A Production Guide for Michigan Wheat

Michigan State University Extension Service

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W•H•E•A•T

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The average wheat yield in Michigan in 1985 was 60 bushels per acre (bu/A). This was not only the highest average yield on record, but also the highest for any state in the United States. It shows that Michigan wheat growers are doing many things right with the resources they have, including varieties that respond well to fertilizers and have excellent lodging resistance. In spite of the excellent yield record and cropping practices, however, many improvements are still possible. A recent two-year survey showed that many wheat growers are still not using as much nitrogen as the crop needs for maximum economic yields. The survey also showed that many growers still have not adopted other proven management practices required for optimum yields.

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Intensive Cereal Management – A Michigan Perspective

The concept of intensive cereal management (ICM) has gained popularity in western Europe and has also received a lot of attention in North America. It is a system intended to integrate all the latest technology into a single management program tailored to specific climatic and soil conditions. In general, it includes such factors as the use of improved varieties; increased seeding rates; more efficient fertilizer programs; more intensive control of insects, diseases, and weeds; and the use of plant growth regulators where lodging is expected to be a problem. Specifically, it usually consists of multiple applications of nitrogen, fungicides and growth regulators.

ICM techniques have been most successful in mild, temperate environments such as England and western Europe, which have an extended period of grain development and ripening, and where problems from foliar diseases such as powdery mildew and leaf rust are chronic and predictable. These techniques have not generally been successful in Michigan, which has a much more rapid period of kernel development and ripening and fewer chronic problems with foliar fungal diseases.

The guidelines in this bulletin have been proven to work well for Michigan conditions. Though they contain elements of ICM techniques, for the most part they are simply good management practices shown to work best in Michigan's environment.

As a wheat grower, you should set a yield goal that you believe is realistic for your farm. Perhaps 10 percent above your five-year average might be a reasonable target. Then follow the management practices that have been proven to help achieve your goal. If you wish to try such elements of ICM as split nitrogen application or use of a plant growth regulator, try them on a small area of five acres or less and use conventional practices on the rest of your acreage. Keep detailed records of your operations and their cost, and use this information to calculate the economic returns and profitability from both systems. Be sure this information includes reliable estimates of yield from a measured area or uniform combine swath. Such evaluations are necessary if you are to achieve maximum economic yields.

How a Wheat Plant Develops

As a plant grows and develops, it undergoes changes in size and complexity as it responds to the environment and certain growth factors. A good understanding of the growth and development of the wheat plant will enable you to better manage your crop. This understanding will allow better timing and precision in making management inputs based on the stage of growth and the needs of the plant rather than on the calendar date.

Various systems, or growth scales, have been developed to describe the various vegetative and reproductive stages that a plant goes through, beginning with germination and ending with grain maturity. Growth scales have been widely used in Europe and other locations where growers practice intensive cereal management. They provide for greater precision in making the multiple inputs required in intensive management systems. The simplest is the Feekes' scale, which describes 11 growth stages beginning with seedling growth and ending with complete development of the plant and seed. The Zadoks' scale begins with the dry seed and describes every phase of seed germination and seedling growth up through tillering, flowering, kernel development and complete plant and seed maturation. Table 1 compares Feekes' and Zadoks' scales.

Fig. 1 shows the best time to apply spring nitrogen and fungicides. Spring-applied herbicides should be used only after complete tillering has occurred, before complete stem growth and before the "boot" stage, when the second node can be detected just above ground level.

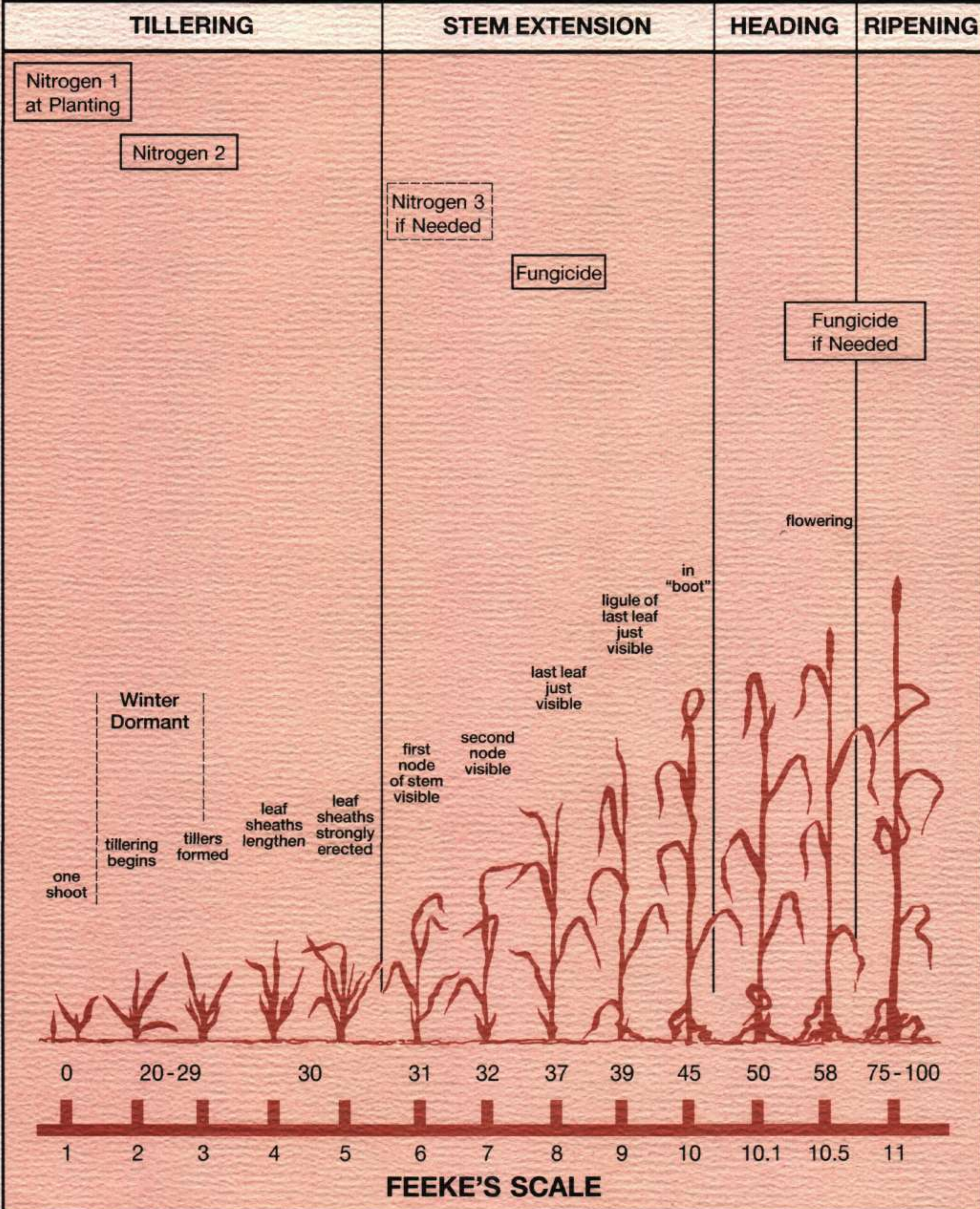
Land Selection and Preparation

Wheat is best adapted to soils that are well drained but have good water holding-capacity. Heavy, poorly drained soils are subject to late winter flooding that can result in poor plant survival. Sandy soils without irrigation do not have the water-holding capacity needed for optimum productivity. The field should be well tiled or have enough slope to provide good surface drainage and be free of quackgrass.

Most Michigan wheat growers will prepare their fields for planting by conventional tillage methods. The objects of tillage are to control weeds, incorporate fertilizers and prepare the field for good seed-soil contact. You may do this by plowing and/or disking or dragging to enable good seed placement with a standard grain drill. New methods of direct seeding (minimum and no-tillage) are workable alternatives to conventional practices and have been proven by extensive field trials in Michigan to produce equivalent and sometimes improved wheat yields.

FIGURE 1

Wheat growth stages according to Zadoks' decimal code and Feeke's scale. Management inputs are indicated.



Variety Selection

Wheat variety performance trials are conducted each year at eight locations throughout Michigan's winter wheat production area. Entries to the trials include Michigan State University experimental lines, promising lines from neighboring state experiment stations and commercial varieties from private seed companies. The primary objective of this variety testing program is to provide the agronomic data needed to determine which lines to release as commercial varieties. A second objective is to show Michigan wheat growers which varieties perform best in their area. Results from these trials are made available each year through local county Extension offices, and multiyear summaries are published in Extension bulletin E-1352, "Wheat Variety Performance in Michigan."

Several excellent varieties of both soft white and soft red winter wheat are available for Michigan growers. The yield of spring wheat under Michigan conditions is about 70 percent of that of the best winter varieties, so spring wheat is not recommended in Michigan.

Seed Treatment

Seed treatment is one of the most important and least expensive measures to avoid problems from seed-borne diseases. Wheat seed should be treated with an effective systemic fungicide and a broad-spectrum fungicide to control seed rot, seedling blight, loose smut, common bunt (stinking smut) and other seed-borne fungal diseases. Seed purchased from a certified seed grower or from other reputable seed sources will normally be

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.
		Inflorescence emergence	
50	10.1	First spikelet of inflorescence just visible	
52	10.2	¼ of inflorescence emerged	
54	10.3	½ of inflorescence emerged	
56	10.4	¾ of inflorescence emerged	
58	10.5	Emergence of inflorescence completed	

TABLE 1 (Continued)

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
		Anthesis	
60	10.51	Beginning of anthesis	
64		Anthesis halfway	
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.
		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	

TABLE 2

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.

treated as part of the conditioning process. If not, it should be taken to a local elevator or to a seed conditioning plant for treatment. You may use drill box treatment as a last resort, but you must do it with care to obtain complete and uniform seed coverage. For additional information on seed treatment and specific recommendations, refer to Extension bulletin E-1199, "Seed Treatment for Field Crops."

Seeding Practices

Method, Depth and Rate of Seeding

Plant wheat in 7- to 10-inch drill strips about 1 to 2 inches deep using 2 to 2.5 bushels of seed per acre (see Fig. 2). Seed size varies greatly among varieties and seedlots and greater precision can be achieved if the drill is calibrated to plant a given number of seeds per unit area or length of row. Table 2 shows the relationship between seeding rate in bushels and pounds per acre, seeds planted per unit area and the resulting plant population for a seedlot with 15,000 seeds per lb and 90 percent germination. Table 3 shows how numbers of seeds per lb of various Michigan varieties influenced seeding rate and plant population in 1984.

You are encouraged to find out the number of seeds per lb in your seedlot and to calibrate your drill accordingly. Seed counts are available upon request from seed testing laboratories, and seed suppliers should be encouraged to list this information on seed bags for their customers. Using this information, calibrate your drill to plant about 22 to 25 seeds per foot of row for a 7-inch row. After germination and overwintering losses, you should have 18 to 22 plants per foot of row.

FIGURE 2

Relationship between seeding rate (bu/A) and yield (bu/A) for wheat (1983-84 data).

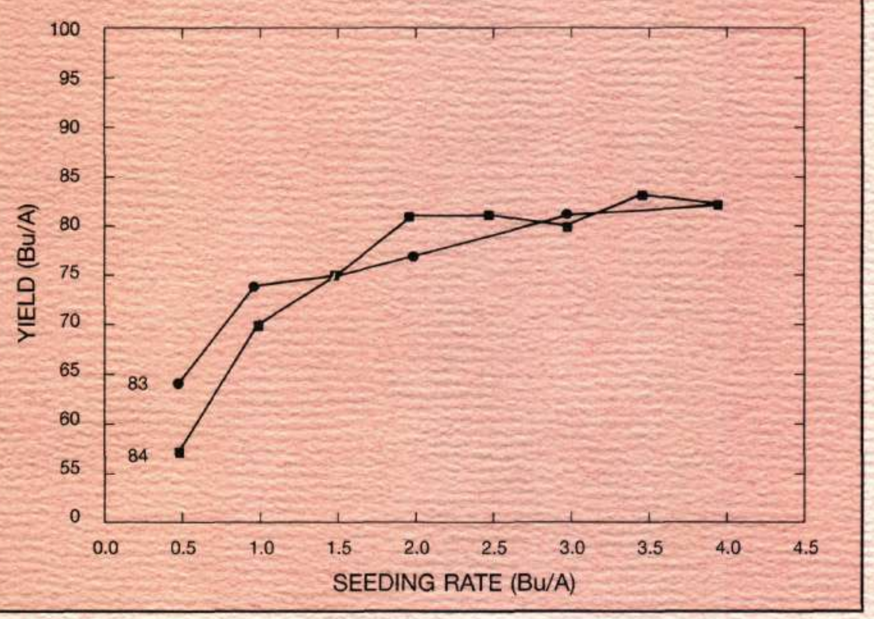


TABLE 3

Influence of seed size (no. of seeds/lb) on recommended seeding rates (lb/A) in 7 inch rows for three varieties of wheat in 1984.

Seeds/lb	Frankenmuth	Augusta	Hillsdale
10,250	167.6	–	–
10,500	163.6	–	–
10,750	159.8	–	–
11,000	156.1	–	–
11,250	152.7	152.7	152.7
11,500	149.4	149.4	149.4
11,750	146.2	146.2	146.2
12,000	143.1	143.1	143.1
12,250	140.2	140.2	140.2
12,500	137.4	137.4	137.4
12,750	134.7	134.7	134.7
13,000	132.1	132.1	–
13,250	129.6	129.6	–
13,500	127.2	–	–

Seeds/lb varied from 10,237 to 13,359 for Frankenmuth; 11,137 to 13,685 for Augusta; and 11,304 to 12,601 for Hillsdale.

Time of Seeding

Seed wheat about 10 to 15 days after the Hessian fly-free date. The actual date varies throughout Michigan (see Table 4), depending on latitude and average date of the first killing frost. Though delayed planting entails some risk of adverse planting weather, research has shown that earlier planting causes greater development of fall foliage growth, which invites infestation by disease and insect pests and weakens spring performance.

Minimum Tillage, No-Till, Direct Drilling and Aerial Seeding

You can drill directly in no-till or minimum tillage situations if you use proper equipment that will place the seed in the soil with good seed-soil contact. Basically, this requires a heavy drill with coulters that open the soil, leaving residue on the surface, and a press-wheel that closes the seed opening and firms the drilled furrow. Research at MSU has shown that such seedings, if properly done, give yields equal to those from conventional seedings. For additional information on direct seeding wheat and specific recommendations, refer to Extension bulletin "Direct Drilling of Winter Wheat" (in production).

Wheat may also be aerially seeded into a soybean field just before leaf drop. Under such conditions, the falling leaves trap enough moisture in close soil contact with the seed to enable adequate stand establishment. Though this method can give good results when continued rain makes conventional planting difficult, it is more risky than normal drilling because of moisture uncertainty and the possibility of planting before the emergence of the last Hessian fly brood.

Avoid aerial seeding or broadcast seeding on bare ground unless you can till the field lightly to provide for seed coverage.

TABLE 4

Hessian fly-free dates for Michigan[1].

County	Earliest seeding date (Sept.)	County	Earliest seeding date (Sept.)	County	Earliest seeding date (Sept.)	County	Earliest seeding date (Sept.)
Alcona	6	Eaton	16	Lapeer	15	Ogemaw	10
Allegan	20	Emmet	4	Leelanau	8	Osceola	10
Alpena	9	Genesee	17	Lenawee	25	Oscoda	7
Antrim	4	Gladwin	12	Livingston	16	Otsego	6
Arenac	13	Grand Traverse	8	Macomb	18	Ottawa	19
Barry	18	Gratiot	15	Manistee	13	Presque Isle	8
Bay	14	Hillsdale	19	Mason	13	Roscommon	7
Benzie	16	Huron	13	Mecosta	12	Saginaw	16
Berrien	23	Ingham	17	Midland	15	Sanilac	15
Branch	19	Ionia	16	Missaukee	9	St. Clair	16
Calhoun	19	Iosco	7	Monroe	21	St. Joseph	23
Cass	22	Isabella	11	Montcalm	15	Shiawassee	16
Charlevoix	3	Jackson	16	Montmorency	7	Tuscola	15
Cheboygan	4	Kalamazoo	20	Muskegon	18	Van Buren	22
Clare	12	Kalkaska	5	Newaygo	15	Washtenaw	18
Clinton	17	Kent	18	Oakland	16	Wayne	18
Crawford	6	Lake	13	Oceana	16	Wexford	9

[1]From "Insect Control in Small Grain Crops", MSU Extension bulletin E-0829.

Soil Fertility

Lime

Wheat grows best when the soil pH is between 6.0 and 7.0. Growing wheat at a pH below 6.0 often results in magnesium (Mg) deficiency, slower mineralization of organic nitrogen (N), reduced availability of phosphorus (P), and increases the possibility of aluminum (Al) and manganese (Mn) toxicity. When wheat is grown on soils above a pH of 7.0, Mn deficiency may occur. Wheat land should be limed to a pH of 6.5. Where other crops are grown in rotation, lime to the optimum pH for the most demanding crop.

Nitrogen

Nitrogen is usually the most limiting nutrient for wheat production. An inadequate N supply can greatly reduce yield and profit. Too much N can result in lodging, decreased yields and reduced profits. Determining the optimum rate of N fertilizer is the key to maximum economic yield. Soil tests for measuring N availability are not adapted for routine use in Michigan. As a result information on soil texture, organic matter level and yield goal is used to select the optimum amount of N fertilizer to apply.

The sandy soils of Michigan do not have the same yield potential as finer textured lake bed soils because of their inherent low water-holding capacity and usually lower organic matter level. Soil organic matter is important because of the amount of N mineralized or released each year. On finer textured soils, drainage plays an important role in selecting the appropriate yield goal. Poorly drained fields that have inadequate tile drainage have a lower yield potential than well tiled soils. They often become waterlogged and can lose a large portion of their N to denitrification. Management — including the timeliness of tillage and planting operations, variety selection, seed quality and pest control — also affects the yield potential. Before choosing the amount of N to apply, select a yield goal that is realistic and achievable at least 50 percent of the time. If the goal is seldom achieved, you will be overfertilizing with N and creating the potential for N contamination of surface and groundwater.

Table 5 gives N fertilizer recommendations for wheat based on research and realistic yield goals for Michigan. Apply only 10 to 25 lb of N in the fall. Excessive N in the fall can cause abundant growth that increases the probability of disease. Apply the remainder early in the spring before the ground thaws or stems elongate. *Do not apply fertilizer*

TABLE 5
Nitrogen fertilizer recommendations for wheat.

Soil type	Percent organic matter	Wheat yield goal (bu/acre)						
		40	50	60	70	80	90	100
		pounds N/acre						
Sandy soils	0-2%	60	70	80	90	100	–	–
Medium-fine textured soils	2-4%	40	55	70	80	95	110	120
Dark colored mineral soils	4-6%	25	30	40	45	50	55	60

on frozen sloping land where runoff can easily enter surface water. Where slopes exceed 6 percent, wait until the soil has thawed before making spring application of N fertilizer.

Split Applications of N

Consider splitting the spring application of N if excellent tillering has occurred (more than 18 plants per foot of row). Research has shown that split applications improve yields in certain years. Periods of above normal rainfall during April and May favor split applications because some N may be lost to leaching or denitrification. These conditions also favor excessive growth and stem elongation during the vegetative stage, which may result in lodging. Putting some N on before stem elongation may prevent lodging and result in better grain fill. Because there is no way of predicting this kind of season, few farmers elect to split their spring application of N. One of the disadvantages of splitting the N application is that dry conditions after the last application may result in poor use of the N.

Nitrogen Sources

In general, all N fertilizer sources are equal, if applied properly. Early spring top-dress applications of urea (46 percent N), ammonium nitrate (33 percent), Urea-ammonium nitrate (UAN) solutions (28 percent) and ammonium sulfate (21 percent) usually give equal results. Ammonium nitrate and ammonium sulfate may be preferred for the second spring application just before stem elongation if conditions are warm and dry. Applications of urea and UAN made during warm and dry conditions may result in some ammonia volatilization loss. If you use UAN solutions after green-up, use no more than 40 lb of N per acre to avoid excessive foliar burn.

Ammonium sulfate has become popular in some regions of the state and is being promoted as a source of sulfur. Michigan State University (MSU) wheat trials with ammonium sulfate, however, have not shown any benefits from the added sulfur. Its disadvantages are its low analysis and greater cost. Ammonium sulfate is also more acid than other sources of N, so it is less desirable on acid soils. On soils with a high pH (7.0), the extra acidity may have some minor benefits, such as improved manganese availability.

Anhydrous ammonia use has been successful when applied in the fall and knifed in at a spacing of 15 inches or less before planting. Fall applications of anhydrous ammonia in Michigan State University trials, however, have not been shown to be as good as spring top-dress applications. Too much N in the fall may also lead to excessive growth and increased disease. Warm soil conditions after application may also lead to the rapid conversion of ammonium N to nitrate N, which can be lost by leaching or denitrification before the crop can take it up. Using nitrification inhibitors with anhydrous ammonia has helped to prevent some N loss in MSU trials, but the benefits of spring top-dress N were still superior.

Phosphorus and Potassium

A regular soil testing program to determine fertilizer needs is essential to obtain maximum economic yields. Soils should be sampled to a depth of 9 inches to determine lime, phosphorus (P), potassium (K), and secondary and micronutrient requirements, all of which must be applied before planting. Broadcast these nutrients along with the 10 to 25 lb of N per acre needed for stand establishment and initial fall growth. You can increase the efficiency of P uptake by banding it through the grain drill at planting.

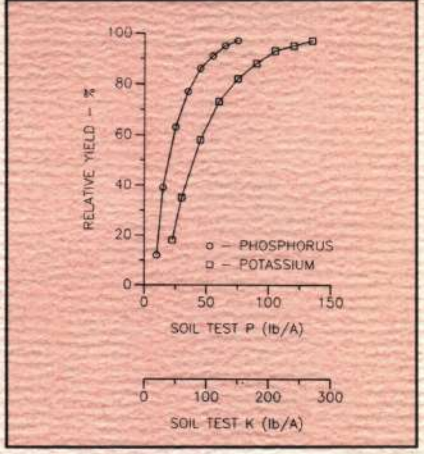
Soil testing is the key to efficient and effective use of P and K fertilizers. **Don't guess — soil test.** Soil testing is the most reliable tool we have for making good economic decisions about applying fertilizers. P and K experiments over the years have been used to correlate wheat yield with soil test levels. Fertilizer recommendations for P and K based on soil tests and estimated yield goals can be found in Extension bulletin E-550.

Typical yield response curves to soil test P and K are shown in Fig. 3. Fig. 3 shows that a soil with a yield potential of 80 bu/A (YP 80) would require a soil test of about 75 lb of P per acre to produce 97 percent maximum yield without supplemental P fertilizer.

Typical response curves due to added P and K fertilizer are shown in Figs. 4 and 5, respectively. Fig. 4 shows that as the

FIGURE 3

Relationship between expected wheat yield and soil test levels of phosphorus (P) and potassium (K), assuming no phosphorus or potassium fertilizers are applied (yield potential is 80 bushels per acre).



soil test (ST) for P increases from 10 to 60, it takes smaller amounts of P fertilizer to reach the 80-bushel yield potential. The loss in yield due to inadequate fertilizer can also be predicted from these curves. For example, a farmer who has a soil test of 10 and uses 50 lb of P_2O5 instead of 140 would obtain approximately 71 bushels instead of 78 bushels (a loss of 7 bu/A). The loss for underapplying P fertilizer is not devastating, but it does represent an economic loss to the farmer ($9 per acre if we assume $3 per bushel of wheat and 20 cents per pound of phosphate). Overapplying P also results in an economic loss to the farmer and increases the potential for P contamination of surface water.

Similar relationships have been developed for K fertilization. MSU recommendations for K are slightly different for sandy soils than for fine- textured soils because of the latter soil's greater ability to hold K. On sandy soils, less K fertilizer is needed to meet crop requirements at low test levels, but at medium to high soil test levels, more K fertilizer is needed because sandy soils have less storage capacity for K than fine-textured soils. As a result, K soil test levels on sandy soils tend to fluctuate much more from year to year. Fig. 6 shows the response of wheat on soils with various yield potentials. Soils with an inherent potential to produce large yields require a higher soil test to obtain optimum yields than soils with a lower yield potential.

FIGURE 4

Relationship between expected wheat yield and applied phosphate fertilizer at three phosphorus soil test (ST) levels (yield potential is 80 bushels per acre).

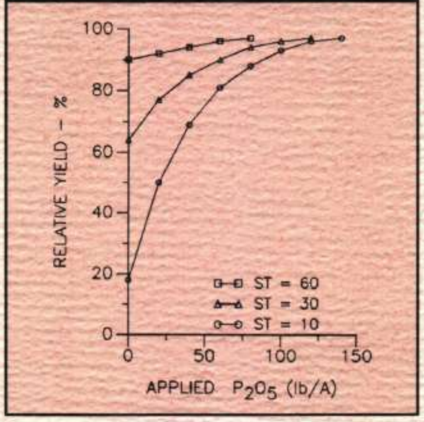


FIGURE 6

Relationship between expected wheat yield on three soils with varying yield potential (YP) to soil test (ST) levels of phosphorus, assuming no phosphorus fertilizer is applied.

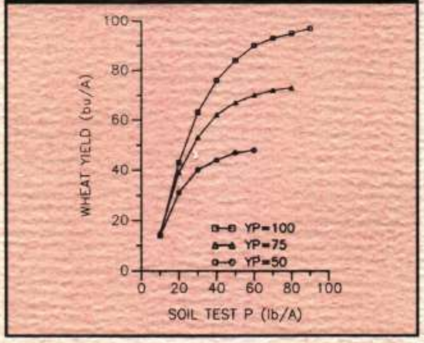
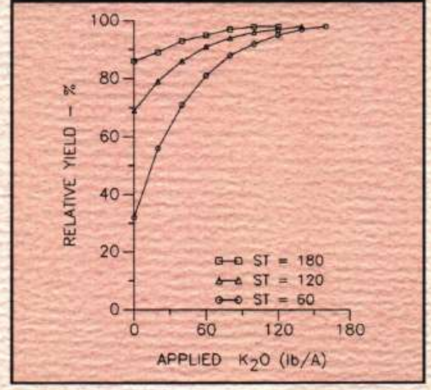


FIGURE 5

Relationship between expected wheat yield and applied potash fertilizer at three potassium soil test (ST) levels (yield potential is 80 bushels per acre).



Placement

Phosphorus and potassium are most efficiently used if banded or placed near the seed at planting. Most grain drills, however, place the fertilizer in direct contact with the seed. **Caution!** Do not apply more than 60 lb of N plus K_2O in direct contact with the seed. If urea is the major source of N in the starter, do not apply more than 10 lb of N in direct contact with the seed. Larger amounts of these fertilizers may easily injure the seed or new seedlings. If larger applications are necessary, the remainder of the fertilizer should be broadcast before planting.

Secondary and Micronutrients

Secondary and micronutrients are essential for optimum growth of wheat. These nutrients, however, are usually well supplied in Michigan soils. Well limed soils will have adequate calcium, magnesium and sulfur. Atmospheric contributions of sulfur each year supply adequate sulfur.

Manganese (Mn) is the most likely micronutrient to be needed in Michigan. Manganese deficiency occurs on organic soils (30% organic matter) and on lake bed soils with a high pH. Four to 6 pounds of elemental Mn per acre may be needed for soils with a pH of 6.5 to 7.0, and 7 to 10 pounds per acre when the soil pH exceeds 7.0. A soil test for Mn is recommended whenever the soil pH is above 6.2. Apply manganese fertilizer in a band or in contact with the seed for best efficiency. The preferred source of Mn is manganese sulfate.

Copper (Cu) deficiency has also been observed on organic soils but not on mineral soils. Because of the extreme Mn and Cu deficiency problems and often excess N availability on organic soils, wheat plantings are not recommended on organic soils.

Weed Control

Weed control is essential to successful winter wheat production. Inadequate weed control can lead to significant yield loss and increase harvesting difficulty. Weed control in winter wheat is accomplished with a combination of chemical and cultural practices.

Cultural Practices

Cultural practices that favor higher wheat yields will improve weed control. When properly managed, wheat is extremely competitive with weeds. Intensive wheat management practices, including crop rotation, contribute greatly to weed control in winter wheat. With proper management, herbicides are often not needed in winter wheat production.

Chemical Practices

When needed, herbicides must be carefully timed to be effective. The most common perennial weeds in winter wheat are quackgrass, Canada thistle and perennial sowthistle. Control quackgrass with a nonselective herbicide before planting wheat. Canada thistle, perennial sowthistle and other perennial weeds should also be controlled before wheat is planted — control is much more difficult after wheat emergence.

Annual weed species that emerge after planting can also become serious problems. The first step in controlling emerged weeds is proper identification. Accurate weed identification is necessary to select the best herbicide. Wheat fields should be scouted regularly to identify developing weed problems early. If a weed problem develops that requires a herbicide for control, the field should be treated as soon as possible.

Detailed information on current herbicide options for winter wheat are available in MSU Extension bulletin E-434, "Weed Control Guide for Field Crops."

Weed Control When Direct Seeding

In general, complete control of all green plants before planting is required for successful weed control. Under conventional tillage, this is accomplished with tillage during seedbed preparation. With direct seeding (no-tillage), vegetation control is accomplished before planting with non-selective herbicides. Nonselective (burndown) herbicides can effectively control emerged annual weeds at the time of planting.

The need for a burndown herbicide depends on the species of weeds present. If no weeds are present, a burndown herbicide is not needed. If small seedlings of species that do not overwinter (summer annuals only) are present at low densities, a burndown herbicide may not be needed. If the weeds are large, however, or capable of overwintering (winter annuals, biennials, perennials) or if identification of the weeds cannot be confirmed, a burndown herbicide should be used.

Herbicides applied after wheat emergence are not affected by the tillage system used. All of the weed control principles discussed previously apply equally in all tillage systems. No weed problems are unique to no-till winter wheat production. Therefore, no-till wheat production does not present any special weed control concerns.

Insect Control

A variety of insect pests regularly inflict minor damage on wheat, with serious injury possible under certain conditions. Most, however, can be maintained below economically important levels through cultural and biological means.

Hessian Fly

The Hessian fly is potentially one of the most serious insect pests of wheat in Michigan, but proper wheat management usually minimizes damage. The larvae feed on wheat stems beneath the leaf sheath, causing stunted, weak plants. Plants damaged by the fall generation of the fly experience increased winter-kill. Feeding by the spring generation results in less vigorous plants, as well as some lodging and subsequent harvest losses. The principal means of controlling the Hessian fly include using resistant varieties, sowing after the local "fly-free date" and maintaining proper soil fertility to produce healthy, vigorous plants. Adult flies are active in the late summer and early fall. Sowing wheat so that it emerges after the flies have ceased activity means that flies will deposit no eggs on the crop. The date after which it is historically safe to plant wheat is referred to as the "fly-free date." Fly-free dates for Michigan are shown in Table 4.

Armyworm

Armyworms occasionally reach outbreak proportions in small grains and other crops in Michigan. Adult females often lay their eggs in dense grasses, including headlands of fields and areas with poor grass weed control. The larvae of the armyworm are typically caterpillar-shaped, with three pairs of pointed legs just behind the head (thoracic legs) and five pairs of fleshy legs on the abdomen (prolegs). They range in color from tan to nearly black, usually with a pale stripe down each side. Larvae feed on plant foliage and can completely strip a heavily infested field. Maintaining good weed control and not double planting headlands can reduce the attractiveness of a field to egg-laying females but cannot assure total protection. Scout fields regularly to detect armyworm infestation.

Cereal Leaf Beetle

The cereal leaf beetle is still a minor problem in some areas of Michigan, though the introduction of a small parasitic wasp has largely controlled this pest. The wasp lays its eggs in the beetle larvae, killing them and largely preventing the typical frosted, skeletonized leaves caused by larval feeding.

Aphids

Several aphids, including the greenbug, the corn leaf aphid and the English grain aphid, can occur in colonies on small grains. Aphids damage plants by sucking plant juices. In addition, the saliva of the greenbug is toxic to wheat, and the English grain aphid transmits barley yellow dwarf virus. Our spring weather is usually unfavorable for greenbug development, natural enemies usually limit English grain aphid below damaging levels, and cool weather normally maintains the corn leaf aphid at low numbers. The oat cherry bird aphid can also transmit the barley yellow dwarf virus. This aphid can overwinter during mild winters in heavy grasses along fencerows and roadways and can be seen in early spring.

Other Insects

Billbugs, stalk borers, white grubs, wireworms and grain thrips can also damage wheat. White grubs and wireworms are most common when wheat is planted into a field that was formerly sod or very weedy. Billbugs and stalk borers are also most abundant in weedy areas of the field. Grain thrips commonly become established in grassy areas, low spots and headlands. By following good weed control practices and scouting regularly, growers can usually avoid serious damage by these insects.

Disease Control

Several wheat diseases have potential to become serious problems in Michigan. You can control most disease problems, however, by following good farming practices, such as the use of resistant varieties, crop rotation and seed treatment. Though the application of foliar fungicide is usually not recommended, it may sometimes be helpful. Table 6 shows various diseases that occur in Michigan, descriptions of symptoms, environmental conditions favoring disease buildup, how the diseases are transmitted, and control methods. Michigan is somewhat protected by both distance and weather conditions from more serious disease levels in wheat-growing regions farther south and east. It is estimated that for a given location, spraying will be economically justified no more than two or three years out of 10. The key to deciding if a foliar fungicide is warranted is a good pest scouting program to help determine infestation levels and predict the likelihood of further disease development. **Preventive fungicide application is not recommended.**

Application of foliar fungicides may become justified when conditions favoring development of foliar diseases, including the availability of disease inoculum, threaten the flag leaf. The flag leaf (see Fig. 1) is the last leaf to emerge at the top of the plant and contributes more than 80 percent of the materials needed for kernel development.

TABLE 6. Wheat diseases

DISEASE	SYMPTOMS	ENVIRONMENTAL CONDITIONS FAVORING DISEASE	METHOD OF TRANSMISSION	RECOMMENDED CONTROL	SPECIAL NOTES
Bacterial mosaic *(Clavibacter michiganense* subsp. *Tesellarium)*	Small, yellow spots and mottling near the midrib coalesce into streaks, turning leaf tissues tan to dark brown.	Warm, moist weather.	Thought to be seed-borne; survives on crop residue; spread by hail, splashing rain and blowing soil particles.	Plant clean certified seed; rotate crops.	
Scab or head blight *(Fusarium* spp., *Gibberella zeae)*	Blighted or bleached spikelets occur after flowering; orange or pink mycelium and spore masses appear at the base of diseased spikelets; bleached spikelets are sterile or contain shriveled seed.	Hot, humid weather during flowering and grain ripening.	Pathogen survives on infected corn and grass residues on the soil; infection occurs from wind-borne spores.	Rotate crops: plant wheat following soybeans, oats, barley or rye—do not follow corn; clean plow.	Scabby wheat may be toxic to non-ruminant animals.
Loose smut *(Ustilago tritici)*	Black, smutty spore masses replace both grain and chaff; smutted heads emerge from the boot earlier than healthy ones.	Cool, cloudy, wet weather at flowering.	Wind carries smut spores to healthy plants at flowering; spores germinate and infect developing grain; smut fungus is carried internally within seed to the next crop.	Plant certified seed treated with an effective fungicide.	
Yellow leaf spot or tan spot *(pyrenophora trichostoma)*	Tan-brown flecks expand into large, oval-shaped blotches with yellow borders; leaves die from tip toward base.	Cool, wet weather.	Pathogen overwinters in wheat stubble as small, raised, black perithecia; infection needs a 6- to 48-hour wet period to occur. All new infections are caused by wind-borne ascospores.	Manage stubble and rotate away from wheat, barley, rye and oats for 2 years.	
Septoria leaf spot *(Septoria tritici)*	Irregular, reddish brown spots occur, often with ashen white centers studded with tiny, black pimples (pycnidia); abundant on lower leaves.	Cool, wet weather.	Fungus survives as mycelium in leaf tissue of living plants. Overwinters as pycnidia on stubble. New spores are wind-borne in the spring.	Sanitation; plow stubble under; rotate at least one year between wheat crops. Delay planting until 10 days after fly-free date.	
Glume blotch *(Septoria nodorum)*	Small, purplish gray spots appear on glumes with pycnidia; light brown spots with dark brown margins occur on leaves.	Warm, wet weather (optimal is 68 to 80°F).	Pathogen is seed-borne; survives as mycelium in living plants and as pycnidia on stubble. Conidia are produced during wet periods and wind-blown to leaves, stems and heads.	Manage stubble where feasible and rotate crops.	
Eye spot or strawbreaker *(Pseudocercosporella herpotrichoides)*	Elliptical or eye-shaped lesions appear just above soil level. The lesions are distinct, gray to tan-brown and oriented longitudinally with the stem.	High moisture, dense crop canopy and high humidity near the soil surface. Mild winters and cool springs prolong sporulation and infection periods.	The fungus survives as mycelium on host debris. Conidia are distributed principally by splashing rain with a dispersal radius of 1 to 2 meters.	Delay planting until 10 days after fly-free date; reduce nitrogen and rotate crops 2 years away from cereals.	

TABLE 6. Wheat diseases					
DISEASE	**SYMPTOMS**	**ENVIRONMENTAL CONDITIONS FAVORING DISEASE**	**METHOD OF TRANSMISSION**	**RECOMMENDED CONTROL**	**SPECIAL NOTES**
Common bunt or stinking smut *(Tilletia caries, Tilletia foetida)*	Grain is replaced by black, powdery spore mass; smut balls give off a fishy odor.	Cool, moist weather at seed germination.	Smut balls break during threshing and spores collect on seeds and in soil; spores germinate and infect young seedlings following planting.	Use resistant varieties if available; treat seed with an effective fungicide.	
Dwarf bunt *(Tilletia controversa)*	Same as for common bunt, except plants may be very stunted or dwarfed.	Extended periods of heavy snow cover and soil temperatures near freezing to 40°F.	Spores germinate over several months. Teliospores can survive for long periods in soil.	Use resistant variety, if available. Seed treatment is not effective. Use disease-free seed.	
C-stripe *(Cephalosporium gramineum)*	During joint and heading, plants show long yellow stripes along the midvein; stripes later become tan to brown; plants become stunted and ripen prematurely.	Wet, acid soils, fluctuating winter temperatures and wheat on wheat.	Pathogen is soil-borne; enters root wounds caused by insects, soil heaving and other stresses.	Use a 2- to 3-year rotation program with spring grains or forages. Deep-plow stubble; plant after fly-free date.	
Powdery mildew *(Erysiphe graminis tritici)*	Patches of white to dull gray-brown mycelium appear on leaf surface; colonies of sexual fruiting bodies (cleistothecia) appear; mature cleistothecia are brown-black dots.	Cool temperatures (65 to 75°F), high humidity (80 to 95%) and low light.	Overwinters as cleistothecia on straw; wind-borne conidia are source of primary inoculum; new infection occurs within 7 to 10 days.	Rotate crops and plant resistant varieties.	
Leaf rust *(Puccinia recondita tritici)*	Small, round or oval, raised, orange-red pustules appear on leaf surface.	Cool nights; warm, bright days, and 6 to 8 hours of free moisture on the leaves.	The orange spores are wind-borne; new infections occur every 10 to 12 days.	Plant resistant varieties.	
Sharp eye spot *(Rhizoctonia solani)*	Necrotic spots resembling eyespots with light gray centers appear on lower stems; distinct black-brown edging and dark brown sclerotia are often evident. Lesions are located just above the first node. Sometimes 2 or 3 eye-shaped lesions occur.	Cool, dry weather; dry, acid and sandy soils increase risk.	The pathogen survives as small, brown-black sclerotia in soil and as mycelium in debris of many kinds of plants.	Plant seed late and shallow; promote root growth with fertilizer.	

TABLE 6. Wheat diseases					
DISEASE	**SYMPTOMS**	**ENVIRONMENTAL CONDITIONS FAVORING DISEASE**	**METHOD OF TRANSMISSION**	**RECOMMENDED CONTROL**	**SPECIAL NOTES**
Take-all *(Gaeumannomyces graminis)*	Plants are stunted and bleached yellow with sparse tillering. Heads become ashen white; base of stem turns brown to black, with a dark brown to black layer of fungus mycelium between stem and leaf sheath; roots rot; diseased plants usually occur in circular patches in the field.	Wet spring weather, poor soil conditions and use of high nitrate fertilizers.	Soil-borne; spreads from plant to plant via runner hyphae advancing through soil and across root bridges.	Rotate crops with legumes and use a balanced soil fertility program; control quack grass and other wild grasses that serve as hosts.	
Pythium root rot *(Pythium* spp.*)*	Pale green, mildly stunted plants; soft, wet, tan-brown areas at root tips.	Cool, wet soils deficient in phosphorus.	Soil-borne; enters roots through direct penetration or wounds; mycelium invade young cells, causing rapid root death.	Provide good soil drainage and good air circulation among plants; plant when temperatures favor fast growth; avoid high nitrate fertilizers.	
Crown and root rot, seedling blight *(Helminthosporium* spp., *Fusarium* spp.*)*	Leaves yellow, roots and crowns rot; crowns are brown-black; plants die or become badly stunted.	Drought and warm temperatures are the most important factors; dry falls and open winters.	Fungi survive in the soil.	Treat seed, eradicate all wild grasses, delay planting until 10 days after fly-free date; plant into a firm, shallow seedbed.	
Barley yellow dwarf virus *(BYDV)*	Leaves turn yellow or bright red, starting at the leaf tip and running to the base. Stunting, no mottling.	Moderate temperatures favor foliar symptoms.	Virus transmitted by aphids only. The four most common are: the green bug, corn leaf, English grain and oat bird cherry aphids.	Avoid planting early in fields that were planted to oats; delay planting until 10 days or more after fly-free date.	All cereals and wild grasses are hosts.
Wheat spindle streak mosaic *(WSSMV)*	Older leaves are a bright yellow-green with mottling; younger leaves show light green or yellow streaks and dashes; streaks and dashes parallel leaf veins and taper at both ends to form spindles.	Cold air temperatures (40 to 55°F).	WSSMV is transmitted by a soil-borne fungus *(Polymyxa graminis)* that invades wheat roots in the fall.	Rotate crops and delay planting until 10 days after fly-free date.	The virus lives in the soil for 8 years or more.

Summary Steps to Successful Wheat Production

1. Control perennial weeds, especially quackgrass.
2. Prepare a smooth seedbed by conventional tillage unless you're using direct drilling methods to control erosion. If you are using direct drilling methods, spread crop residues evenly at harvest and select a drill properly equipped for drilling wheat in an untilled field.
3. Have soil tested by a research-oriented laboratory and apply recommended amounts of lime and fertilizer, plus 10 to 20 lb of actual N per acre. Maintain the soil pH near 6.5.
4. Select certified seed of a high-performing variety adapted to your area.
5. Treat seed for control of seed- and soil-borne diseases.
6. Seed with properly equipped grain drill in 7-inch rows 1 to 2 inches deep at seeding rates of 2 to 2.5 bu/A.
7. Plant 10 to 15 days after the fly-free date.
8. Top-dress with 80 to 100 lb of actual N per acre as soon as possible after spring green-up to achieve yield goal.
9. Spray for broadleaf weeds when crop is fully tillered.
10. Control insect pests and foliar diseases with effective pesticides only when pest scouting determines a need. Be sure to apply at growth stages recommended on product label.
11. Apply growth regulator at proper growth stage only when you expect lodging to be a problem.
12. Harvest after grain moisture reaches 14 percent.

References

1. Clayton, J. L., et al. 1987. Wheat diseases. Extension bulletin E-1978, Michigan State University, East Lansing, Mich. 6 pp.
2. Copeland, L. O., et al. 1979. Seed treatment for field crops. Extension bulletin E-1199, Michigan State University, East Lansing, Mich. 6 pp.
3. Everson, E. H., et al. 1986. Wheat variety performance in Michigan. Extension bulletin E-1352, Michigan State University, East Lansing, MI. 8 pp.
4. Kells, J. J., and K. A. Renner. 1989. Weed control guide for field crops. Extension bulletin E-434, Michigan State University, East Lansing, Mich, 91 pp.
5. Large, E. C. 1954. Growth stages in cereals: illustration of the Feeke's scale. Pl. Path. 3:128-29.
6. Oplinger, E. S., et al. 1985. Intensive wheat management. Extension bulletin A3337, University of Wis., Madison, Wis. 18 pp.
7. Pierce, F. J. 1989. Direct drilling of winter wheat (in preparation).
8. Ruppel, R. F. 1977. Insect control in small grain crops. Extension bulletin E-0829, Michigan State University, East Lansing, Mich. 4 pp.
9. Vitosh, M. L., and D. D. Warncke. 1977. Fertilization of wheat. Extension bulletin E-1067, Michigan State University, East Lansing, Mich. 6 pp.
10. Warncke, D. D., et al. 1985. Fertilizer recommendations: vegetable and field crops in Michigan. Extension bulletin E-550, Michigan State University, East Lansing, Mich. 34 pp.
11. Wiese, M. V., et al. 1979. A derivation of optimal planting dates for winter wheat in Michigan. Research Report 387, Michigan State University Agricultural Experiment Station, East Lansing, Mich. 7 pp.
12. Zadoks', J. C., T. T. Chang and C. F. Konzak. 1974. A decimal code for growth stages of cereals. Weed Research 14:415-21.

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