A3337

INTENSIVE WHEAT MANAGEMENT

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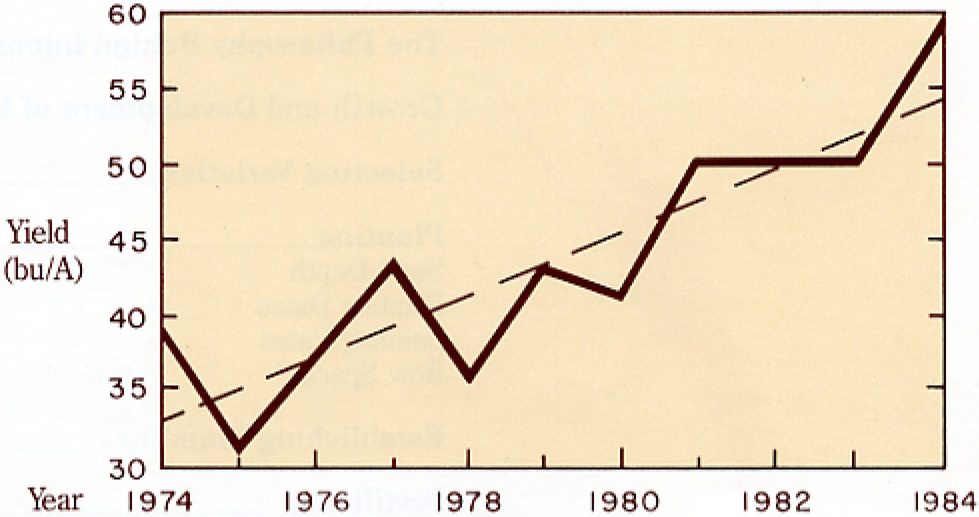
INTRODUCTION

Winter wheat is grown primarily as a cash grain crop and also for straw. Higher cash wheat prices and lower costs of production in relation to corn and soybeans have encouraged more acreage in recent years—a 300% increase in acreage in Wisconsin alone during the past five years. Other advantages of growing winter wheat include: crop rotation options, spreading the workload at planting and harvesting, high quality feed for livestock, and good yields of high quality straw.

Winter wheat yields in the Midwest and Wisconsin have risen moderately during the past 10 years (Fig. 1). Much of this can be attributed to research leading to improved cultivars and better soil fertility. In the near future, we should see even more significant yield increases as a result of continued research.

In several European countries, average yields of winter wheat are above 70 bu/A, and intensive wheat management systems commonly produce yields of 130 to 150 bu/A. Recent studies conducted in Wisconsin, Michigan, Ohio, Virginia and other states suggest similar yields can be attained by using improved wheat production systems—often called intensive management systems or intensive cereal management (ICM). ICM includes the use of improved cultivars; increased seeding rates; better fertilization; programs to control insect, disease and weed infestations; and plant growth regulators (PGRs) to reduce lodging.

Figure 1. Winter wheat yields in Wisconsin (1973-84).



THE PHILOSOPHY BEHIND INTENSIVE CEREAL MANAGEMENT

This publication explains several aspects of cereal management that can lead to increased yields. The integration of these management practices is the basic principle of intensive crop management. While no single management practice will greatly increase yields, using an integrated system of intensive crop management will substantially boost yields.

This concept of integrated management acknowledges that environmental factors, like weather, play just as much a role in influencing yield as the plant's genetic makeup and man's management practices. We need to investigate and understand all contributing factors so that we can develop models that predict timely and economic applications of management practices.

To fully understand these factors will take time and much work to accumulate and analyze new data. Nevertheless, progress is made one step at a time and much-improved management practices are already available.

This publication presents the general ICM principles and practices known to date. However, this integrated management approach will need to be "fine-tuned" for each grower, field or environment. We challenge all growers to work at adjusting individual field environments to achieve *triple digit yields of wheat*.

GROWTH AND DEVELOPMENT OF WINTER WHEAT

To better understand wheat production practices, we need a sound understanding of the growth stages of wheat. Implementing management practices such as fertilization and weed, disease, insect and lodging control requires planned application times based on the stage of plant growth rather than calendar dates. Plants have optimum times at which they respond to inputs, and the best way to judge these times is to observe the plant, not the calendar.

Wheat plants progress through several major growth stages, each of which is marked by specific plant part formations. Different systems have been developed to identify these growth stages. In this publication, Zadoks' decimal code system is used because we consider it the most descriptive growth staging system. Zadoks' decimal code numbers growth stages from 00 to 100 (Table 1 and Fig. 2). Feeke's scale is also shown for comparison.

During germination (Growth Stage or GS 00-09) the radicle or seedling roots emerge along with the coleoptile. Seedling growth (GS 10-19) begins with the emergence of the first leaf and continues until tillering. Three leaves usually emerge before tillering is initiated. During this phase the fibrous root system develops more completely, aiding in plant establishment. Tillering (GS 20-29) is the formation of lateral shoots out of the axillary buds which already exist in the wheat plant.

The next phase of growth is stem elongation (GS 30-39). During this time, just prior to heading, stem length is determined. Some intermediate stages of elongation include emergence of the nodes of the stem (GS 31-36) and the appearance of the last leaf (GS 37-39), commonly called the flag leaf.

Just prior to heading is the "booting" stage (GS 40-49) when the inflorescence, or head, swells within the stem to form a "boot". At the end of booting (GS 49), the awns of the head are first visible. As plant growth continues into heading, the inflorescence (heads) emerge and flower (GS 50-59).

Table 1. Zadoks' decimal code for the growth stages of cereals and a comparison to Feeke's scale.

Zadoks' Scale	Feeke's Scale	General Description	Additional Remarks
		Germination	
00		Dry seed	
01		Start of imbibition	
03		Imbibition complete	
05		Radicle emerged from caryopsis	
07		Coleoptile emerged from caryopsis	
09		Leaf just at coleoptile tip	
		Seedling growth	
10	1	First leaf through coleoptile	Second leaf visible (<1 cm).
11		First leaf unfolded	
12		2 leaves unfolded	
13		3 leaves unfolded	
14		4 leaves unfolded	
15		5 leaves unfolded	50% of laminae unfolded.
16		6 leaves unfolded	
17		7 leaves unfolded	
18		8 leaves unfolded	
19		9 or more leaves unfolded	
		Tillering	
20		Main shoot only	
21	2	Main shoot and 1 tiller	
22		Main shoot and 2 tillers	
23		Main shoot and 3 tillers	
24		Main shoot and 4 tillers	
25		Main shoot and 5 tillers	
26	3	Main shoot and 6 tillers	
27		Main shoot and 7 tillers	
28		Main shoot and 8 tillers	
29		Main shoot and 9 or more tillers	
		Stem elongation	
30	4-5	Pseudo stem erection	
31	6	1st node detectable	Jointing stage.
32	7	2nd node detectable	
33		3rd node detectable	
34		4th node detectable	Nodes above crown.
35		5th node detectable	
36		6th node detectable	
37	8	Flag leaf just visible	
39	9	Flag leaf ligule/collar just visible	
		Booting	
40		—	
41		Flag leaf sheath extending	Early boot stage.
43		Boots just visibly swollen	
45	10	Boots swollen	
47		Flag leaf sheath opening	
49		First awns visible	In awned forms only.

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Anthesis (pollination) and fertilization (GS 60-69) occur next, followed by kernel formation (GS 70-89) and ripening (GS 90-99).

Wheat is physiologically mature at the "hard dough" stage (GS 87), even though its moisture content is still at 25 to 35%. A plant is considered to be physiologically mature when the flow of nutrients from the leaves, culms and spike to the grain ceases. Harvest occurs after the plant and grain dry to approximately 13 to 16% moisture.

Thus, the life cycle of wheat can be summarized by dividing it into two growth stages, with anthesis (GS 60-69) marking the transition between stages. In the first stage, vegetative growth, ear initiation and ear development occur. These processes determine the final yield potential of the crop. This stage also provides the photosynthetic equipment necessary for maximum yield.

The second stage is the grain-filling period in which the potential yield created in the first phase is realized. The environment determines the extent to which this potential yield is realized. So to realize triple digit yields, there must be optimum climatic conditions and proper management inputs during the period before anthesis and during grain filling.

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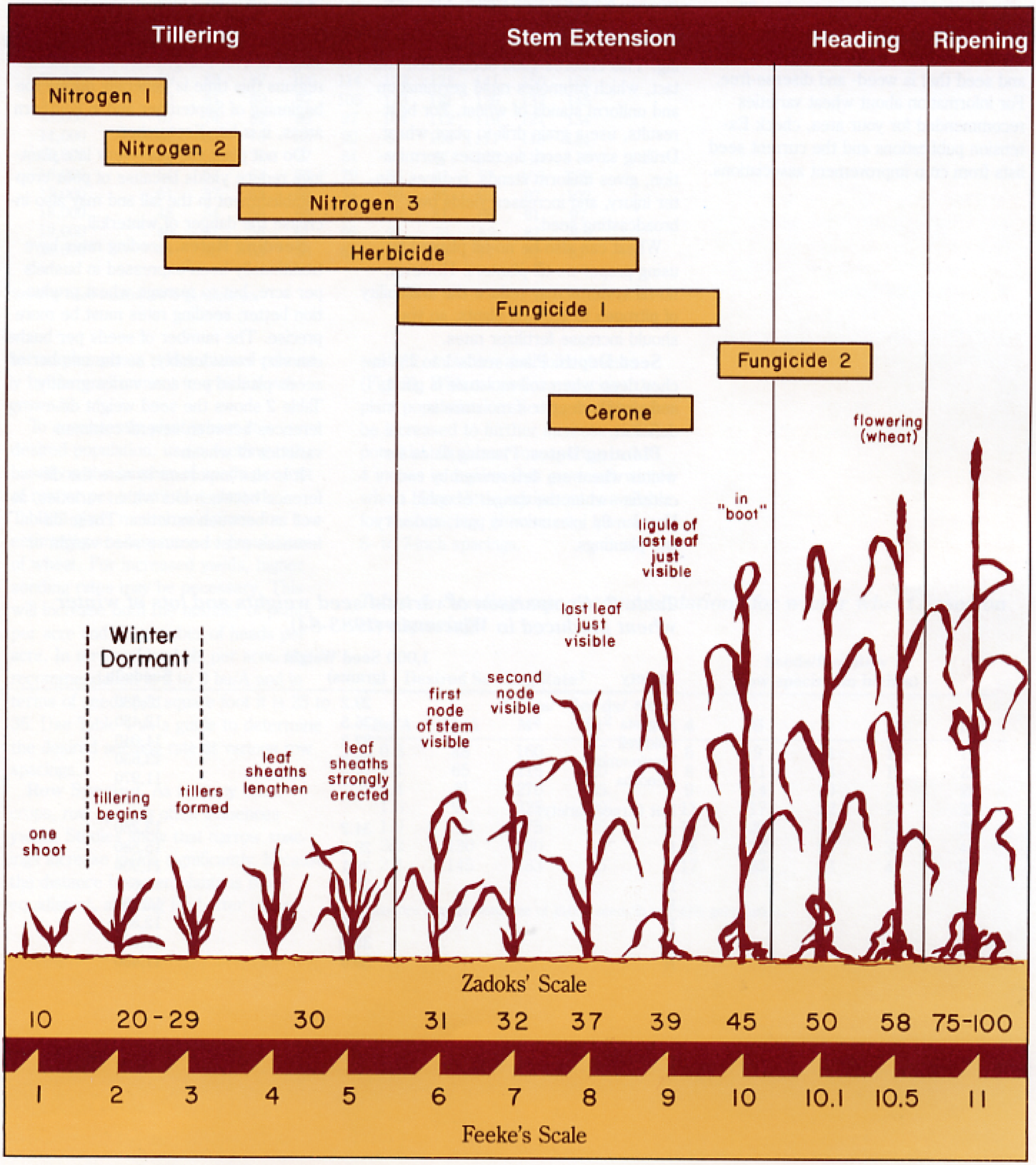
Zadoks' Scale	Feeke's Scale	General Description	Additional Remarks
		Inflorescence emergence	
50	10.1	First spikelet of inflorescence just visible	
52	10.2	1/4 of inflorescence emerged	
54	10.3	1/2 of inflorescence emerged	
56	10.4	3/4 of inflorescence emerged	
58	10.5	Emergence of inflorescence completed	
		Anthesis	
60	10.51	Beginning of anthesis	
64		Anthesis half-way	
68		Anthesis complete	
		Milk development	
70		—	
71	10.54	Caryopsis watery ripe	
73		Early milk	
75	11.1	Medium milk	Notable increase in solids of liquid endosperm when crushing the caryopsis between fingers.
77		Late milk	
		Dough development	
80		—	
83		Early dough	
85	11.2	Soft dough	
87		Hard dough	Fingernail impression not held.
89		—	Fingernail impression held; inflorescence losing chlorophyll.
		Ripening	
90		—	
91	11.3	Caryopsis hard (difficult to divide by thumbnail)	
92	11.4	Caryopsis hard (can no longer be dented by thumbnail)	
93		Caryopsis loosening in daytime	
94		Overripe, straw dead and collapsing	
95		Seed dormant	
96		Viable seed giving 50% germination	
97		Seed not dormant	
98		Secondary dormancy induced	
99		Secondary dormancy lost	

Figure 2. Wheat growth stages according to Zadoks' decimal code and Feeke's scale. Intensive management inputs are indicated by [box]



SELECTING VARIETIES

High quality seed is essential for profitable crop production. The most reliable seed is certified—assuring varietal purity, good germination and seed that is weed- and disease-free. For information about wheat varieties recommended for your area, check Extension publications and the current seed lists from crop improvement associations.

PLANTING

A productive field must not only be fertile, but should also be in good physical shape. For most wheat growers this means plowing and firming or leveling the soil before planting. This ensures good seed to soil contact, which promotes rapid germination and uniform stands of wheat. For best results, use a grain drill to plant wheat. Drilling saves seed, increases germination, gives uniform stands, reduces winter injury, and increases yields over broadcasting seed.

Wheat can also be no-till planted by using proper no-till planters. However, no-till systems may reduce the availability of nitrogen to growing plants, so you should increase fertilizer rates.

Seed Depth. Plant seeds 1 to 1½ inches deep when soil moisture is good, and slightly deeper if moisture is deficient.

Planting Dates. Planting dates for winter wheat are determined by two criteria—when the danger of aphid or Hessian fly infestation is past, and very late plantings.

Aphids and Hessian flies are carriers and transmitters of disease. In particular, aphids transmit Barley Yellow Dwarf Virus. To prevent potential disease infestation, wait to plant until aphids are no longer active. For growers in northern regions this time is generally during the beginning of September and in southern areas, it is late September.

Do not plant too late—very late plantings reduce yields because of poor crop establishment in the fall and may also increase the danger of winterkill.

Seeding Rates. Seeding rates have traditionally been expressed in bushels per acre, but to manage wheat production better, seeding rates must be more precise. The number of seeds per bushel can vary considerably; so the number of seeds planted per acre varies greatly. Table 2 shows the seed weight differences between several common varieties of wheat.

It is also important to note the difference between lots within varieties, as well as between varieties. These differences exist because seed weight or

Table 2. Comparison of varietal seed weights and lots of winter wheat produced in Wisconsin (1983-84).

Variety	1,000 Seed Weight (grams)	Seeds/lb
Argee	29.2	15,580
Augusta	36.5	12,430
Caldwell	32.3	14,040
Frankenmuth	33.2	13,650
Kenosha	37.9	11,970
Lot (Argee variety)		
A	34.2	13,280
B	29.2	15,580
C	38.1	11,900
D	25.7	17,630
E	35.3	12,850
F	35.2	12,890
G	35.0	12,980
H	39.6	11,450

Table 3. Seeding rates for winter wheat based on seed size.[1]

Seed Size	Desired Population in Seeds/ft²									
	18	20	22	24	26	28	30	32	34	36
(seeds/lb)	Seeding Rate (lb/acre)									
10,000	87	97	106	116	126	136	145	155	165	174
11,000	79	88	97	106	114	123	132	141	150	158
12,000	73	81	89	97	105	113	121	129	137	145
13,000	67	74	82	89	97	104	112	119	127	134
14,000	62	69	76	83	90	97	104	111	118	124
15,000	58	65	71	77	84	90	97	103	110	116
16,000	54	61	67	73	79	85	91	97	103	109
17,000	51	57	63	69	74	80	85	91	97	102
18,000	48	54	59	65	70	75	81	86	91	97
19,000	46	51	56	61	66	71	76	82	87	92
20,000	44	48	53	58	63	68	73	77	82	87

[1]Seeding rates assume 90% germination.

kernel plumpness is determined primarily by the environment in which it was grown.

To consistently plant wheat at a desired population, use a seeding rate based on the number of seeds per foot of row or per square foot planted. Table 3 gives recommendations for estimating seeding rates or populations of wheat. For increased yields, higher seeding rates may be necessary. This will increase both the number of plants per acre and the number of heads per acre. In terms of bushels per acre, the recommendation is 2 to 3 bu/A and in terms of seeds per square foot it is 25 to 35. Use Table 4 as a guide to determine the desired seeding rate at various row spacings.

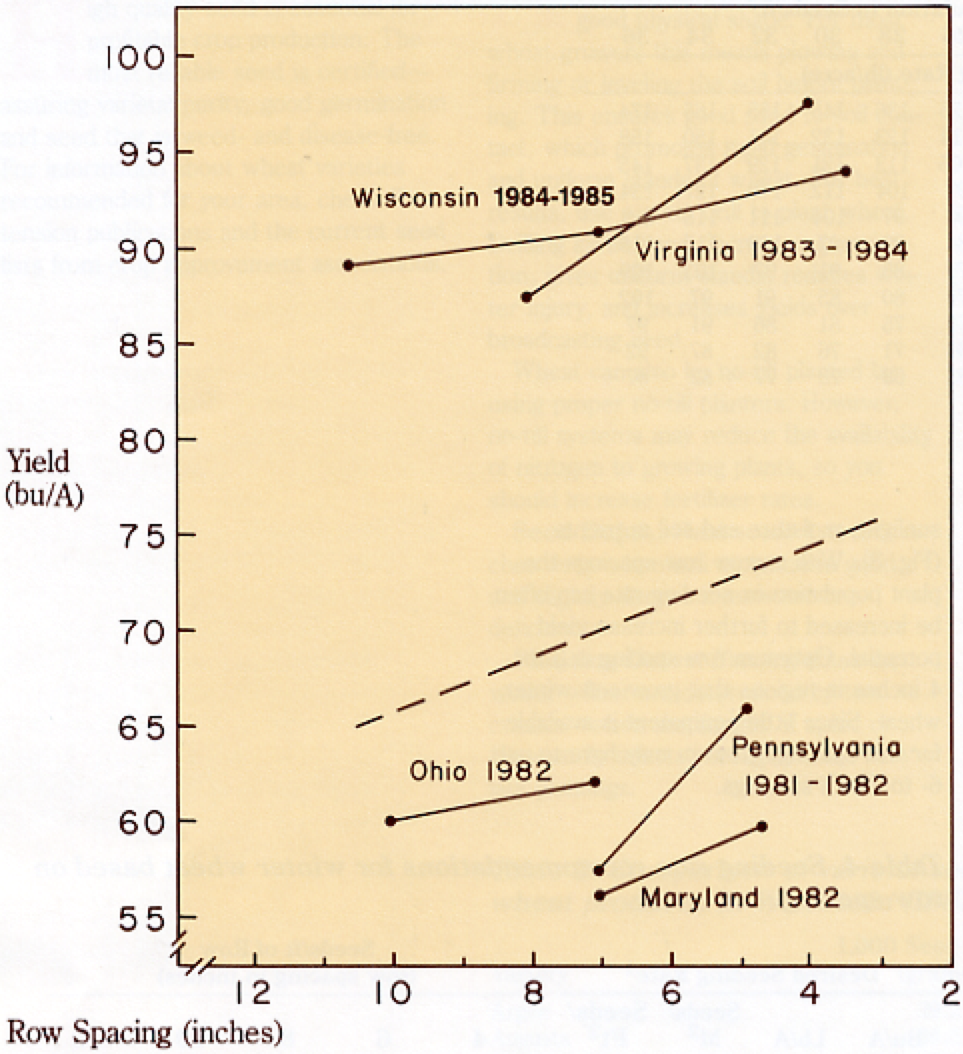
Row Spacing. As in many other crops, row spacing often influences yields. Studies show that narrow spacings increase yields significantly, because the distance between plants is more equidistant, allowing for better use of sunlight, moisture and soil nutrients (Fig. 3). With narrow row spacings the plant population or seeding rate can often be increased to further increase yield potential. Optimum row spacing is 3 to 4 inches in regions that grow soft winter wheat. Since little equipment is available for this spacing, growers may have to use 6- to 7-inch spacings.

Table 4. Seeding rate recommendations for winter wheat based on row spacing.

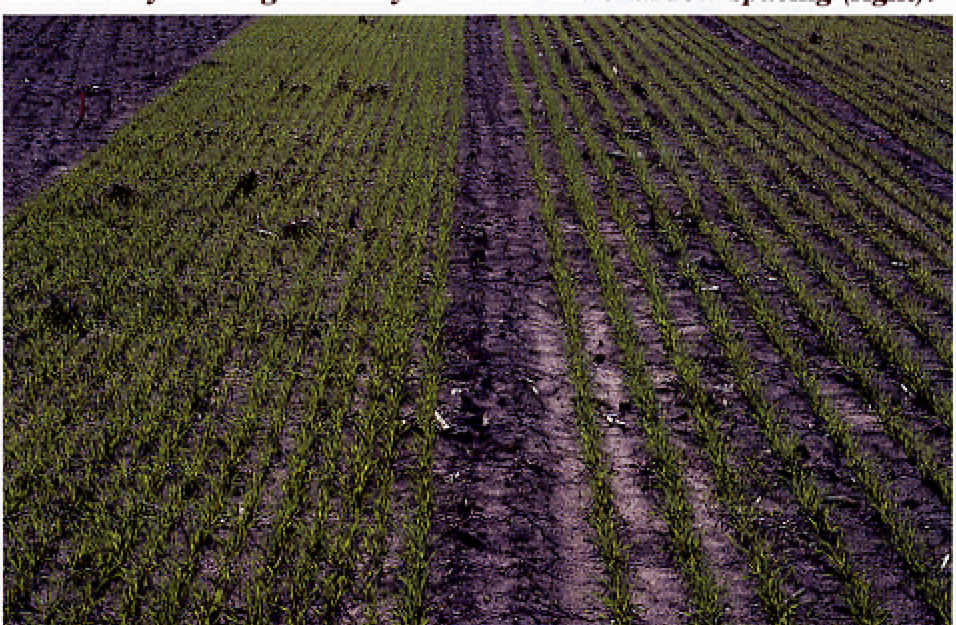
Desired Seeding Rate[1]				Seeds/ft of Row (row spacing in inches)				
Bu/A	Lb/A	Seeds/ M²	Seeds/ Ft²	4	6	8	10	12
0.8	48	160	15	6	9	11	14	17
1.1	65	215	20	8	11	14	19	22
1.4	81	270	25	9	14	19	23	28
1.6	97	325	30	11	17	22	28	33
1.9	113	375	35	13	20	25	32	39
2.2	130	430	40	14	22	30	36	44
2.4	145	483	45	17	25	33	42	50

[1]Assumes average seed size of 15,000 seeds/lb and 90% germination.

Figure 3. Effect of row spacing on winter wheat yields (1982-85).



Narrow row spacing (left) produces better plant distribution and increases yields significantly over conventional row spacing (right).



ESTABLISHING TRAMLINES

Tramlines are unseeded strips through a field used to facilitate spraying or spreading of fungicides, herbicides, insecticides, plant growth regulators and fertilizers without destroying the standing crop (Fig. 4). The advantages of tramlines include:

- More precise application of inputs.
- Less chance for disease development because plants are not driven over and damaged.
- Border plants along the strips compensate for yield losses, whereas plants damaged by tires rarely produce grain.
- Bare strips can be more compacted and dry faster than the remainder of the field, permitting timely treatments.

The best time to establish tramlines is at planting. The distance from center to center of the tramlines should be the same width as the application equipment. The distance to the first tramline from the edge of a field should be one-half the width of the sprayer. To make the tramline, block the drill openers that correspond to the width of the tracks of the sprayer tractor. In most cases, blocking a single opener per tire is sufficient, but this depends both on tire size and row spacing.

Tramlines make it easier to apply intensive management inputs without damaging the standing crop.

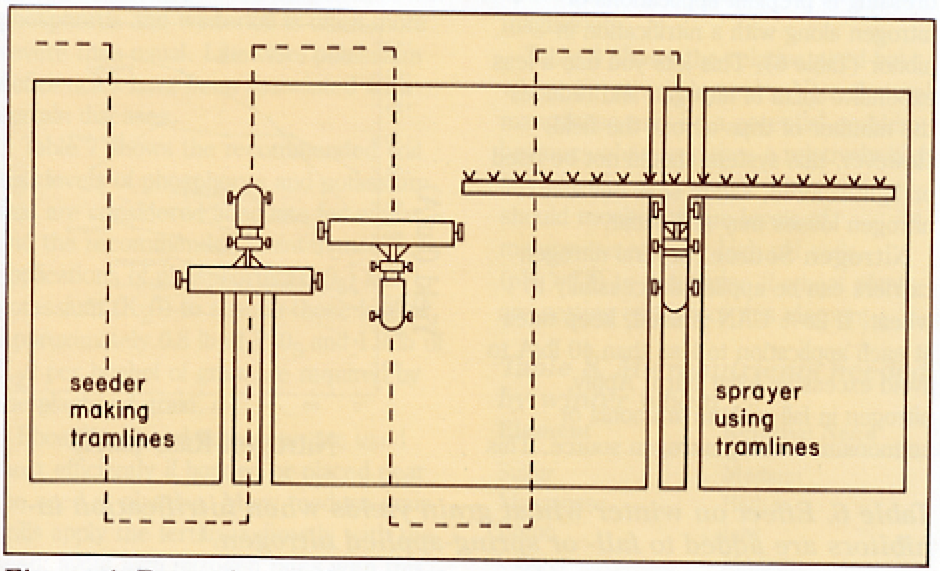


Figure 4. Preparing and using a tramline system.

FERTILIZING

Some fields need more fertilizer than others. Soil testing is the best method of determining fertilizer needs and leads to more efficient fertilizer use. By testing soil and following the recommendations, soil fertility can virtually be eliminated as a limiting factor in producing top yields. Recommendations are based upon estimates of maximum yield and should be fine-tuned according to local conditions.

NITROGEN

Usually it is the amount of available nitrogen that limits wheat and other small grain yields. Nitrogen availability depends on many soil and plant factors, including previous crop, moisture, temperature, soil pH and the amount of organic matter. Other management practices are also important to nitrogen availability such as timing of fertilizer applications. Fall fertilizer applications are especially susceptible to substantial leaching losses over the winter and spring, thus reducing available nitrogen.

Nitrogen has specific effects on the growth and development of wheat plants. Because of this, both excessive and inadequate nitrogen availability can be detrimental to plant growth. Excessive nitrogen results in too much vegetative growth, poor overwintering ability, increased disease incidence and serious lodging problems. Inadequate nitrogen levels lower grain and straw yields, and cause poor plant growth.

Rates. Table 5 gives nitrogen recommendations for wheat based on research in Wisconsin and other areas of the United States. These are nitrogen recommendations for an intensive management system where disease, insect, weed and lodging problems will be controlled so rates can be higher. Figure 5 summarizes the effect of these nitrogen rates on winter wheat.

Often, residual nitrates are not considered in fertilizer recommendations. However, the rates in Table 5 adjust for this and are reduced as soil organic matter increases.

Increased vegetative growth due to nitrogen fertilization.

Other rate adjustments include nitrogen credit for incorporated forage legumes (40 lb N/A plus 1 lb/percent legume in stand), nitrogen credit for manure applied (3 to 5 lb/ton), and reducing rates by 20 to 30 lb N/A where a legume is under-seeded.

Timing. The timing of nitrogen applications is critical to induce high numbers of fertile heads and good kernel filling. For intensive management practices, nitrogen applications should be split between a fall application (20 to 30 lb N/A) followed by two spring applications. The fall application improves overwintering ability.

Make the first spring application of nitrogen at the onset of tillering (GS 20) to increase the number of tillers and the potential number of heads. If stands are adequate (>18 plants/ft of row), apply 25 lb of nitrogen; however, if stands are poor (<18 plants/ft of row), apply up to 50 lb of nitrogen to promote tillering. A second spring nitrogen application of 50 to 75 lb N/A should be made as stem elongation begins (GS 30); this determines the number of tillers that will head and produce fertile ears. If this application is too early, an excessive number of small, low-yielding heads may be produced. And if this application is too late, it may result in nitrogen starvation and poor head fertility.

This sequence of nitrogen application also helps plants avoid excessive vegetative growth in the fall, thereby decreasing the probability of disease occurrence; and it allows you to adjust spring rates to reflect realistic yield goals.

One major disadvantage of split nitrogen applications is that it may be difficult to apply the nitrogen without damaging the soil or crops. However, tramlines can prevent this problem.

A good alternative to early spring topdressing is preplant applications of nitrogen along with a nitrification inhibitor (Table 6). This lets you use a less expensive form of nitrogen and reduces the number of trips across the field. However, this system should not be used on light-colored, sandy soils because nitrogen losses may still occur.

Nitrogen Source. Several nitrogen carriers can be applied successfully to wheat. If 28% UAN is used, keep rates at each application to less than 40 lb/A to avoid excessive foliar burn. Apply nitrogen in fall with an ammonia or ammonium-forming nitrogen source. This is essential if an inhibitor is used with the fertilizer. These ammonia or ammonium-forming nitrogen fertilizers appear to have the added benefit of reducing the amount of take-all disease.

Figure 5. Effect of various nitrogen rates on winter wheat.

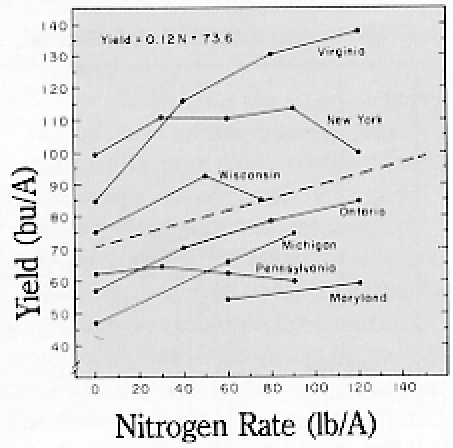


Table 6. Effect on winter wheat grain yields when nitrification inhibitors are added to fall- or spring-applied nitrogen.[1]

Fertilizer	Number of Comparisons	Number of Increases	Average Yield Increase (%)
Fall			
Urea	18	15	14.4
NH^3	3	3	17.8
Spring			
Urea[2]	13	8	7.1

[1]Adapted from Nelson and Huber (1980).

[2]Fertilizer was injected between established wheat rows.

Table 5. Nitrogen recommendations for winter wheat for several north central states (lb N/A).[1]

Yield Goal (bu/A)	Wisconsin	Michigan	Illinois	Indiana	South Dakota	Minnesota
			2% Organic Matter			
20-40	40	45	—	70	30	40
40-60	60	75	60	80	65	80
60-90	100	—	80	100	100	100
			2-3.5% Organic Matter			
20-40	30	30	—	55	30	30
40-60	40	50	40	65	50	60
60-90	80	80	60	95	80	80
			3.5-6% Organic Matter			
20-40	20	20	—	40	0	30
40-60	30	30	25	50	25	60
60-90	60	45	45	85	60	80

[1]Data gathered from Extension fact sheets and personal communications.

PHOSPHORUS AND POTASSIUM

It is a well-known fact that wheat responds to the addition of phosphorus and potassium when tests show soils have low to medium levels of these nutrients. Wheat plants do not tiller adequately when they are deficient in phosphorus and winterkill is often more severe than usual. Likewise, potassium deficiencies have been associated with certain diseases.

Table 7 shows the recommended soil test levels of phosphorus and potassium that are considered adequate for wheat, and the recommended maintenance applications of phosphorus (P_2O_5) and potassium (K_2O) to sustain those levels. Approximately 0.8 lb of P_2O_5 and 1.9 lb of K_2O per bushel of grain are required by the plant and grain.

Phosphorus and potassium are used most efficiently if banded or placed near the seed at planting. Many modern grain drills apply the fertilizer directly with the seed; avoid high nitrogen rates with this application method that can lead to seedling injury, especially on dry or sandy soils. In these situations, apply no more than a total of 30 lb/A of nitrogen plus K_2O with the seed (8- to 10-inch row spacing). Where urea is included with the row material, reduce the nitrogen application by 75%. If higher amounts of fertilizer are needed, broadcast the remainder.

SECONDARY AND MICRONUTRINETS

Secondary and trace elements are also essential for high yielding wheat. However, these elements are required in small amounts, and most well-limed soils will supply these nutrients adequately. In fact, soils limed above pH 6 will not respond to further additions of calcium or magnesium.

Table 8 shows the relative need by wheat for other elements. Note that only manganese may be a potential problem because wheat requires a relatively high amount of this element. Thus, you should monitor tissue levels of manganese on very high pH soils (pH >7.8) to determine if wheat plants are getting enough of this element.

Table 8. Micronutrients needed by winter wheat.

Element	Relative Need
Sulfur	Medium
Manganese	High
Boron	Low
Copper	Medium
Zinc	Low
Molybdenum	Low

LIME

Small grains, including wheat, grow well at a soil pH of 6.0 or above and lime should be added to get the soil in this pH range. However, if wheat is grown in rotation, lime the soil to the optimum pH for the most demanding crop in the rotation.

Table 7. Minimum Wisconsin soil test levels for phosphorus and potassium and maintenance amounts of these nutrients for winter wheat.[1]

		Medium Textured Soils		
	Sand	Southern and Western Soils	Eastern Red Soils	Northern Soils
Correct to (lb/A):				
Available P	75	45	50	45
Exchangeable	200	240	220	300
Maintenance (lb/A):		P_2O_5	K_2O	
20-40 bu		15	20	
40-60 bu		25	30	
60-90 bu		40	40	
90-120 bu		60	55	

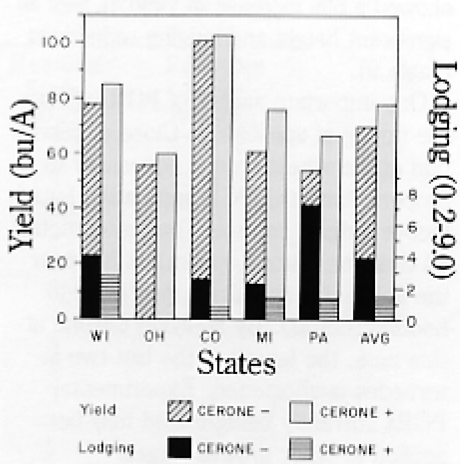
[1]Adapted from Kelling et al. (1981).

USING PLANT GROWTH REGULATORS

Winter wheat and other cereal crops frequently suffer severe losses from lodging, especially when the soil is very fertile. The lush, spindly, top-heavy growth of wheat grown in a highly fertile environment makes it susceptible to damage by wind and rain. Early lodging results in poor grain fill and often leads to disease problems. Late lodging hinders harvesting operations and can lower grain quality.

Newer stiff-strawed wheat varieties reduce lodging by decreasing the height of wheat and strengthening the stem. Chemical plant growth regulators (PGRs) also have been developed to do basically the same thing. These PGRs, when applied at the correct stage of plant growth, shorten and strengthen the stem of the wheat plant making it less likely to lodge. Because PGRs decrease lodging, disease becomes less of a potential problem. You also should harvest more efficiently, with increased yields of higher quality grain with more uniform grain moisture content. All these improvements add up to increased profits.

Figure 6. Effect of Cerone on winter wheat yield and lodging (summary of data from five states).



Severely lodged wheat field.

To obtain a quantitative measure of crop lodging, the Belgium lodging rating system has been developed for small grain crops. It has the advantage over other systems in that it considers both the area lodged and the degree of lodging.

To use this system, begin ratings when the first plots or areas (presumably the check or control plots) begin to lodge. Take ratings on at least three different dates to measure the progression of lodging throughout the growing season. To determine the lodging index, use the following formula:

Lodging Index = S × I × 0.2

S = Area of surface lodged (1 =no lodging, 9 = totally lodged).

I = Intensity of lodging (1 = completely upright, 5 = completely flat)

0.2 = Factor used to bring the index into the scale of 0.2 to 9.0.

The first PGR that is available for use in the United States and Canada is ethephon, marketed under the trade name "Cerone." Figure 6 illustrates the effect of Cerone on lodging and yield of winter wheat, based on studies conducted in five states. In Wisconsin, 100 tests using Cerone consistently showed a 6% increase in yield as well as significant height and lodging reductions (Table 9).

One important aspect of PGR use is the timing of application. Close observation of the wheat crop is necessary to properly time the PGR application for effective lodging control. The recommended time for Cerone application is when the flag leaf is appearing, just prior to booting (GS 37). By applying Cerone at this time, the length of the last two internodes is shortened. Experimental PGRs currently being tested may be applied at other growth stages.

ICM plots show that a PGR applied at the proper growth stage reduces lodging—increasing yields.

Table 9. Effects of Cerone on winter wheat in Wisconsin (1982-84).

Factor	No. of Tests	Control	Cerone	Actual Response	Percent Response
Yield (bu/a)	100	68.66	72.97	+4.31	+6.3
Height (in)	100	38.30	36.72	-1.6	-4.3
Lodging (0.2-9.0)	100	2.74	1.83	-0.9	-10.1
Test Wt. (lb/bu)	100	54.20	54.75	+0.6	+1.0
Moisture (%)	28	10.74	11.30	+0.6	+5.2

CONTROLLING PESTS

Weeds, insects and diseases significantly reduce wheat yields if they are not controlled. You can control these pests by selecting resistant or tolerant varieties, rotating crops, and using fungicides, herbicides and insecticides correctly. However, use pesticides only when needed. Careful observation of the crop throughout the growing season will enable you to apply timely pest control when necessary. You may even need to apply several pesticides to plants during the growing season.

Current pest control recommendations are discussed in detail in Extension publications.

DISEASE CONTROL

Intensive cereal management systems normally use high nitrogen rates that produce more vegetative growth, and this in turn may increase the incidence of disease. So to attain high yields, both in quantity and quality, you need to control these disease problems.

Table 10 lists common wheat diseases, the growth stage at which they occur, and how severe these diseases normally are. Table 11 lists characteristic symptoms of wheat diseases and methods of control.

Table 10. Common wheat diseases in Wisconsin and the stages of growth when symptoms occur.

Disease	Growth Stage (GS): Seedling (10-20)	Tillering (20-30)	Stem Extension (30-40)	Boot Stage (40-50)	Heading Stage (50-75)	Ripening Stage (75-100)
Seedling blight	3[1]	0	0	0	0	0
Septoria leaf blotch	1	1	2	3	3	3
Powdery mildew	1	2	2	3	3	3
Barley yellow dwarf	1	2	3	3	3	3
Stem rust	1	1	2	3	3	3
Leaf rust	1	1	2	3	3	3
Scab	0	0	0	0	2	3
Loose smut	0	0	0	1	3	3
Bunt	0	0	0	1	3	3
Take-all	1	1	2	3	3	3
Septoria glume blotch	0	0	1	1	3	3
Cephalosporium stripe	1	1	2	3	3	3

[1]Probability of occurrence and/or severity in the upper Midwest: 0 = none, 1 = low, 2 = moderate, 3 = high.

Table 11. Wheat diseases and strategies for their control.

Common Name	Symptoms/Signs	Control
Seedling blight	Seed rot, seedling death, reduced vigor or chlorosis.	Fungicide seed treatment; high quality and pathogen-free seed.
Loose smut	Grain replaced by black, sooty spores.	Plant noninfected seed, fungicide-treated seed and resistant varieties.
Scab	Individual florets initially appear bleached and are followed by extensive bleached areas of heads; grain is shriveled.	Crop rotation (but avoid wheat after corn); some varieties are less susceptible.
Bunt	Grain replaced by black, foul-smelling spores; head somewhat blue-green, but fairly normal in appearance.	Fungicide seed treatment; plant noninfected seed.
Barley yellow dwarf	Dwarfing and yellowing of plants during vegetative phases; poor grain development; chlorotic symptoms of flag leaf confused with nitrogen deficiency in spring.	Moderate differences in resistance among varieties; delay planting of winter wheat or early planting of spring wheat to avoid high aphid activity.
Wheat streak mosaic	Symptoms begin in early spring as yellow, stunted strips adjacent to where volunteer wheat plants grew the previous year. Individual plants are yellow, stunted and wilted. Mosaic begins as light green to yellow dashes forming a streaked appearance.	Eliminate volunteer wheat plants; delay planting in fall. Resistant varieties not available.
Soil-borne mosaic	Best recognized in early spring by distinct but irregularly shaped areas of yellow plants. Plants are stunted and bronze-yellow; leaves are mottled with a yellow background and darker green islands.	Resistant varieties are available; crop rotation is not effective; adequate nitrogen fertility will enable infected plants to tolerate the virus to some degree.
Stem rust	Brick-red pustules (spore masses) primarily on stems.	Resistant varieties; foliar-applied fungicides.
Leaf rust	Light red pustules primarily on leaves.	Varieties differ in resistance; foliar-applied fungicides.
Septoria leaf blotch	Tan, necrotic lesions develop first on lower leaves and progress to flag leaf; pycnidia apparent in necrotic leaf tissue.	Crop rotation; deep tillage of wheat debris; foliar-applied fungicides; varieties differ in susceptibility.
Powdery mildew	White-gray spore masses on foliage, stems or heads.	Varieties differ in resistance; foliar-applied fungicides.
Take-all	Plants stunted, chlorotic; root rot and black discoloration of lower stem; heads bleach before crop matures.	Crop rotation; control other hosts; fertilize and maintain nitrogen as NH_4; delay planting of winter wheat.
Cephalosporium stripe	Vascular infection leads to broad yellow stripes extending the length of the leaf; brown lines are visible with yellow stripes. Diseased tillers head out prematurely, die and turn white.	Crop rotation; deep incorporation of wheat debris; delay planting in fall; resistant varieties are not available.

Seed Treatment Fungicides. Historically, fungicides for wheat were applied as seed treatments to control seedling blight, loose smut or bunt. Table 12 lists several formulations of currently registered fungicides used to treat seeds.

Foliar-applied fungicides. These fungicides fit best into intensive management systems that use high nitrogen rates, higher seeding rates, plant growth regulators and high-yielding varieties. In many cases, these management practices can lead to environmental conditions in the crop canopy that favor leaf diseases.

The objective of foliar-applied fungicides is to maintain the health of the flag leaf, the first leaf below the head. The flag leaf contributes 60 to 85% to the final grain yield. Yield reduction results if even 5 to 10% of the flag leaf surface is diseased. For each additional 1% of leaf area diseased, yield is reduced 0.5 bu/A.

The following foliar-applied fungicides are registered for use on wheat to control rust, powdery mildew and Septoria leaf blotch: Bayleton (triadimefon), Manzate 200 (mancozeb), Dithane M-45 (mancozeb) and Dithane Z-78 (zineb). Tilt (propiconazol) has an experimental use permit for these same foliar wheat diseases (1985) and may be registered in the future.

Consult the product label for application rates and other information regarding the use of a specific product.

Fungicide applications may not be worth the time and effort if factors such as soil fertility, variety selection, and other diseases and pests are not managed. For example, if you apply minimal fertilizer, you would expect only small yield responses to foliar-applied fungicides. Foliar-applied fungicides, nitrogen applications and other management practices each contribute more to increased grain yield when used together than when used alone.

Foliar-applied fungicides may provide economical yield increases if:

- Disease is present on the lower leaves at jointing.
- Humid weather with moderate air temperatures have occurred and are forecasted until maturity.
- Management practices provide for high yield potential.
- Other diseases and pests are controlled.
- Wheat was planted in the field the previous year.
- A susceptible to moderately resistant wheat variety was planted.

Table 13 illustrates how fungicides increase yields, as well as the importance of selecting disease resistant varieties.

Table 12. Seed treatment fungicides registered for wheat.

		Disease		
Fungicide	**Common Name**	**Loose Smut**	**Bunt**	**Seedling Blights**
Vitavax 25DB	Carboxin	X	X	
Vitavax T	Carboxin & Thiram	X	X	X
Vitavax 200 Flowable	Carboxin & Thiram	X	X	X
Vitavax Flowable	Carboxin	X	X	
Orthocide Vitavax 20-20	Captan & Carboxin	X	X	X
Granox NM	Maneb & HCB		X	X
Dithane M-22	Maneb		X	X
Dithane M-45	Mancozeb		X	X
Manzate 200	Mancozeb		X	X
Granox Plus Flowable	Maneb & Thiabendazole		X	X
Granox Plus	Maneb & Thiabendazole	X	X	X
Enhance	Carboxin & Captan Lindane	X	X	X
Enhance Plus	Maneb, Carboxin &	X	X	X
Terracoat L21	PCNB & Etridiazol		X	X

Table 13. Effect of foliar-applied fungicides on the severity of foliar disease and yield of Argee and Caldwell winter wheat (Arlington, WI, 1984).

			Septoria %[1]		Leaf Rust%		Bu/A[1]	
Fungicide	**Rate (lb/A)**	**Number of Applications**	**Caldwell**	**Argee**	**Caldwell**	**Argee**	**Caldwell**	**Argee**
Tilt	0.06	2	4	21	4	5	102	71
Bayleton	0.25	1	6	50	7	18	96	65
Dithane M-45	1.6	2	2	18	3	9	103	83
Control	—	—	27	61	8	21	83	48
LSD .10[2]			3		2		8	
			12		3		10	

[1] Disease severity measured as percent of flag leaf surface area that is diseased at the dough stage.

[2] Top LSD value compares fungicide treatments while bottom LSD value compares means of cultivars within a treatment.

WEED CONTROL

There are few weed problems in winter wheat in the upper Midwest. While some perennial weeds may be present, annuals are generally suppressed by crop competition and freezing winters. However, local weed problems may persist and, in these situations, weed control should be considered in order to maximize yields.

A sound weed control program combines cultural, mechanical and chemical control measures. Although controlling weeds with herbicides is sound crop management, no herbicide treatment provides guaranteed weed control, and the control options are limited in small grains. Therefore, wheat producers need to consider all possible weed control measures.

Cultural Methods. Cultural methods of weed control are important for preventing weed problems during the growing season. Preplant tillage weakens perennial weeds and reduces the number of annual weeds. Proper seedbed preparation and clean seed are other cultural methods that deter weeds.

Crop competition is one of the most useful and economical methods of weed control in wheat. By using production practices that favor the crop, weeds are crowded out. Intensive cereal management encourages crop competition by providing adequate soil fertility, adapted cultivars, higher seeding rates, narrower row spacing, and insect and disease control.

Crop rotation also effectively controls weeds. Since some weeds are more common in certain crops than in others, rotation to other crops can reduce the numbers of a particular weed.

Herbicides. Herbicides also are available to control common weeds found in wheat. However, herbicide effectiveness depends on several factors, including weather, and time and rates of application.

Weather plays a major role in herbicide effectiveness, since temperature and moisture levels influence the rate at which plants take up herbicides, and the sensitivity of the crop and weeds to herbicides. Generally, both weeds and crops are more sensitive to herbicides at higher temperatures. Thus, lower herbicide rates should be used in hot, humid weather to minimize wheat injury.

Weeds are more difficult to kill in cool, dry weather, not only because lower temperatures make weeds less sensitive to herbicides, but also because dry weather slows the movement of herbicides in the soil—reducing or delaying weed control.

If conditions are dry, use a preplant-incorporated herbicide. Mixing the herbicide with the soil minimizes the need for rainfall for effective herbicidal action. Foliar-applied herbicides are affected to an even greater extent by weather.

Table 14 lists several herbicides that will control weeds in wheat. Consult Extension publications and product labels for correct rate and time of application, because certain herbicides are not registered for use in some states.

Most herbicides should be applied in spring after the wheat crop reaches the four- to five-leaf stage (GS 14-15)—plants are normally 4 to 8 inches tall at this time. Broadleaf weeds should have no more than two to four leaves when herbicides are applied. Earlier applications increase the risk of injury to wheat seedlings, while later applications during booting or heading (GS 40-70) may prevent kernels from filling (blasting). Herbicides also can be applied after the grain has headed to control late, tall-growing weeds that might interfere with harvest operations.

INSECT CONTROL

Insect problems are generally minimal in the upper Midwest, but problems occasionally occur that warrant control measures. Wheat growers are concerned with insects in two areas of wheat production—field insects and insects in stored grain.

Field Insects. Aphids and armyworms are the primary insect problems of wheat in the field. Aphids damage plants indirectly by transmitting barley yellow dwarf virus and other viruses. They also damage wheat plants directly by sucking the plant sap. Later planting dates can prevent barley yellow dwarf because major aphid populations are avoided. Unfortunately, later planting can also mean potentially lower yields.

Table 14. Herbicides for controlling weeds in winter wheat.

Weed Problem	Common Name	Trade Name
Grasses (wild oats, foxtail, downey brome)	diclofop-methyl	Hoelon
	metribuzin	Lexone, Sencor
	chlorsulfuron	Glean
Broadleaves	2,4-D	—
	MCPA	—
	Bromoxynil	Brominal, Bronate, Buctril
	Bromoxynil + MCPA	Brominal Plus,
	3 + 3 Brominal, Bronate	

Armyworms are another insect problem. To guard against severe losses, check several areas of each wheat field carefully. Check lodged areas first, because these are most susceptible to armyworm infestation. If you find armyworms in lodged areas, check several other areas in the field, too. Use an insecticide if there is an average of three or more armyworms per square foot.

Table 15 lists insecticides that can be used to control aphid or armyworm problems.

Table 15. Insecticide recommendations to control insects in wheat.

Insect	Insecticide[1]
Aphids	Cygon 400/Defend Malathion parathion[2] Penncap-M[2]
Armyworms	Malathion Dylox/Proxol Lannate[2] Penncap-M[2]

[1] Read labels for complete information on rates, time of reentry and other precautions.

[2] Restricted-use pesticide; for use by experienced or commercial applicators trained and equipped to apply it.

Stored Grain Insects. Insects that invade stored grain are best controlled by preventive grain handling practices. Clean equipment and storage areas, and dry grain are important for effective insect control. The following guidelines should prevent major insect problems in stored grain:

- Clean out bins, removing all debris from inside and outside of bins.
- Patch all holes in bins where rodents, birds or rain might enter.
- Spray inside surfaces of clean bins with malathion about two weeks before harvest.
- Never put new grain on top of old grain.
- Do not store grain close to livestock feeding areas that may be infested with insects.
- Inspect grain monthly with a grain probe and control insects with fumigant if necessary.

HARVESTING

Harvest is the most critical time of the wheat growing season. A lot of money, time and planning is invested in a wheat crop during the course of the growing season, yet whether or not you turn a profit depends on only a few days of harvesting. Serious delays or interrruptions can mean loss of grain and money.

To ensure maximum profits, make sure that your harvesting equipment, transporting equipment and storage facilities are in top working order. This assures a rapid harvest with minimum outlay of time and money. A crop that is only minimally lodged or not lodged at all improves harvest efficiency.

The proper harvest time depends on grain moisture content. Harvesting too early means that some grain is harvested "green", while harvesting too late may mean higher shattering losses. Lower moisture levels are better for grain storage—an optimum harvest moisture level is 13 to 16%.

STORING WHEAT

Wheat storage is the final step to grain handling. Inadequate storage facilities or poor grain quality at storage time can result in substantial grain losses. The suitability of grain for storage depends both on temperature and moisture content. Ventilation or drying can decrease moisture content and temperatures of stored grain. Careful preparation of storage bins also is necessary to control insects, diseases or molds that can damage stored wheat.

SUMMARY

Table 16. Effect of management practices on winter wheat yields (Arlington, WI, 1983).

Management Practice		Yield Increases bu/A	%
Nitrogen	25 lb	72	
	50 lb	83	+15
Cultivar	Kenosha	71	
	Argee	84	+20
Fungicide	None	76	
	Tilt	80	+ 5
PGR	Control	75	
	Cerone	82	+ 9
None of these practices		65	
All of these practices		95	+46

Increasing wheat yields to more than 100 bu/A requires careful management coupled with the practices explained in this publication. Table 16 summarizes increases in wheat yields due to specific management practices and yield increase due to all these practices combined into a single management system. *Maximum yields are only reached when all available practices are incorporated into a complete package—intensive cereal management.*

15 STEPS FOR MAXIMUM WINTER WHEAT YIELDS

1. Test soil to determine fertility of field.
2. Control perennial weeds such as quackgrass.
3. Use good tillage practices.
4. Fertilize to a yield goal of 100 to 150 bu/A.
   a) Nitrogen—25 lb/A in fall.
   b) Phosphorus and potassium—fertilize to high levels in fall prior to planting.
5. Select a variety with the highest yield for your area, as well as good winterhardiness.
6. Plant at optimum date for your area considering location and likelihood of aphid infestation.
7. Plant in 4- to 7-inch row spacings, incorporating tramlines for subsequent management practices.
8. Seed 30 to 40 seeds/ft^2 of certified seed.
9. Check stand density in the spring as soon as winter survival can be rated.
   a) If stand is adequate (>18 plants/ft of row), apply 25 lb of nitrogen just prior to or at tillering time (GS 20).
   b) If stand is poor (>18 plants/ft row), apply up to 50 lb of nitrogen to promote tillering.
10. Use proper weed control measures if weeds are anticipated to be a problem.
11. Apply an additional 50 to 75 lb nitrogen at GS 30 for grain filling.
12. Apply Cerone plant growth regulator (0.25 lb/A) at GS 37 to control lodging.
13. Apply fungicides as needed for disease control during the growing season.
14. Harvest on time at optimum grain moisture.
15. Provide for adequate, safe storage space.

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