mixture and soak for 24 hours before use to facilitate germination. Place 1/2 cup of the mixture in a hole 4" wide and 10" deep, cover with soil, and then cover the soil over the bait with a black plastic trash bag to warm the surface and speed germination. Cover the edges of the bag with soil to prevent it from blowing away in the wind. Four traps per acre are a reliable sampling plan for wireworms, but this trap density may be unrealistic because of the time and effort involved in the scouting process. As a compromise, at least 10 traps should be used in each field. Collect the samples after one week, count the number of wireworms in each trap and determine the average. If the number of wireworms exceeds 1 per cup, seed treatment will probably be economically valid.

Table 2.3 Management of Insect Pests.

ALWAYS READ THE LABEL – THIS INFORMATION IS SUBJECT TO CHANGE WITH CHANGES IN PRODUCT REGISTRATION !!

Product Rate/Acre	Restrictions/Comments
Aphids	
Dimethoate (Dimethoate 4E, Dimethoate 400, Digon 400) – 0.5 - 0.75 pt.	Wheat only. Do not apply within 14 days of grazing younger plants, 35 day phi, no more than 2 applications per season. Do not re-enter treated fields within 48 hrs of application.
Di Syston 8 RUP – 4.0 – 12.0 fl.oz.(foliar app)	Wheat & barley only. 30 day phi, do not re-enter treated fields within 48 hrs of application (72 hrs in areas with <25" rain/year)
Lannate LV RUP 12-24 fl.oz Lannate SP RUP 0.25 - 0.5 lbs.	7 day phi, do not graze/forage within 10 days of application, do not enter treated fields within 48 hrs after application. Do not make more than 4 applications / crop, do not apply more than 1.8 lbs a.i. per crop.
Lorsban 4E RUP / 4ESG RUP – 0.5 -1 pt	Wheat only. No more than 2 apps/season, 28 day phi, no grazing/forage on wheat or straw within 14 days of application, do not feed straw from treated wheat within 28 days after application. Do not re-enter fields within 24 hrs of application.
Malathion 5EC – 1.5 pts.	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion 57EC – 1.5 – 2.0 pts	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion 8EC – 1 – 1.25 pts	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Methyl Parathion 4EC RUP – 0.5 – 1.5 pts.	15 day phi, do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr).
Penncap-M RUP – 2-3 pts.	15 day phi, do not apply within 15 days of forage/grazing. Do not apply more than 6 pts/year. Do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr)
Armyworms	
Carbaryl (Sevin) - rate varies by formulation, max allowable application varies by formulation (check label)	Wheat only, 21 day phi, do not apply within 7 days of grazing/forage or harvest for grazing/forage. Do not re-enter treated fields within 12 hrs of application.
Lannate LV RUP 12-24 fl.oz Lannate SP RUP 0.25 - 0.5 lbs.	7 day phi, do not graze/forage within 10 days of application, do not enter treated fields within 48 hrs after application. Do not make more than 4 applications / crop, do not apply more than 1.8 lbs a.i. per crop.
Malathion 57EC – 2.0 pts	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion 8EC – 1 – 1.25 pts	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Methyl Parathion 4EC RUP – 1.5 pts.	15 day phi, do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr).
Mustang Max RUP – 1.76 – 4.0 fl.oz.	14 day phi, Do not re-enter treated fields within 12 hrs of application. Do not apply more than 20 fl.oz. per acre per season.
Penncap-M RUP – 2-3 pts.	15 day phi, do not apply within 15 days of forage/grazing. Do not apply more than 6 pts/year. Do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr)
Proaxis RUP – 2.56 – 3.84 fl.oz.	Wheat only. 30 day phi, do not graze or forage. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Tracer (Spinosad) – 1.5 – 3.0 fl.oz.	21 day phi, do not forage or hay harvest within 14 days of application. Do not re-enter treated fields within 4 hrs of application. Do not use more than 9.0 fl.oz. of Tracer per acre per yr.

Product Rate/Acre	Restrictions/Comments
Armyworms	
Warrior RUP – 2.56 – 3.84 fl.oz	Wheat only. 30 day phi. ,do not graze or harvest treated wheat for forage within 7 days of application. Do not feed treated straw to meat or dairy animals within 30 days of last treatment. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Barley Thrips	
Methyl Parathion 4EC RUP – 0.5 – 0.75 pts.	15 day phi, do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr).
Cereal Leaf Beetle	
Lannate LV RUP 12-24 fl.oz Lannate SP RUP 0.25 - 0.5 lbs.	7 day phi, do not graze/forage within 10 days of application, do not enter treated fields within 48 hrs after application. Do not make more than 4 applications / crop, do not apply more than 1.8 lbs a.i. per crop.
Lorsban 4E RUP / 4ESG RUP – 1.0 – 2.0 pts.	Wheat only. No more than 2 apps/season, 28 day phi, no grazing/forage on wheat or straw within 14 days of application, do not feed straw from treated wheat within 28 days after application. Do not re-enter fields within 24 hrs of application.
Malathion 5EC – 1.0 - 1.5 pts.	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion ULV – 4.0 – 8.0 fl.oz.	7 day phi. Wheat, barley & oats. Do not re-enter treated field within 12 hrs of application.
Tracer (Spinosad) – 1.0 – 3.0 fl.oz.	21 day phi, do not forage or hay harvest within 14 days of application. Do not re-enter treated fields within 4 hrs of application. Do not use more than 9.0 fl.oz. of Tracer per acre per yr.
Carbaryl (Sevin) - rate varies by formulation, max allowable application varies by formulation (check label)	Wheat only, 21 day phi, do not apply within 7 days of grazing/forage or harvest for grazing/forage. Do not re-enter treated fields within 12 hrs of application.
Mustang Max RUP – 1.76 – 4.0 fl.oz.	14 day phi, Do not re-enter treated fields within 12 hrs of application. Do not apply more than 20 fl.oz. per acre per season.
Proaxis RUP – 2.56 – 3.84 fl.oz.	Wheat only. 30 day phi, do not graze or forage. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Warrior RUP – 2.56 – 3.84 fl.oz	Wheat only. 30 day phi. ,do not graze or harvest treated wheat for forage within 7 days of application. Do not feed treated straw to meat or dairy animals within 30 days of last treatment. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Cutworms	
Lorsban 4E RUP / 4ESG RUP –1.0 pt	Wheat only. No more than 2 apps/season, 28 day phi, no grazing/forage on wheat or straw within 14 days of application, do not feed straw from treated wheat within 28 days after application. Do not re-enter fields within 24 hrs of application.
Mustang Max RUP – 1.28 – 4.0 fl.oz.	14 day phi, Do not re-enter treated fields within 12 hrs of application. Do not apply more than 20 fl.oz. per acre per season.
Proaxis RUP – 1.92 – 3.20 fl.oz.	30 day phi, do not graze or forage. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Warrior RUP – 1.92 – 3.20 fl.oz	Wheat only. 30 day phi. ,do not graze or harvest treated wheat for forage within 7 days of application. Do not feed treated straw to meat or dairy animals within 30 days of last treatment. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.

Product Rate/Acre	Restrictions/Comments
Grasshoppers	
Dimethoate (Dimethoate 4E, Dimethoate 400, Digon 400) – 0.75 pt.	Wheat only. Do not apply within 14 days of grazing younger plants, 35 day phi, no more than 2 applications per season. Do not re-enter treated fields within 48 hrs of application.
Furadan 4F – 0.25 – 0.50 pts. (rotational & gallonage restrictions – check label)	Wheat, oats, & barley – apply prior to heads emerging from boot. Do not graze or feed foliar treated foliage to livestock or cut for silage or hay. Minimum gallonage - 10 gals of finished spray per acre with ground equipment, 2 gals per acre with aircraft.
Lorsban 4E RUP / 4ESG RUP – 0.5 -1.0 pt	Wheat only. No more than 2 apps/season, 28 day phi, no grazing/forage on wheat or straw within 14 days of application, do not feed straw from treated wheat within 28 days after application. Do not re-enter fields within 24 hrs of application.
Malathion 5EC – 1.5 pts.	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion 8EC – 1 – 1.25 pts	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion 57EC – 1.5 - 2.0 pts	7 day phi on wheat, oats, rye, and barley. Do not re-enter treated field within 12 hrs of application.
Malathion ULV – 8.0 fl.oz.	7 day phi. Wheat, barley & oats. Do not re-enter treated field within 12 hrs of application.
Methyl Parathion 4EC RUP – 0.75 – 1.0 pts.	15 day phi, do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr).
Mustang Max RUP – 3.2 – 4.0 fl.oz.	14 day phi, Do not re-enter treated fields within 12 hrs of application. Do not apply more than 20 fl.oz. per acre per season.
Penncap-M RUP – 2-3 pts. (use high rates if most are large or weather cool)	15 day phi, do not apply within 15 days of forage/grazing. Do not apply more than 6 pts/year. Do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr)
Proaxis RUP – 2.56 – 3.84 fl.oz.	30 day phi, do not graze or forage. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Tracer (Spinosad) – 1.0 – 3.0 fl.oz.	21 day phi, do not forage or hay harvest within 14 days of application. Do not re-enter treated fields within 4 hrs of application. Do not use more than 9.0 fl.oz. of Tracer per acre per yr.
Warrior RUP – 2.56 – 3.84 fl.oz.	Wheat only. 30 day phi. ,do not graze or harvest treated wheat for forage within 7 days of application. Do not feed treated straw to meat or dairy animals within 30 days of last treatment. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Hessian Fly	
	Rarely a problem in Minnesota. Insecticide treatments generally uneconomical, populations rarely warrant treatment. Best management rotation with non-susceptible crops, resistant varieties, bury stubble/volunteer wheat after first killing frost or early spring before fly emergence.
Orange Wheat Blossom Midge	
Lorsban 4E RUP / 4ESG RUP – 1.0 pt	Wheat only. No more than 2 apps/season, 28 day phi, no grazing/forage on wheat or straw within 14 days of application, do not feed straw from treated wheat within 28 days after application. Do not re-enter fields within 24 hrs of application.
Penncap-M RUP – 2-3 pts.	15 day phi, do not apply within 15 days of forage/grazing. Do not apply more than 6 pts/year. Do not re-enter treated fields within 4 days of application (5 days in areas with <25" rain/yr)
Proaxis RUP – 2.56 – 3.84 fl.oz.	30 day phi, do not graze or forage. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.
Warrior RUP – 2.56 – 3.84 fl.oz.	Wheat only. 30 day phi., do not graze or harvest treated wheat for forage within 7 days of application. Do not feed treated straw to meat or dairy animals within 30 days of last treatment. Do not re-enter treated fields within 24 hrs of application. Do not apply more than 0.48 pts per acre per season.

Product Rate/Acre	Restrictions/Comments
Wheat Stem Maggot	
	Chemical control not effective. Damage may occur in May through June. Damage causes white heads. Can delay planting after fly-free date in heavy infestation years but has obvious hazards. No chemicals presently registered for this insect.
Wheat Stem Sawfly	
	Rarely a problem in Minnesota or North Dakota. Damage worst in wheat on wheat fields. Damage occurs May through June, tunneling in stems reduces yield, causes lodging and reduces protein content. Chemical treatment not consistent, best management in resistant varieties, rotation to non-susceptible crops, delayed planting/shallow tillage
Wireworms	
Various seed treatments - Cruiser (thiomethoxam), Gaucho (imidacloprid), Lindane	Caution – do not use treated seed for feed or food purposes. Thoroughly clean trucks, bins, and augers which have been used with treated seed to prevent contamination of commercial grain.

RUP = Restricted Use Pesticide
phi = Pre-Harvest Interval
ALWAYS CHECK THE LABEL, THIS INFORMATION MAY CHANGE WITH CHANGES IN REGISTRATION!!

Note: The insecticide tables are based on the latest information available from the Minnesota Agricultural Experiment Station, North Dakota Agricultural Experiment Station, United States Department of Agriculture, Environmental Protection Agency, and the agricultural chemical industry. The information conformed to federal and state regulations at the time of printing. Always follow label directions, making certain to check instructions on how to apply, when to apply, how long to wait prior to harvest, whether the treated crops can be fed to livestock, and what safety precautions should be followed.

Author: Ian MacRae

SECTION VIII: HARVEST & STORAGE MANAGEMENT

CHAPTER 1 – HARVEST MANAGEMENT

ESTIMATING GRAIN YIELD Grain yield can be estimated prior to harvest at several stages during crop development. The earliest possible time to make an estimate is when stem elongation has started. During stem elongation, the growing point develops what ultimately will become the spike. At this point, the number of spikelets can be determined by counting the number of so-called "double ridges." The daily maximum temperature just prior to jointing and during jointing heavily influences the number of spikelets that will form. Depending on the variety, the number of spikelets can decrease by as much as 33 percent if the daily maximum temperatures increase from 60 to 90 degrees F during that period.

To determine grain yield early, multiply the number of spikelet primordia times 3 for wheat or times 6 for barley, if the stand is close to optimum. This estimate is not very reliable as the conditions later in the growing season will determine how many kernels will form in each spikelet and the weight of each kernel also will change, depending on the growing conditions during grain fill.

A more accurate estimate of grain yield can be made when the crop is fully headed. The general formula to estimate grain yield is:

Wheat: Grain yield (bu/acre) = (kernels per spike x spikes per 3 ft row) x 0.0319

Barley: Grain yield (bu/acre) = (kernels per spike x spikes per 3 ft row) x 0.0389

Oats: Grain yield (bu/acre) = (kernels per spike x spikes per 3 ft row) x 0.0504

The formulas are for 7" row spacing and three feet of row. To adjust for other row spacing, multiply the estimated grain yield with the factor in Table 1.1 to calculate the correct grain yield estimate.

Table 1.1 Factors to correct grain yield estimates for different row spacing.

Spacing	Factor
6"	1.17
10"	0.70
12"	0.58

PREHARVEST MANAGEMENT There are two methods of pre-harvest management that can speed up harvest. Swathing or windrowing is one method. An application of glyphosphate is a second option in wheat.

The optimum time for either pre-harvest management tool is right at or just after physiological maturity of the crop. At physiological maturity, the crop has the maximum kernel dry weight and no additional dry matter will be deposited in the grain. The kernel moisture percentage at physiological maturity is relatively high and can vary from 20 percent to 40 percent.

Research has shown that swathing just before physiological maturity does not harm the grain yield or quality. This practice, however, is not recommended when using as a pre-harvest tool.

There are two visual indicators that can be used to determine whether the crop has reached physiological maturity. The first indicator is the loss of green in the kernel and the appearance of a dark layer of cells or pigment strand along the crease of the wheat kernel.

Kernels in the same spike will reach physiological maturity at different times with the middle of the head maturing first.

Another visual indicator is the loss of green from the peduncle and glumes. If the peduncle just below the head becomes straw-colored, transportation of water and nutrients to the head has been cut off and the crop has reached physiological maturity. The advantages and disadvantages of pre-harvest Round-Up and swathing are listed in Table 1.2.

Table 1.2 Advantages and disadvantages of different methods of pre-harvest management.

Method	Advantages	Disadvantages
Pre-harvest Round-Up	Fast More even and faster ripening compared to untreated standing grain. Standing crop will dry faster after a rain than grain in a swath. Opportunity to control weeds.	Poorer weed control of large perennial perennial weed control, compared to post-harvest weed control Potential for herbicide drift onto other crops.
Swath	Grain in a swath will have less hail damage. More and faster ripening and drying when compared to straight cutting grain.	Additional pass through the field Sprouting damage more likely if swaths are heavy and rain or heavy dew persists.

GRAIN HARVEST Harvesting is one of the most important farming operations. Grain loss at harvest is a direct loss of income. Harvesting often is a compromise between getting the job done in a reasonable period of time and living with a reasonable seed loss. Studies have shown that losses can run as high as 20 percent, even with a properly adjusted machine when it is overloaded. A reasonable loss is considered to be 3 percent of the total crop or less. Total harvest losses are seldom, if ever, zero.

Usually over 60 percent of the grain left in the field is due to shattering of the crop and grain lost in getting it cut and into the combine header. Once the crop is in the combine, loss is very low with properly adjusted and operated equipment.

To keep harvest loss low, an operator must determine how much grain is being left in the field. A simple, accurate method to estimate losses requires the use of a foot square frame. Pick several typical areas in the field after the combine has passed and follow these steps.

1. Count the kernels left directly behind the rear of the combine. Count several separate square foot areas (A). Figure 1.1
2. Count the kernels already in the field due to shatter and cutter bar loss (B).
3. Subtract (B) from (A).
4. Divide the results of Step 3 by the ratio of:

$$\frac{\text{Width of windrower/header width (ft)}}{\text{Width of combine (ft)}}$$

5. Divide the result of Step 4 by the number of kernels for the particular crop from the table on the next page for one bushel per acre loss. This is the approximate machinery loss in bushels per acre.

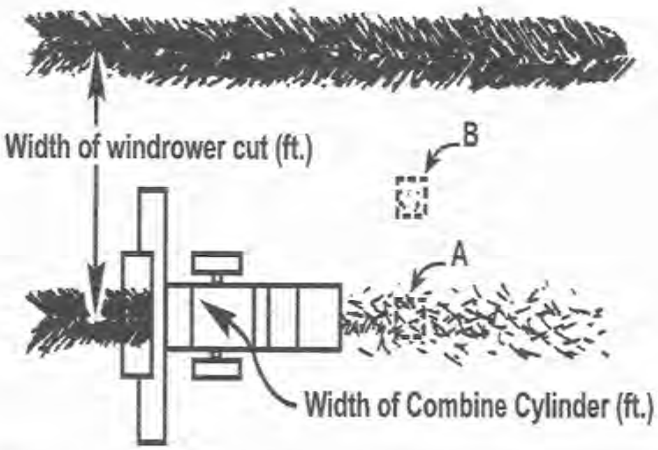

Figure 1.1 Sampling locations to estimate combine yield losses.

6. To find total loss, add the count in (B) to the result in Step 4. This gives the total seed count from shatter, cutter bar and machine loss.
7. Divide the total seed count of Step 6 by the number of kernels for the particular crop for one bushel per acre loss (Table 1.3). This will give the approximate total loss in bushels per acre.
8. For a percentage loss, divide the loss in Step 7 (loss in bushels per acre) by the total yield (harvest yield plus loss) in bushels per acre for the field.

Table 1.3 Number of kernels per square foot to equal one bushel per acre loss.

Crop	Number of kernels / ft2
Hard Red Spring Wheat	20
Durum	16
Barley	14
Oats	10

Some operator manuals have tables that give a grain loss by counting seeds in the area directly behind the combine. Selecting the header or swather width in their chart will give the grain loss in bu/acre.

Swathing Versus Straight Combining Grain grading standards are almost sure to become more rigid; cracked or broken kernels will be discounted in the market. Improving quality will require harvesting at optimum moisture levels, expert combine operation, natural air/low temperature drying, and minimizing rough handling.

Grain threshed at high moisture content is subject to damage. Less damage occurs when grain moisture content is near storage levels, but as standing grain dries in the field, shatter loss increases. Swathing should occur after the grain has reached physiological maturity. This occurs at about 35 percent moisture in wheat and durum. Swath grain at 20 percent to 30 percent moisture. If grain is left to stand at moisture levels under 20 percent, straight combining results in the least amount of loss. Swathing at this stage causes excessive shatter loss.

Straight combining is best done at 15 percent to 18 percent moisture and the grain dried to safe storage levels. Cylinder speeds should be as slow as possible to reduce grain damage, but fast enough to thresh the grain out of the heads. It is usually best to follow combine manufacturers recommendations. In wet grain, slightly faster cylinder or rotor speeds may be needed to get complete threshing. Reduce cylinder-to-concave spacing first to increase threshing action, and then increase cylinder speed as a last resort.

Table 1.4 Combine Troubleshooting Guide.

Threshing – Underthreshing		
Grain Tank	Mainly large kernels Very little grain damage	1) Increase cylinder/rotor speed (limit: grain cracks and shoe chaff loading).
Return	Unthreshed heads	2) Decrease concave clearance (limit: shoe chaff load).
Walkers	Unthreshed heads, long undamaged straw	3) Put in concave filler blanks (limit: grain damage and separating loss).
Shoe	Light chaff load	4) Decrease feed rate.
Threshing – Overthreshing		
Grain Tank	Cracked, split, peeled kernels Short lengths of straw	1) Increase feed rate (limit separating loss)
Return	Damaged grain	2) Decrease cylinder/rotor speed to reduce grain damage. (Be sure to check the return for clean grain first.)
Walkers	No unthreshed grain Straw torn, broken, shortened	3) Open concave if excessive straw breakup is the major overthreshing problem.
Shoe	Heavy chaff load Chaff contains a lot of straw	
Separating – Poor		
Walkers or Rotors	Free grain; more than 2% is excessive	1) Take out concave filler blanks 2) Increase cylinder/rotor speed (limit: grain damage) 3) Decrease concave clearance (limit: shoe chaff load, power) 4) Decrease feed rate
Cleaning: Loss – Sloughing		
Chaffer	Grain, chaff dropping just over end of chaffer	1) Increase air blast 2) Decrease chaffer opening 3) Check air distribution, redirect air, usually towards rear of chaffer sieves 4) Open cleaning sieves 5) Decrease threshing and separating aggressiveness 6) Reduce feed rate
Cleaning: Loss – Blowing		
Chaffer	Grain dropping over end of chaffer with chaff beyond Light seeds in air system	1) Open chaffer 2) Direct air blast toward front of sieves 3) Decrease air blast 4) Open cleaning sieve (air may be going under sieve and up at back end
Cleaning – Light Trash in Grain		
Grain Tank	Light Chaff	1) Look for wind blowing chaff forward into fan inlet 2) Increase air blast 3) Decrease chaffer opening 4) Direct air to dead spots on chaffer or cleaning sieve 5) Close cleaning sieve
Cleaning – Heavy Trash in Grain		
Grain Tank	White caps, part heads	1) Check threshing 2) Close cleaning sieve 3) Increase air blast 4) Use round hole sieve
Cleaning – Grain in Return		
Grain Tank	Excessive grain damage for a reasonable cylinder/rotor speed	1) Check route of grain into return. Close chaffer-tailing section. If grain loss increases and grain in return decreases, it shows late separation on chaffer – treat as grain loss. If grain in the return is unchanged it is going over the cleaning sieve – follow next steps
Return	Carrying a large volume of clean grain	
Shoe	A noticeable amount of damaged grain particles Overloading to point of grain loss from section where return is delivered	2) Check air distribution. direct air blast to front of sieves or away from cleaning sieves 3) Open cleaning sieve 4) Decrease air blast
Cleaning – Light Trash in Return		
Return	Loaded with light chaff, straw	1) Check for wind blowing chaff into fan inlet 2) Increase air blast 3) Decrease chaffer opening, chaffer tailing section opening. If chaff persists: 4) Check rout chaff is entering return. It may enter either through tailings section or over cleaning sieve. For chaff through the tailing section: Shift air towards rear; increase blast or decrease opening. For chaff over sieves: Check air distribution, front to back and side-to-side and adjust if possible. NOTE: Windboard at angle to fan throat can cause "down drafts: for least disturbance, position parallel to fan throat. Check chaff and grain distribution. If uneven, try to shift load evenly or to areas of stronger air blast.
Cleaning – Green Material in Return		
Grain Tank	Green Material	1) Close chaffer and chaffer tailing section
Return	Green Material	2) Increase air blast
Shoe	Green Material	3) Reduce feed rate

Small Grains for Forage Small grain crops can provide excellent quality forage. Data in the table 1.5 represents spring seeded small grain species grown in Minnesota. Quality, crude protein and in-vitro digestible dry matter is highest at boot stage when the forage yield was 38 percent to 42 percent of that at dough stage. These small grains were fertilized with 75 pounds per acre of added nitrogen and not planted as companion crops. Removing small grains at the boot stage allows for double cropping with another annual, such as sudangrass, rape or ryegrass. Barley and sudangrass produced 4.9 tons dry matter per acre when barley was harvested at the boot stage (1.7 from barley) followed by grazing 'trudan' sudangrass for 41 days (mid August through September). Double cropping offers reasonable yields of high quality forage, but input costs can be higher than normal.

Table 1.5 Yield, crude protein and dry matter digestibility of four spring small grain species grown at St. Paul and Rosemount at four stages of maturity.

Small Grains	Growth Stage			
	Boot	Milk	Dough	Average
	DM yield, T/a			
Wheat	1.45	2.74	3.78	2.44
Triticale	1.71	2.96	4.05	2.64
Oats	1.56	3.01	4.09	2.64
Barley	1.71	3.18	4.39	2.81
	Crude % of DW			
Wheat	22.8	15.7	11.9	16.8
Triticale	22.2	15.2	11.6	16.3
Oats	20.5	14.6	11.5	15.7
Barley	23.4	15.7	12.3	17.1
	IVDDM, % of DW			
Wheat	76.2	63.3	58.8	66.1
Triticale	79.6	66.4	61.3	69.1
Oats	77.6	61.5	56.8	65.3
Barley	81.3	68.5	64.4	71.4

Oats as Silage from Companion Crop Establishment Many farmers grow oats as a companion crop with forage seedlings. Silage made from these oats can supply good quality feed for livestock. Oat silage quality is influenced by the stage of maturity at harvest and the moisture level of the material.

The early harvest of oats for hay or silage improves the legume establishment process. During the seeding year, oats compete with the legume for moisture and essential nutrients. Early harvest also prevents lodging and smothering problems later in the growing season. Problems related to straw removal and volunteer oats from shattered seed heads are eliminated by the silage harvest process.

When growing oats for silage, select a variety with good lodging resistance and early maturity. The taller, later maturing varieties can produce the best quality silage, but they must be harvested early to prevent excessive damage to the underseeded legumes.

Seed oats at 1½ to 2 bushels per acre with the various legume underseedings at the rates suggested below:

Alfalfa	7 lb/A; 32 plants/ft2
Birdsfoot trefoil	4 lb/A; 34 plants/ft2
Red clover	5 lb/A; 30 plants/ft2

Table 1.6 Harvest moisture, protein content and total dry matter at growth stages for oats.

Growth stage	Harvest moisture (%)	Protein (%)	Dry Matter/A (tons)
Flowering	87	17	1
Heading	83	15	2
Flowering	78	12	2
Milk	72	12	2
Dough	67	8	3
Seed	59	8	3

Plan the fertility program based on soil test and yield level for the legume and oat crop because nutrient requirements in the two crops are not the same. Nitrogen, phosphorus, and potassium are the key elements to consider. Liming may be necessary to adjust the pH for proper growth of the legume.

Yields of oat silage vary depending on weather, variety, planting date, stage of growth at cutting, and soil fertility, but 10 tons of silage have been harvested from fields capable of producing about 70 bushels of grain. A ratio of 1 ton of silage per 7-8 bushels of grain is routinely used to estimate silage yield.

Protein content (dry weight basis) of oat silage varies from 6 percent at the dough stage to nearly 16 percent at the early boot stage. Protein and dry matter yields for oats harvested for silage at various growth stages in Minnesota are dependent on maturity.

1. Early heading and flowering harvests are high in protein, low in fiber, and very high in moisture. The crop should be wilted to less than 70 percent moisture or preservatives should be added. Such silage is low in energy value, but high in protein.
2. Late milk or early dough stage harvests are lower in protein and moisture, but higher in fiber. Because moisture may still be too high for storage in conventional silos, wilt silage to less than 70 percent or add preservatives.
3. Mid dough stage cuttings are high in fiber and energy value, but low in protein. The field may be yellowing due to maturity by this stage, and direct cutting is possible. No preservatives are needed to preserve the silage.

In summary, the best oat silage will result if you follow these recommendations:

1. Select a proper variety.
2. Use a high fertility program.
3. Cut at late milk or early dough stage.
4. Wilt if cut early to reduce moisture.
5. Chop short.
6. Pack well and cover in silo.

Authors: Vern Hofmann and Jochum Wiersma

CHAPTER 2 – STORAGE MANAGEMENT

After you've invested money to produce grain, make sure you protect that investment by managing grain properly in storage to prevent dry matter and quality losses due to mold and insect activity. Here are some tips for managing stored grain.

Clean Bins Before Harvest Grain and fines (small pieces of broken grain, weed seeds, and chaff) remaining from previous crops almost always contain stored grain insects. To reduce insect problems in the new crop, avoid mixing old and new grain. Also, clean bin walls and floors, the space under perforated floors, and the area outside of bins to remove old grain dust, fines, and kernels.

Manage Fines Fines cause problems in grain storage because they are more susceptible to mold and insect attack than are whole kernels, they restrict airflow during aeration, and they tend to concentrate under fill spouts during grain handling. Select and use grain harvesting and handling equipment to minimize the amount of fines in stored grain and consider using a grain cleaner to remove fines before the grain is stored. In addition to improving grain storability, research has shown that cleaning scab infected grain over a gravity table reduces DON levels in the cleaned grain. Fill bins in a way to prevent concentration of fines at the center. Use a grain spreader to distribute fines uniformly throughout the bin, or don't use a spreader and periodically withdraw fines from the center as the bin is filled (Figure 2.1).

Control Moisture Molds and insects need moisture to live and reproduce, so make sure the grain is dry before it is stored. Maximum recommended moisture content for wheat is 14 percent (wet basis) for up to 9 months storage, and 13 percent for more than 9 months storage. Barley moisture should be 13.5 percent and 12.5 percent, respectively, for the same storage periods.

If grain is too wet when it is harvested, dry it with unheated (natural) air if the bin is equipped with a full perforated floor and a large enough drying fan. Recommended airflow values for natural-air wheat and barley drying are 0.5 cfm/bu (cubic feet of air per minute per bushel of grain) for 14 percent to 16 percent moisture grain, 0.75 cfm/bu for 16 percent to 18 percent moisture and 1.0 cfm/bu for 18 percent to 19 percent moisture (Table 2.1). Get a copy of the University of Minnesota Extension Service bulletin ***Selecting Fans and Determining Airflow for Crop Drying, Cooling and Storage***, FO-5716, or download a copy of the FANS computer program from the Web at: www.bae.umn.edu/extens/postharvest for help in estimating airflow in bins. In general, operate natural-air drying fans continuously (24 hours/day) until all the grain in the bin is dry or until average daily temperatures drop below freezing. Tables 2.2 and 2.3 list the grain moisture content that can be attained based

on the ambient temperature and relative humidity when using natural-air drying. If drying is not completed in the fall, run fans as needed to keep grain at 20 to 30 °F during winter, and resume drying early in the spring. Figure 2.2 illustrates the natural-air drying process.

Table 2.1 The recommended airflow for natural-air and low-temperature wheat and barley drying.

Moisture content (% wet basis)	Minimum Airflow(cfm/bu)
16	0.50
17	0.75
18	1.00

Table 2.2 Equilibrium moisture content (% wet basis) for hard wheat exposed to air at various temperatures and humidities.

Temperature (°F)	Relative humidity (%)			
	20	40	60	80
40	8.5	11.7	14.6	18.0
50	8.2	11.3	14.2	17.4
60	7.9	11.0	13.7	16.9
70	7.7	10.7	13.3	16.5
80	7.5	10.4	13.0	16.0

Table 2.3 Equilibrium moisture content (% wet basis) for barley exposed to air at various temperatures and humidities.

Temperature (°F)	Relative humidity (%)			
	20	40	60	80
40	6.5	9.4	12.2	15.6
50	6.4	9.3	12.1	15.4
60	6.3	9.2	11.9	15.2
70	6.2	9.1	11.8	15.0
80	6.1	9.0	11.7	14.9

Wheat and barley also can be dried in the types of heated-air dryers that were designed for use with corn, but you might have to reduce the drying air temperature to prevent grain damage. Keep grain temperature below 140 °F for grain used for milling, and keep it below 110 °F for grain used for seed or malting.

For more information on drying and storage, get copies of the University of Minnesota Extension Service fact sheets ***Wheat and Barley Drying***, FS-5949 and **Wheat and Barley Storage**, FS-5947 or North Dakota State University Extension Service publications ***Natural Air and Low Temperature Crop Drying***, EB-35, ***Grain Drying***, AE-701, and ***Crop Storage Management***, AE-791.

Aerate to Control Grain Temperature Dry grain should be cooled to less than 60°F as soon as possible after harvest by operating aeration fans during cool weather. In late summer, this might mean running fans only at night. Don't worry too much about high nighttime relative humidity during aeration because grain rewets much slower than it cools.

In late fall or early winter, use aeration fans to cool the grain to 20 to 30°F for winter storage. If grain is not stored at less than 20°F during winter, you shouldn't need to run fans to warm the grain in spring. If you do run fans in the spring, start early in the season (March or April) and make sure you don't warm the grain beyond 40 °F. Cooling grain limits mold and insect activity and it reduces moisture migration. Moisture migration can result in rewetting and eventual spoilage of the grain at the top center of inadequately cooled bins (Figure 2.3).

Estimate the number of hours a fan must be operated to cool a bin of grain by dividing the number 15 by the airflow in cfm/bu. For example, in a storage bin that has an airflow of 0.2 cfm/bu (a typical value for farm bins), it takes about 15 / 0.2 = 175 hours, or about three days of fan operation to cool the grain. See the University of Minnesota Extension Service bulletin ***Management of Stored Grain with Aeration***, FO-1327 or the North Dakota State University Extension Service Publication, ***Crop Storage Management***, AE-791, or get a copy of ***Managing Dry Grain in Storage***, AED-20, from the MidWest Plan Service (www.mwpshq.org) for more information. Figure 2.4 illustrates how grain cooling occurs and how to check for completion of cooling.

Check Stored Grain Regularly Every two to four weeks in cold weather and every one to two weeks in warm weather, measure the grain temperature and moisture, and look for moldy, discolored, or crusted kernels, and for signs of insects. Permanently installed cables that hold electronic temperature sensors can make checking the grain temperature much easier (Figure 2.5). Also, start the fan briefly and smell the first air to leave the bin for musty or sour odors. If problems are detected, run aeration fans to cool the grain. If aeration doesn't control the problem, unload the bin and clean, dry, feed, or sell the grain. Wear a dust mask designed to filter mold spores when you handle moldy grain to avoid health problems.

Storage of Scab-Infected Grain University of Minnesota research on the storability of grain infected by Fusarium head blight indicated that infected grain deteriorated slightly faster in storage than did grain that had been cleaned on a gravity table to remove scab-infected kernels. But the differences in storability between cleaned and uncleaned grain were relatively small. This means that instead of selling scab-infected grain at a low price during harvest, careful grain managers can store the crop and wait for better marketing opportunities. There was so much sample-to-sample variability in DON (deoxynivalenol or vomitoxin) measurements taken during the study on storage of scab-infected wheat that no conclusions could be drawn about changes in DON during storage. The fungus species that causes scab infection and produces DON remained viable during storage at 18 percent and 20 percent moisture, but this fungus species died during storage at 16 percent moisture. This means that DON production during storage is unlikely for wheat stored at less than 16 percent moisture.

Authors: William Wilcke and Kenneth Hellevang

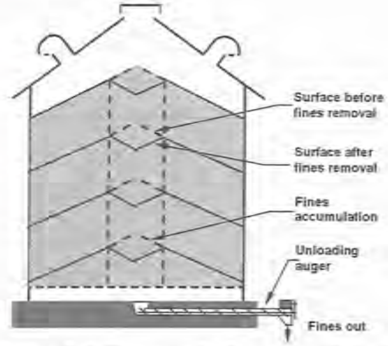

Figure 2.1 Removal of accumulated fines during bin filling.

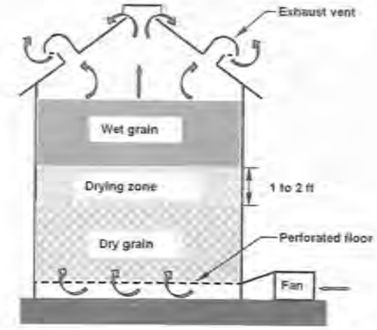

Figure 2.2 Illustration of a natural-air drying bin.

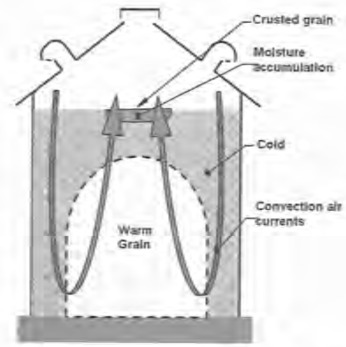

Figure 2.3 Moisture migration in grain that has not been adequately cooled.

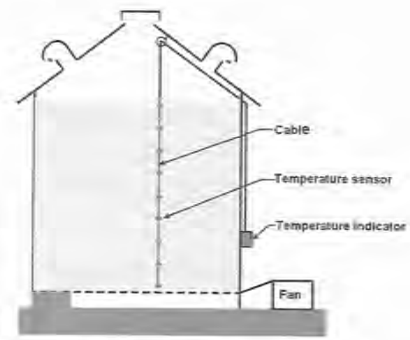

Figure 2.4 Permanently installed grain temperature cables.

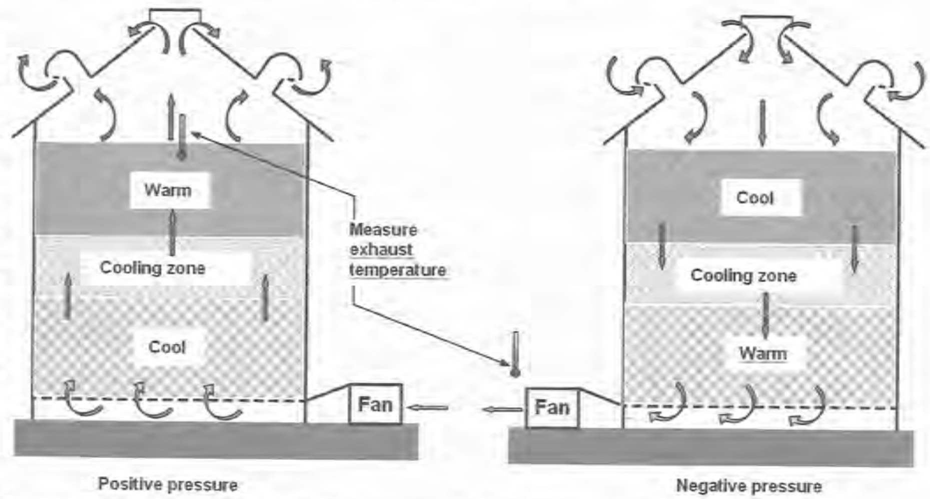

Figure 2.5 Movement of cooling zones during grain aeration.

Section IX: Wheat Marketing

WHEAT MARKETING

An old saying among commodity traders is "plan your trades, and then trade your plan." So the first step in successful grain marketing is to develop a solid plan. Your marketing plan should include price or profit objectives, and a time plan for action. This plan is a necessity to protect yourself from changing plans on a whim in response to the market emotions of the moment. Market emotions can and will affect your selling decisions, so a solid trading plan is the only effective weapon against these emotions.

Other elements are important considerations in the development of a grain marketing plan. These include:

1. Know and control your costs
2. Treat grain marketing as a year-round task
3. Respect seasonal price trends
4. Know your basis

Know and Control Your Costs Wheat is a commodity, and for long-term survival in a commodity market, producers must continually strive to keep production costs low. Recent changes in government programs have created a number of new opportunities. However, they also expose all growers to lower market prices if and when supplies are ample to meet demands in the market.

For growers seeking to get a better handle on their costs and cash flow, consider using FINPACK, a popular farm financial software package. FINPACK was developed by the University of Minnesota Center for Farm Financial Management, 130 Classroom Office Building, St. Paul, MN 55108. A description and demonstration of FINPACK also can be found on the Web at www.cffm.umn.edu.

Treat Grain Marketing as a Year-Round Task Too many producers approach grain marketing as a task to be dealt with after their grain is harvested. For many, this is the only certain way to deal with production risks. However, in today's environment of increased price volatility, pricing opportunities can develop at any time, sometimes well before the crop is harvested. Weather scares and new crop uncertainty can push prices higher in a developing crop. Many research studies have shown that pre-harvest pricing strategies that take advantage of market bulges are more profitable than post-harvest strategies.

There are several ways to price grain before harvest. Among the tools available are the forward contract, futures contract, and the hedge-to-arrive contract. To sell futures against your developing crop, you will need to open an account with a broker and post margins. With the hedge-to-arrive contract, your local elevator sells futures for you, relieving you

of any margin issues. The forward contract is the simplest way to establish a price for your grain. With the forward contract, you can establish a price for your grain with your local elevator well in advance of the harvest, with no worry about margin calls.

Respect Seasonal Price Trends All commodity prices tend to follow some well-defined patterns throughout the marketing year. Shown in the chart below is a 10-year history of average monthly Minnesota wheat prices received by farmers. While not every year is the same, we can define certain times in the year as better selling opportunities. For example, the August/September harvest period is (on average) the low period in prices - a good reason to seriously consider pre-harvest pricing strategies particularly if the crop has developed in an uneventful manner. This chart clearly points to higher average prices in the November/December post-harvest period. The highest prices come in the spring, but producers must bear in mind that a modest price increase so late in the marketing year may not be enough to cover the costs associated with storing grain.

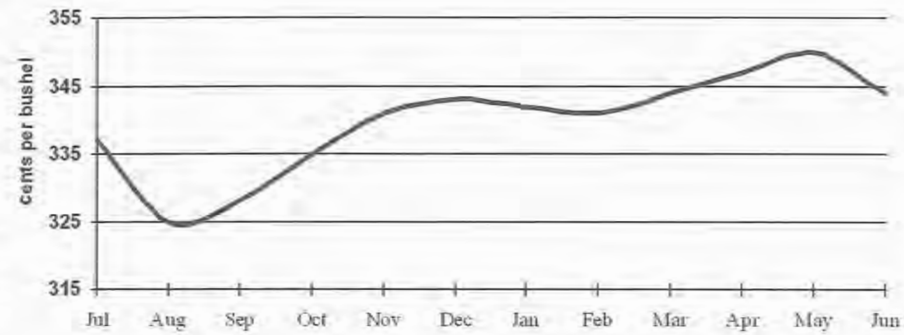

Figure 1.1 Average All Wheat Prices Received by Minnesota Farmers, 1980-2003.

Know Your Basis The effective use of marketing tools demands a solid knowledge of cash-futures price relationships. In the grain trade, wheat prices are usually quoted as so many cents "under" or "over" the futures price. This difference between cash and futures prices is commonly known as the "basis." The basis is simply the difference between a cash price at a specific location (e.g. wheat prices in Thief River Falls) and the price of a particular futures market (e.g. December futures prices in Minneapolis).

Basis is the link between the general price level (the futures market) and the cash price at some specific location. Local cash prices reflect not only the general price level, but also local economic values. These local differences include (1) transportation costs and availability, (2) local supply and demand for the commodity, and (3) the availability of local storage. What really makes basis a valuable decision tool is that basis levels are more predictable than cash and futures prices.

The basis for storable commodities display distinct seasonal patterns (see the following chart of Crookston, Minn. wheat basis). With grain stocks and the demand for storage high at harvest, cash prices are often at their largest discount to the futures (i.e. the basis is weakest at harvest). As the crop is stored and some is used, the supply of storage increases relative to the demand base, and the basis narrows. The following chart shows how the wheat basis in Crookston is at its widest points in August and September. The basis chart shows the same strengthening trend into the last two months of the year. The astute decision maker will gather a 3-to-5 year history of their local basis using daily or weekly data.

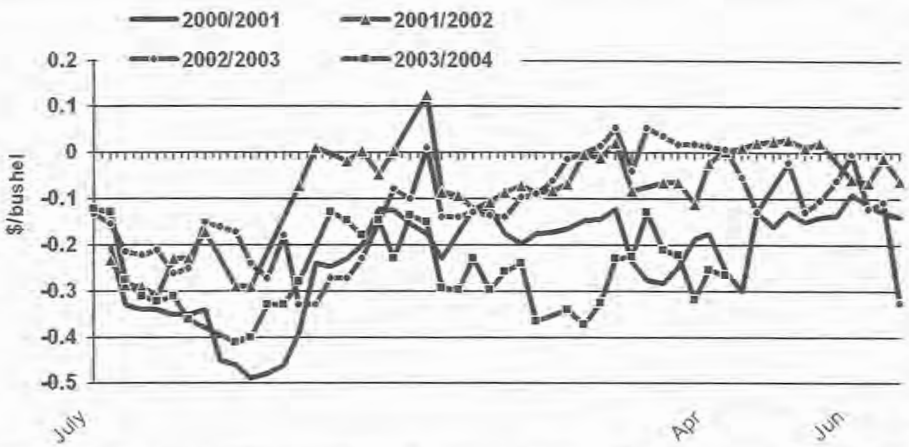

Figure 1.2 Crookston nearby spring wheat basis in 2000-2004 (52 weeks starting July).

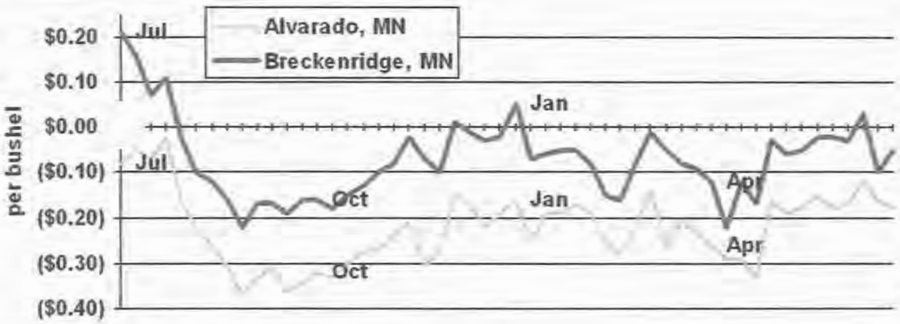

Figure 1.3 Alvarado and Breckenridge nearby spring wheat basis, 1995-1998 average (52 weeks starting July).

The number of marketing tactics that employ a knowledge of the basis are too numerous to cover here. But one tactic is worthy of discussion. More and more farmers are examining the possibility of "paper farming." Paper farming is the term used to describe the strategy of selling your harvested grain and replacing the sale with the purchase of futures or call options. The advantages of this strategy are two-fold. First, the farmer is able to generate cash from the sale of wheat. Second, the costs (mainly shrink and interest) and hazards of storing grain are avoided. Let's examine this idea further by taking into consideration the local basis.

Consider the logic of this strategy when the basis is "weak." A weak basis simply means that your cash price is lower than normal relative to the futures market. In this situation, does it make sense to sell low (sell the depressed cash market) and buy high? That doesn't make sense! On the other hand, if the basis is strong - cash prices are high relative to futures - this strategy may make very good sense. Paper farming in this situation involves selling the high priced market and buying the low priced market. This one example serves as a reminder of the importance of basis as one more factor in your marketing decisions.

Many observers of agriculture believe that crop marketing is the largest challenge facing farmers today. Recent changes in farm legislation will create a number of opportunities for farmers and pose challenges as grain prices are now fully exposed to world events. Success in the future will demand new efforts in marketing that rival the current efforts placed on production.

Authors: Edward Usset and George Flaskerud

USEFUL INTERNET INFORMATION SOURCES

Below follows a small compilation of small grains information sources that are available on the Web. The sites are organized in broad categories and generally, the Internet address listed points to the main page rather than specific articles or sections within the site. Use the search tools within each of the sites to help find information of interest.

National & State Organizations:	
American Malting Barley Association	http://www.ambainc.org/
Minnesota Assoc. of Wheat Growers	http://www.smallgrains.org/
National Association of Conservation Districts	http://www.nacdnet.org/
National Association of Wheat Growers	http://www.wheatworld.org/
North Dakota Wheat Commission	http://www.ndwheat.com/
Northern Crops Institute	http://www.northern-crops.com/
US Wheat & Barley Scab Initiative	http://www.scabusa.org/
US Wheat Associates	http://www.uswheat.org/
Wheat Foods Council	http://www.wheatfoods.org/
Wheat Quality Council	http://www.wheatqualitycouncil.org/
Extension Services:	
Alberta	http://www.agric.gov.ab.ca/
Manitoba	http://www.gov.mb.ca/agriculture/
Minnesota	http://www.extension.umn.edu/
North Dakota	http://www.ext.nodak.edu/
Saskatchewan	http://www.agr.gov.sk.ca/
South Dakota	http://sdces.sdstate.edu/
Federal & State Government:	
Agricultural Research Service	http://www.ars.usda.gov/
Animal & Plant Health Inspection	http://www.aphis.usda.gov/
Cereal Disease Laboratory, St. Paul	http://www.cdl.umn.edu/
Economic Research Service	http://www.ers.usda.gov/
Farm Service Agency	http://www.fsa.usda.gov/
Grain Inspection	http://www.usda.gov/gipsa/
Minnesota Department of Agriculture	http://www.mda.state.mn.us/
National Ag Statistics Service	http://www.usda.gov/nass/
Natural Resources Conservation Service	http://www.nrcs.usda.gov/
North Dakota Department of Agriculture	http://www.agdepartment.com/
Risk Management Agency	http://www.rma.usda.gov/
United State Department of Agriculture	http://www.usda.gov/

Production Information Sites	
Grain Genes	http://wheat.pw.usda.gov/
NDSU Small Grains Production	http://www.ag.ndsu.nodak.edu/aginfo/smgrains/
Small Grains	http://www.smallgrains.org/
Markets	
Chicago Board of Trade	http://www.cbot.com/
Kansas City Board of Trade	http://www.kcbt.com/
Minneapolis Grain Exchange	http://www.mgex.com/
Scientific Societies	
American Phytopathological Society	http://www.scisoc.org/
American Society of Agronomy	http://www.agronomy.org/
Crop Science Society of America	http://www.crops.org/
Soil Science Society of America	http://www.soils.org/
Seed	
AgriPro	http://www.agriprowheat.com/
Minnesota Crop Improvement Association	http://www.mncia.org/
North Dakota Crop Improvement Association	http://www.ndcropimprovement.org/
NorthStar Genetics	http://www.northstargenetics.com/
WestBred	http://www.westbred.com

USEFUL E-MAIL MAILING LISTS & LIST SERVERS

E-mail is a great tool to quickly deliver information to a large number of people. For this purpose, many organizations and businesses use mailing lists that forward messages to all the people on that particular list. A second tool to distribute e-mail to multiple recipients is a list server. A list server is an e-mail tool that manages databases of user e-mail accounts and automates the sending of messages to specified groups of users. Subscriptions to a list server can provide anyone subscribed with a copy of the information that another member submitted.

Companies or organizations often have a place on their Web site where you can submit your e-mail address if you want to be added to their mailing list. Joining a list server generally requires you to submit a request to the administrator of the list server or sometimes can be done automatically using your e-mail software. Contact the administrator for detailed instructions and/or permission on how to subscribe. Some list servers are moderated, which means that the administrator reviews the submitted e-mail before it is forwarded to all the members on the list server. When posting messages to the mailing list, be certain to be courteous, brief, and stick to subjects of interest to the group. After all, everyone who subscribes to the list will see every message you send to the list.

The University of Minnesota and NDSU maintain the following two list servers that are very useful for small grains producers:

1. **Red River Ag** - Unmoderated list server for Extension personnel, state specialists, and producers focusing on production agriculture in Northwest Minnesota.

Administrator is Dr. Jochum Wiersma, University of Minnesota small grains specialist (wiers002@umn.edu). To subscribe to Red River Ag, visit http://mailman.coafes. umn.edu/mailman/listinfo/redriverag and follow the instructions. Then, when you want to post a message to the group, send an e-mail to redriverag@mail.coafes.umn.edu.

2. **Agdakota** - Unmoderated list server for Extension personnel, state specialists, and producers focusing on production agriculture in North Dakota. Administrator is Dr. Richard Zollinger, NDSU Extension weed scientist (r.zollinger@ndsu.edu). To subscribe to the Agdakota mailing list: 1) Send an e-mail message to majordomo@ndsuext.nodak.edu 2) Leave the subject line blank; and 3) In the body of the message type "subscribe agdakota." Then, when you want to post a message to the group, send an e-mail to agdakota@ndsuext.nodak.edu.

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3. Growth and Development Guide for Spring Wheat. S.R. Simmons, E.A. Oelke and P.M. Anderson. University of Minnesota Extension Service (FO-2547-D). 1995.

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PHOTO CREDITS

1. Cover: Deb Tanner

2. No Till Production: Roger Ashley

3. Crop Growth & Development: Dave Hansen

4. Small Grains Weeds: Gerald Miller & Oliver Strand

5. Herbicide Injury:
   - Beverly Durgan: 1, 4, 5, 6, 8, 17, 18
   - Rich Zollinger: 2, 3, 7, 9, 10, 11, 12, 13, 14, 15, 16

6. Cultural Practices: Rich Zollinger

7. Environmental Factors
   - Kevin Cavanaugh: 1
   - Rich Zollinger: 2, 3, 4, 5, 6, 7, 8

8. Small Grains Diseases:

   - Roger Jones: 1,2,3,4,5,6,8,9,10,11,12,16,17,18, 20,22,23,24,25,26, 28,29
   - Marcia McMullen: 7,27
   - Char Hollingsworth: 13,14,15,19,21,30

9. Small Grains Insects

   - Ian MacRae: 1,2,3,4,5,7,8,9,10,11,12,13
   - David Noetzel 6a (larvae OWBM)
   - Phillip Glogoza 6b (adult OWBM)