


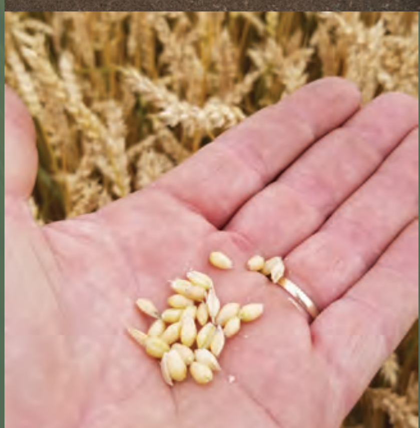


MICHIGAN WHEAT 101

A Guide for Soft Winter Wheat Production in Michigan.

Brought to you by Michigan's Wheat Farmers through the Michigan Wheat Program and Michigan State University Extension

MICHIGAN WHEAT 101

The Michigan Wheat Program was voted in by the state's wheat farmers in the summer of 2011. The goal for the check-off program was to increase yields and decrease quality issues for farmers growing the golden grain in the Great Lakes State.

Since its early meetings in 2012, the board of directors has focused on those two priorities. As they have continued their programming, they have found that research is just one of the pillars of that foundation. They have also needed to fund people and invest in infrastructure. This *Michigan Wheat 101* publication highlights those research projects funded over the past 10 years to benefit Michigan's 8,000 wheat farmers.

In fact, during these first years of the Michigan Wheat Program nearly 60-65% of grower funds annually have been channeled into wheat research specific to Michigan. Most of that research has been done at MSU with researchers seeking information and solutions for growing wheat more efficiently and cost-effectively here in the Great Lakes State.

Every year those research projects are individually reported out to the board and discussed at winter grower meetings, which accounts for another 23% of the budget that goes toward grower events and communication to share these research results.

This year, for the first time, the Michigan Wheat Program, MSU Extension and MSU researchers along with wheat specialist Dennis Pennington have compiled the best of these reports along with the most recent recommendations into a new publication. *Michigan Wheat 101* is the culmination of a decade of wheat-focused research and hard work made possible through the financial support and guidance from the farmer-led board of directors of the Michigan Wheat Program.

To complement that research there have been additional investments. Over the last decade the Michigan wheat check-off has identified and supported grower needs including…

- Nearly $3.5 million targeted to almost 150 research projects;
- A $700,000 donation to MSU put towards a land purchase at the Saginaw Valley Research & Extension Center to ensure long-term wheat research;
- $250,000 for essential, modern field and lab research equipment bought through partnerships and collaborations; and
- Additional boots on the ground through the collaborative funding of positions to strengthen research and coordination in priority areas.
    - Wheat breeder Dr. Eric Olson who is releasing new varieties (including Whitetail) was supported collaboratively by industry and growers for his first three years;
    - Wheat specialist Dennis Pennington is funded on an annual basis in a 50/50 partnership with MSU and the Michigan Wheat Program; and
    - Wheat educator Martin Nagelkirk who was funded prior to and now during his retirement to keep his wheat work ongoing and to coordinate with others as he more fully retires.

As the three areas of research, staff and infrastructure have come together over the past 10 years, it makes sense to pull information together and publish this vital information in one place: This *Michigan Wheat 101* publication.

Our goal is to have this available in both an electronic format on the Michigan Wheat Program website (www.miwheat.org) and in a printed format as a way to provide an overview of "best practices" for wheat production in the Great Lakes State. Our goal is for this to become a living document that will be updated by researchers as more and new information is available so the best and most recent information is easily accessible for growers use.

Hopefully as you read this publication in either its entirety or just use it as a reference, you will find nuggets of information to enhance your farming operation now and into the future.

MICHIGAN WHEAT PROGRAM

www.miwheat.org

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Published March 2021

Wheat Seed Variety Selection

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Variety selection

Selecting which variety of wheat to plant is one of the most important decisions a grower will make that affects the outcome of all agronomic inputs. It sets the bar for yield potential of the crop. Wheat varieties differ in a range of traits that affect performance. In 2020, an 18 bushel yield difference was found between the highest and lowest yielding varieties, which can have a significant impact on profitability. All wheat varieties have a unique combination of traits that provide both strengths and weaknesses. The specific traits of a variety can be leveraged in a tailored management program to achieve maximum profitability. Growers should consult the MSU Wheat Performance Trial Reports (https://varietytrials.msu.edu/wheat/) published annually for a nonbiased, science-based evaluation of yield, disease resistance and grain quality performance of about 50-60 commercially available wheat varieties.

Yield potential

Individual wheat varieties differ greatly in their yield performance. Variety selection is best made using at least three years of data to account for annual variations in weather conditions. Varieties selected using data across all locations will likely perform well under a wide range of conditions. As one would expect, performance of a given variety will vary based on testing location.

In selecting varieties for a specific location, look for varieties that perform well near the location where the variety will be grown.

Disease Resistance

Varieties are available that have both high yield potential and high levels of resistance to disease. For Michigan growers, the number one disease threat is Fusarium head blight (FHB). Variety resistance in combination with a fungicide applied at the proper time provides the best possible control of FHB. Look for varieties that have the moderately resistant (MR) designation and low DON levels. Other diseases to consider include leaf rust, stripe rust, *Septoria*, *Stagonospora* and powdery mildew.

Maturity

In Michigan, flowering date can differ up to six days between the earliest and latest maturity wheat varieties. For managing diseases like FHB, flowering date is critical for fungicide timing. Planting varieties with staggered flowering dates can create a larger window for fungicide applications and spread risk.

Height

Wheat varieties can differ in height up to 12 inches. Height can influence management decisions like utilizing a plant growth regulator. Selecting a shorter variety is an economical way to reduce height. The amount of straw produced is directly related to variety height. Height is sometimes related to lodging, but not in all cases. Many tall varieties are available with good straw strength and low risk of lodging.

Additional factors to consider when selecting varieties include: resistance to preharvest sprouting, yield potential, disease resistance, maturity, winter hardiness, straw strength, plant height, resistance to lodging, test weight, and milling and baking quality. Varieties should be selected that fit a specific management program and ensure marketability of the crop.

Planting two or more varieties with different traits is recommended. For example, planting a variety that has very high yield potential but is susceptible to foliar pathogens may entail the use of a fungicide to preserve yield. For operations applying fewer inputs, it is possible to identify varieties with high levels of disease resistance.

Seed source

Without question, the best seed is certified and professionally treated. Purchase certified seed from a reputable seed dealer.

Saving seed

Growers often inquire about saving seed to plant back on their farms. Most varieties released today from private companies and universities carry Plant Variety Protection (PVP) licenses. It is legal to save seed from PVP varieties for your own use on your own farm. It is *illegal* to provide bin-run or uncertified seeds to others.

While hiring a contractor to clean and treat seed on your farm may save you money in the short run, purchasing seed that has been run over a gravity table will provide the best uniformity in germination and emergence.

Seedling diseases such as *Pythium, Rhizoctonia* and *Fusarium* can reduce stands significantly. Where growers elect to plant their own seed, steps must be taken to increase the odds of success.

1) Reject grain from fields having any sign of a disease that can infect kernels internally (e.g., loose smut) or weeds whose seed tends to carry with the grain (e.g., cheat);

2) Thoroughly clean the grain to remove small and light weight kernels;

3) Submit the seed to a quality testing laboratory; and

4) Have the seed professionally treated with a fungicide.

Wheat Agronomy

***Dennis Pennington**, MSU wheat specialist and*
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Planting preparations

Achieving top yields requires a uniform stand of healthy seedlings. This depends on seeds being dropped as evenly as possible and at a uniform depth. Good seed placement, in turn, requires that fields are appropriately prepared, and that planting equipment receives disciplined inspection, necessary adjustments and deliberate calibrations.

Tillage systems

Wheat establishment can be successful under conventional, minimum tillage and no-till systems. Generally speaking, no-till has won favor in recent years. It tends to result in more unevenness in the stand, but it can often provide improved moisture retention and less susceptibility to cold temperature damage. Tillage, even at a minimal level, can be helpful in distributing and incorporating residue, fertilizer and lime; and create a more uniform seedbed. Tillage can also be useful when attempting to reduce disease inoculum borne in crop residue (e.g., corn stubble or stalks infected with *Fusarium*).

Seeding date

Ideally, winter wheat is planted while soil and air temperatures are still warm to ensure that seedlings can emerge quickly and in plenty of time to develop a couple of tillers and a strong root system before winter. In a recent study conducted by MSU, yield loss of about 0.6 bushels per day occurred when planting after October 1, and progressively declined to less than 0.3 bu/ac/day when planting was delayed to mid-October.

Hessian fly-free date still matters. While the Hessian fly no longer poses a significant threat to wheat in Michigan, the fly-free-date is still a useful reference. See Table 1.

Table 1. Hessian fly-free dates for Michigan by county.

County	Sept.	County	Sept.	County	Sept.	County	Sept.
Alcona	6	Eaton	16	Lapeer	15	Ogemaw	10
Allegan	20	Emmett	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

The standard fly-free-date falls during the first week of September in the northern Lower Peninsula; mid-September in the middle of the Lower Peninsula; and the third or fourth week of September in southern Michigan.

Highest yields are often attained when seeding occurs within two weeks after the posted fly-free-date, assuming heat unit accumulation is near normal in October and November. When wheat is planted within a few days of the fly-free date, seeding rates and fall-applied nitrogen rates should be significantly reduced to avoid excessive growth. The goal is to plant early enough to achieve 2-3 tillers prior to the winter vernalization period.

Late planted wheat

Sometimes, weather conditions make it difficult to plant wheat on time. How late a wheat crop can be planted is really a question of how much risk a grower is willing to take. If a grower expects to have the crop insured, the answer is straightforward: October 25 is the last planting date for crop insurance eligibility.

For those trying to estimate the odds of achieving a reasonable yield, it's important to recognize that the challenge to late wheat is not only the inherent constraints on grain yield, but also its greater susceptibility to winter injury.

One issue contributing to late planting of wheat is the inability of getting the previous soybean crop harvested early enough to get wheat planted on time. Selecting the appropriate soybean varieties that mature early can help in this case. Therefore, optimum planting time and maturity group (MG) selection for soybean fields that are to be planted to wheat in the fall is necessary. When planting soybeans early (before May 15), select late-maturity soybean varieties (e.g., 3.0 vs. 2.0 MG), which can lead to a 5-8 bushel/acre increase in soybean yield while maturing by the end of September, in time for wheat planting.

When planting soybeans late (after May 15), plant early-maturity varieties in order to balance timely harvest along with minimal soybean yield loss.

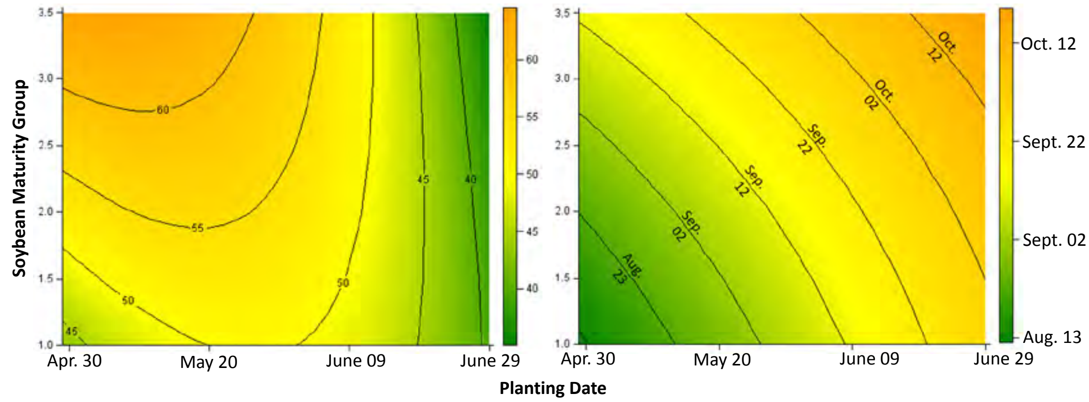


Figure 1. Impact of planting date and maturity group selection on soybean seed yield (bushel/acre, left panel) and date to reach R7 stage (one mature pod on the main stem, right panel). Add about 15 days to R7 to estimate harvest date. Data is average of four Michigan site-years.

Seeding depth

Uniform planting depth is critical for even emergence, tiller development and winter survival. Attaining a consistent seed depth is important to increase the probability of even emergence throughout the field. Usually, a planting depth of 1-1.5 inches is enough in heavy soil. Deeper seed placement may have an advantage when some types of winter stresses occur, but usually this is outweighed by the advantage in more rapid emergence of more shallowly placed seed. However, shallow depth (<1 inch) can also lead to low tiller numbers and poor winter survival. The exception may be where a coarse soil is very dry. In this case, seed should be planted as deep as possible to reach moist soil.

Seeding rate

The recommendation is to plant between 1.2-2.2 million seeds/acre. Seeding rates on the lower end of the range should be used when planting within a week of the fly-free date to avoid overly thick stands that can promote disease development and increase the likelihood of lodging the following season. High seeding rate during early planting has not shown to increase yield, but will result in increased input cost.

As the calendar advances, seeding rates should become progressively higher. If planting continues into the second half of October, the seeding rate should be increased to at least 1.8 million seeds/acre.

Table 2 identifies the pounds of seed needed based on the number of seeds/pound and your population target. For example, if seed size is 12,000 seeds/pound and the target seeding rate is 1.4 million seeds/acre, then 117 pounds/acre is needed.

Table 3 is useful for assessing the number of seeds being dropped by each row unit (7.5 inch row spacing) and for evaluating actual seedling density. So, with the 1.4 million target, a 7.5 inch drill would drop approximately 20 seeds/foot.

Table 2. Relating seed size and target seeding rates to the number of pounds required per acre.

	Target seeding rates (millions of seeds per acre)					
	1.2	**1.4**	**1.6**	**1.8**	**2**	**2.2**
Seed size	Actual pounds of seed required per acre*					
9,000	133	156	178	200	222	244
10,000	120	140	160	180	200	220
11,000	109	127	145	164	182	200
12,000	100	117	133	150	167	183
13,000	92	108	123	138	154	169
14,000	86	100	114	129	143	157
15,000	80	93	107	120	133	147
16,000	75	88	100	113	125	138

*Target seeding rate divided by seeds per lb = required pounds of seed per acre.

Table 3. Relating target seeding rate per acre to seed (for 7.5 inch row spacing).

Seeding Rate (millions/ac)	Seeds per foot of row
1.2	17.2
1.4	20.1
1.6	23
1.8	25.8
2	28.7
2.2	31.6

Wheat Fertility and Fertilization

***Dr. Kurt Steinke**, Associate Professor of Soil Fertility and Nutrient Management Department of Plant, Soil and Microbial Sciences, Michigan State University*

Soil pH

The soil pH indicates the relative acidity or alkalinity of a soil. Wheat grows best with a soil pH between 6.0 and 7.0. Growing wheat at a pH below 6.0 may result in magnesium (Mg) deficiencies, slower mineralization of organic nutrients, reduced availability of phosphorus (P), and increases the possibility for aluminum (Al) and manganese (Mn) toxicity which may adversely affect root growth.

When wheat is grown above a pH of 7.0, Mn deficiencies may occur. Wheat acres should be limed to a target pH of 6.5. Within a crop rotation, lime the soil for the crop with the highest target pH.

Nitrogen

Soft red and white winter wheat are often responsive to nitrogen (N) applications. N is often the most limiting nutrient for wheat production, and determining the optimal N rate is important for crop production, profitability and long-term sustainability.

Although producers wish to be 100% certain of N sufficiency, that level of certainty is not necessarily the most profitable. Sufficient N can promote tillering, improve yield, and optimize profitability. However excessive N may result in lodging, reduced yield and profitability, and environmental concerns due to unneeded N.

When developing an optimal N fertilizer rate, soil texture, organic matter, residual manure or fertilizer contributions, crop rotation, planting date and yield goal should all be considered. The wheat nitrogen recommendations provided here are pre-season guidelines and should be considered a starting point with adjustments made based on these factors and in-season growth and weather observations.

Sandy soils have lower water-holding capacities and usually decreased organic matter levels compared to finer-textured lakebed soils and thus a lower yield potential. Although soil organic matter is important for N mineralization and release, the synchrony between peak wheat N uptake and N mineralization may not coincide in Michigan.

Drainage impacts wheat growth as soils can be waterlogged in the spring during critical growth periods and lose a substantial portion of applied N to denitrification. Poorly drained fields or locations with insufficient drain tile have a lower yield potential compared to well tiled soils.

Crop rotations will impact yield potential through carbon: nitrogen ratios of crop residues and soil residual N from the previous crop. The harvest timing of previous crops will affect the planting date of winter wheat, which in turn influences yield potential.

Before considering an amount of N to apply, choose an expected yield goal that is realistic and achievable at least 50% of the time. A five-year running average – omitting unusually low or high yields – is another good tool to consider when establishing a yield goal. Yield goals that are rarely achieved will always result in the over-application of N, increase lodging risk, and increase potential for surface- and groundwater contamination.

A timely planted winter wheat crop will enable sufficient plant development and autumn tillering prior to dormancy and may allow for reduced N rates than those listed in Table 4.

Table 4 provides recommendations for winter wheat, based on the following equation:

N recommended (pounds N/acre) = (1.33 x yield potential) -13

Beyond the 100 bushel/acre yield threshold listed in Table 4, factors other than N application rate (e.g., planting date, autumn development, disease incidence, fungicide usage, plant lodging, varietal characteristics, etc.) often influence overall production levels.

Soft white winter wheat often has a greater yield potential than soft red winter wheat in Michigan due to production acres focused on more fertile, highly buffered, finer-textured soils located near the Great Lakes shorelines creating an environmentally buffered setting subject to fewer temperature extremes.

N application guidelines suggest anywhere from 10-30 additional pounds of N/acre for soft white winter wheat yield potentials beyond the 100 bushel/acre threshold listed in Table 4 (130-150 pounds N/acre total). May and June weather conditions will influence wheat response to greater rates of N.

Table 4. Nitrogen recommendations for soft winter wheat.

Wheat yield goal (bushel/acre)				
60	70	80	90	100
lbs N/acre				
70	80	90	110	120

Increasing grain protein. N fertilization for grain protein is not a common practice in the Great Lakes Region but that may change in the future. Nitrogen applied to increase grain protein is required later in wheat growth and development than N utilized for grain yield, which may affect N application timings. Early-applied slow release N sources or organic N sources may be better suited for these situations.

Timing and split N applications

Application of 20-30 pounds N/acre in autumn combined with timely planted wheat can promote establishment, autumn growth, and tillering by providing developing roots access to soil-supplied nutrients. Excessive autumn N application can cause extensive growth, biomass and tillering that increases the probability of disease and lodging.

Pre-plant soil NO3 (nitrate) values < 10 ppm increase the probability of a grain yield response to autumn-applied N. The remaining spring N fertilizer should be applied between green-up (Feekes 3) and the beginning of stem elongation (Feekes 5). Applications prior to this time period may partially assist with spring tiller development but increases the risk for N losses.

Spring rainfall variability will influence not only the success of individual spring N application timings but also the success of split N applications as shown in Table 5. Above average April-May rainfall may favor later applied (i.e., Feekes 5) or split N applications due to leaching or denitrification N losses, but dry soil conditions from below average rainfall and lack of soil moisture during this same time period may create difficulties for getting the split-applied or later-applied N into the plant. Wet soil conditions may also delay or prevent split N applications.

Generally due to the inability to predict an excessively wet or dry season, many growers choose to apply a single spring N application and adapt to in-season weather conditions if needed.

Table 5. Effects of spring nitrogen application timing on soft red winter wheat grain yield receiving 90 pounds N/acre total, Lansing, MI, 2013-2016.

	Wheat yield (bu/A)			
Year	Green-Up	Feekes 5	50% Green-Up 50% Feekes 5	April rainfall (inches)
2013	83 b[2]	95 a	92 ab	8
2014	97 a	97 a	94 a	1
2015	109 a	109 a	110 a	0.8
2016	91 a	90 a	91 a	2.9

[1] Adapted from K. Steinke. 2013-2016, Michigan Wheat Research Reports

[2] Values in a row followed by the same lowercase letter are not significantly different at a = 0.10

[3] Mean April total rainfall for Lansing is 2.9 inches

Nitrogen stabilizers

Both urease and nitrification inhibitors delay specific modes of N transformation to reduce nutrient loss and increase nutrient availability. Urease inhibitors (UI) will delay ammonia volatilization from surface-applied N but many begin to lose efficacy 10-14 days after application and still require a significant rainfall event (e.g., 0.5 inches) to effectively move applied N into the soil.

Nitrification inhibitors (NI) inhibit the soil bacterial conversion of ammonium to nitrate by blocking a specific enzyme within nitrification bacteria. Depending on environmental conditions, NIs may remain effective from 4-10 weeks.

Table 6. Impact of nitrogen stabilizers on soft red winter wheat grain yield, Lansing, MI, 2013-2017. All treatments received 90 pounds N/acre broadcast applied as urea at green-up.

Wheat yield (bu/A)				
Year	90N	90N with UI[2] + NI	90N with UI only	April rainfall[4] (inches)
2013	83 a[3]	96 a	87 a	8
2014	97 a	103 a	100 a	1
2015	109 a	108 a	107 a	0.8
2016	91 a	96 a	92 a	2.9
2017	82 a	78 a	79 a	5.2

[1] Adapted from K. Steinke. 2013-2017, Michigan Wheat Research Reports
[2] UI, Urease inhibitor; NI, Nitrification inhibitor
[3] Values in a row followed by the same lowercase letter are not significantly different at ? = 0.10
[4] Mean April total rainfall for Lansing is 2.9 inches

Grain yield responses to both UI and NI application have been inconsistent (Table 6). Cool spring soil temperatures, increased rainfall frequency during peak wheat growth, and lack of volatile N loss conditions (i.e., dry, warm, windy) during winter wheat spring N application timings have limited effectiveness of UI applications.

Positive wheat yield gains from an NI application are variable due to product application on an already growing crop and should only be expected during N loss conditions (i.e., leaching, denitrification). Other factors including N source (e.g., urea vs. urea ammonium nitrate (UAN)) will affect N volatilization potential as UAN only contains 50% urea with the ammonium and nitrate N portion unaffected by the NI.

Significant rainfall soon after UI application to urea-based fertilizers can leach N deeper into the soil profile and past the wheat rooting zone as urea is an uncharged mobile form of N. The addition of a UI may further delay urea transformation to other forms of N.

Phosphorous (P) and potassium (K)

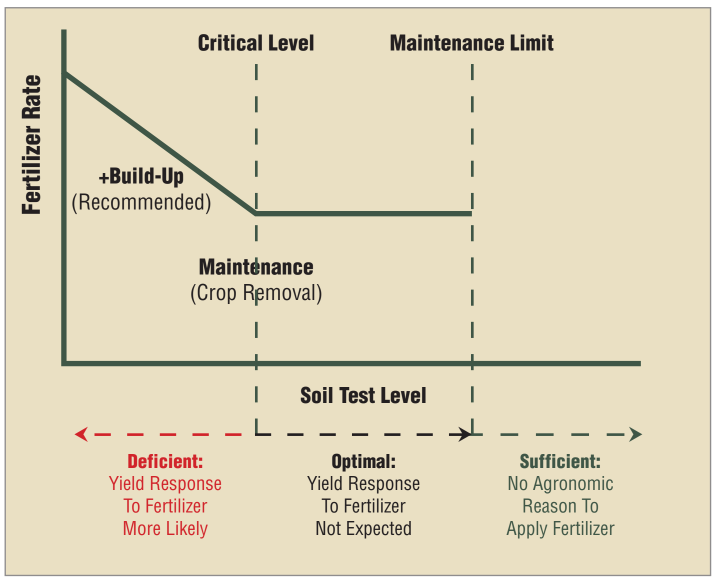
Soil testing is key for both the efficient and effective use of P and K fertilizers. Knowing your soil's critical level is essential to making economic and environmentally sound decisions regarding fertilizer application as guidelines are built upon soil test values.

The framework for P and K guidelines attempts to build soil test levels up to a critical level and then maintain these values over time. Soil test values below critical are more likely to result in a grain yield response to fertilizer application whereas values above critical are not likely to result in a yield response (Figure 1).

Within the maintenance range, guidelines approximate crop removal to replace nutrients removed in grain. Soil test values are considered "optimal" when above the critical value but less than the maintenance limit.

Current grain P and K removal values for winter wheat are 0.50 lbs. P_2O_5 /bushel and 0.25 pounds K_2O/bushel while wheat straw removal values are 3.7 pounds P_2O_5/ton and 29 pounds K_2O/ton. Beyond the maintenance range there is little agronomic reason to apply fertilizer.

Figure 1. The Tri-State Fertilizer Recommendation Framework. Adapted from Culman, Fulford, Camberato, and Steinke. 2020. Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa.



A recent review of critical soil test P and K levels across Indiana, Ohio and Michigan found that when soil test levels were above critical and within the maintenance range, the opportunities for a yield response to P or K fertilizer were not likely and provided no evidence that critical levels are too low or require modification.

What has changed is that critical soil test levels are now reported utilizing the Mehlich-3 extractant for soil test P and K instead of the previous Bray-P and Ammonium Acetate -K for P and K, respectively (Table 7). To convert Bray-P to Mehlich-3P, multiply Bray-P values by 1.35; or conversely, divide Mehlich-3P values by 1.35 to convert to Bray-P. To convert Ammonium Acetate-K values to Mehlich-3K multiple by 1.14; or conversely, divide Mehlich-3K values by 1.14 to convert to Ammonium Acetate K.

Table 7. Mehlich-3 Soil Test Phosphorus and Potassium Levels for Soft Winter Wheat[1].

		Mehlich -3 Potassium Maintenance Range	
Crop	Mehlich-3Phosphorus Maintenance Range	Sandy soils (CEC<5meq/100g)	Loam and clay soils (CEC>6meq/100g)
Wheat	30–50 ppm	100–130 ppm	120–170 ppm

[1] Adapted from Culman, Fulford, Camberato and Steinke. Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa.

Potassium recommendations have always been slightly different for sandy soils as compared to fine-textured soils due to the greater ability to hold K on the fine-textured soils. Sandier soils (i.e., Cation Exchange Capacity (CEC) <5) require less K fertilizer to meet crop requirements at low soil test levels, but medium to high soil test levels require more K fertilizer due to greater K storage capacity or fixation. Potassium soil test levels on sand tend to show much greater year-to-year fluctuations than finer textured soils. Soils that have a greater potential to produce larger yields require a higher soil test to obtain those yields than soils with a lower yield potential.

Starter fertilizer

While both P and K are most efficiently used when banded or placed near the seed at planting, the decision to use a P or K starter fertilizer depends upon factors including soil test levels, amount of surface residue, and soil temperatures.

Most grain drills, place fertilizer in direct contact with the seed. Do not apply more than 60 pounds/acre of N and K_2O in direct contact with the seed. Dry soils at planting can increase seedling damage. If urea is utilized in starter, do not apply more than 10 pounds/acre N in direct contact with the seed. Greater rates may be considered if soils are moist at planting.

Typically, if greater N rates are required at planting, the remainder of N should be broadcast pre-plant. Potassium is often unnecessary to include in banded starter blends unless soil test K levels are low (< 70 ppm K). Ammonium thiosulfate and boron fertilizers should not be placed in direct contact with the seed due to seedling sensitivity.

Secondary and micronutrients

Secondary and micronutrients are essential for optimal wheat growth but many of these nutrients are generally adequate in Michigan soils. Well-limed soils often have sufficient calcium and magnesium levels.

Sulfur (S). Declines in atmospheric deposition, less incidental S in fertilizers, and more reduced tillage systems have all resulted in grain yield responses to S fertilizers becoming more common but not widespread. Winter wheat undergoes rapid periods of biomass growth during cool air and soil temperatures with minimal soil S mineralization.

Recent research in Michigan has shown inconsistent responses to 25 pounds/acre of S applied as sulfate at planting with yield increases ranging from 0-10 bushels/acre. Variabilities in yield response depend on factors including previous crop, previous S applications, amount of winter precipitation between wheat planting and green-up, planting date, and soil texture and physical properties. Broadcast applying 25 pounds/acre of S should be sufficient on most soil textures including sandy soils.

Manganese (Mn). Mn is the most likely micronutrient deficiency to be observed in Michigan (Table 8). Mn deficiency may occur on lakebed soils with a pH above 6.5 and on organic soils with a pH above 5.8. A soil test for Mn is suggested for mineral soils with a pH above 6.2 as critical Mn values change from 6 ppm at pH 6.3 to 12 ppm at pH 6.7.

Table 8. Relative responsiveness level of winter wheat to micronutrient fertilizers. Adapted from MSU Extension bulletin E-486, Secondary and micronutrients for vegetable and field crops.

Winter Wheat Response to Micronutrients			
Manganese	Boron	Copper	Zinc
High	Low	High	Low

Manganese fertilizer should be either band applied or in contact with the seed to improve efficiency. Broadcast and incorporated applications are often fixed into unavailable forms when mixed with soil and not recommended. Foliar Mn sprays may be applied at 1-2 pounds/acre of Mn to correct in-season observed deficiencies. Severe deficiencies may require multiple applications 10 days apart. For further recommendations refer to MSU Extension Bulletin E2904, *Nutrient Recommendations for Field Crops in Michigan*.

Copper (Cu). Cu deficiency has only been observed on organic soils and Cu is not currently suggested for wheat grown on mineral soils. Due to issues with multiple micronutrient deficiencies and excessive N availability on organic soils, wheat planting is not recommended on organic soils.

Wheat Lodging Considerations

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***Martin Nagelkirk**, retired wheat educator*
MSU Extension

There are two types of lodging in wheat: Stem breakage and root lodging. High winds from storms are typically the culprit, but a number of contributing factors play into the severity of lodging.

Many research programs have studied lodging and have developed ways to measure and model the impact of different forces on standability of the plant. Plant height, stem wall width, stem strength, root plate spread and soil strength influence the degree of lodging caused by a windstorm (Figure 2).

The financial risks associated with lodging include compromises to grain yield due to greater harvest losses; and losses in grain quality which may be due to decreased test weight, increased grain moisture, elevated scab (DON) levels, and lower falling number scores. Management practices to minimize these factors will help reduce the risk of lodging.

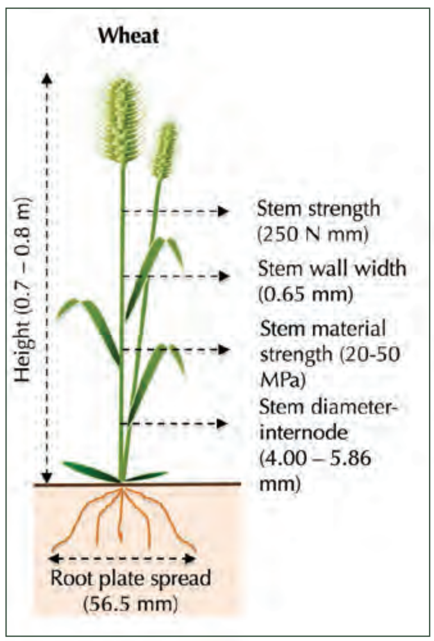

Figure 2. Ideotype wheat plant to protect against lodging. Photo courtesy of ResearchGate.

Role of variety selection, nutrition, and seeding depth

Height, stem strength and stem diameter can be affected by variety selection and application of a plant growth regulator (PGR). Further, stem strength and diameter are also influenced by the degree of tillering and potassium nutrition. Crown roots are essential to providing anchorage to plants. Seed should be planted at least 1 inch deep, resulting in crown roots developing about three quarters of an inch below the soil surface. Planting too shallow brings the crown roots closer to the surface and reduces their effectiveness in holding up the plant.

Nitrogen's role

Soil N. Sometimes lodging can be attributed to an underestimation of the availability and contribution of N already in the soil system. In some cases, relatively high levels of nitrate can be carried over from previously N-loving crops such as corn, sugar beets, pickles, or even dry beans. Soil nitrates levels following one of these crops have been known to exceed 50 lbs/ac nitrate-N in some cases. The other potential boost in soil N can be due to mineralization. N mineralization from organic sources such as cover crops, previous rotation crop, manure or mucky soils can result in higher levels of total N than what a grower anticipates and, thereby, may experience greater risks of lodging.

Excessive N Fertilization. Too much N fertilizer can promote vegetative growth to the extent that the plant becomes unstable in high winds. Efforts to increase wheat yields often include more intensive N management, increasing both the number of N applications and overall N rate. Achieving a N management plan that maximizes yield while minimizing lodging potential can be a challenge. Lodging resulting from high N rates is more apparent on headlands and overlaps where the fertilizer is double applied.

Insects

Role of insects. Insects can also cause stem breakage, the most common culprit being wheat stem maggot. Other suspects include sawflies and Hessian fly. Their feeding is often conspicuous upon close examination and typically causes breakage in the mid-section of the stem.

High tiller densities. Tillering is a good thing – until it's too much. A healthy wheat plant should have no more than 4-5 tillers. Weak stems due to high planting populations and excessive tillering (more than 5 tillers per plant) can result from seeding relatively early in the fall (within a few days of the Hessian-fly-free date) and not reducing seeding rates or starter N.

Diseases. Wheat diseases including Fusarium root and crown rot, Rhizoctonia root rot, take-all and sharp eyespot can contribute to lodging. In addition, disease can impact grain quality in the lodged wheat. Lodged wheat tends to trap moisture, making the micro-environment conducive for disease development and grain quality losses. In addition to losses in test weight, both deoxynivalenol (DON) and falling number scores can be adversely affected.

Recommendations. Making management decisions to reduce risks associated with lodging is complicated as there are many contributing factors. A field by field assessment may be necessary. Variety selection, nitrogen management, disease and insect pressure will need to be addressed. In fields with very high yield potential, application of plant growth regulator should be considered. Consult your local extension program for guidance and advice on how to manage lodging.

Wheat Weed Management

***Dr. Christy L. Sprague**, Professor and Weed Extension Specialist*
Department of Plant, Soil and Microbial Sciences, Michigan State University

Effective weed management is essential to maximize winter wheat yields and improve harvest efficiencies. Weeds compete for water, nutrients, and light. Yield losses due to weed competition can range from as little as 1% up to 55% in Michigan wheat fields. The extent of yield loss is affected by the competitiveness of the wheat crop, the type and number of weeds present, weather conditions, and effectiveness of the weed control strategy.

To effectively manage weeds, a combination of cultural, chemical, and sometimes even mechanical weed control practices is implemented. These practices can occur at various times throughout the winter wheat production season. This chapter outlines key weed management practices and different strategies that can be used to help ensure a healthy, weed-free, productive wheat crop. In addition to this chapter, consult the *Weed Control in Small Grains* chapter in the *MSU Weed Control Guide for Field Crops (E0434)* for specific recommendations. This guide can be purchased from the MSU Extension Bookstore or accessed through www.MSUWeeds.com or www.canr.msu.edu/weeds/.

Cultural practices

A competitive crop is the first step for effective weed management in winter wheat. Unlike other crops, a healthy and vigorous wheat stand can be extremely effective in reducing weed emergence, growth, and competition. In fact, in some cases a vigorous wheat stand can eliminate the need for herbicide application.

However, newer weed problems and difficulty in establishing a uniform competitive wheat stand across an entire field often require additional weed control measures. Variety selection, planting date, seeding rates and other production practices (i.e., fertility) that increase wheat establishment and vigor in the fall can reduce the potential impacts that weeds have on the crop. It is also important to plant weed-free wheat seed to prevent introduction of new weed problems. This can be done by purchasing and planting certified seed.

Wheat varieties that grow rapidly, are winter hardy and have good tillering characteristics are ideal attributes for a competitive wheat crop. Earlier planting (September) at recommended seeding rates will also help in the establishment of competitive wheat stands. However, if wheat is planted later in the season it is important to increase seeding rates to improve stand establishment. For more information on wheat planting dates and seeding rates refer to Wheat Agronomy on pages 2-4.

Wheat that is planted later in the season at lower seeding rates is more likely to result in a poorer wheat stand and winterkill, which can allow the emergence of new weeds that will be problematic throughout the growing season. Additionally, areas in the field with poor fertility (i.e., low soil pH) or where other production problems may have occurred (i.e., planter skip, uneven planting due to previous crop residues, etc.) reduce wheat growth and leave open areas in the field for greater weed competition. It is extremely important in these areas to implement effective weed control strategies.

Weed control before and at planting

Starting with a weed-free seedbed is critical when planting winter wheat. Complete control of all weeds that are present at the time of planting is required for successful weed management. If not controlled, weeds can reduce stand, hinder growth, and potentially harbor insects and diseases that can negatively impact wheat establishment and vigor. In Michigan, winter annual broadleaf weeds including common chickweed, henbit, purple deadnettle, and several mustard species (e.g., yellow rocket and shepherd's-purse) are normally present at wheat planting. Additionally, glyphosate-resistant horseweed (marestail) that has shown emergence in the fall and in spring is often present. Annual bluegrass and dandelion are also problematic weeds at wheat planting. Farmers need to control these weeds prior to or at planting with tillage or with burndown herbicide applications.

Tillage. This is the most effective way to control most weeds before planting wheat. Tillage implements that effectively uproot established weeds and mix the upper few inches of soil are generally the most effective. However, most farmers prefer to no-till wheat following soybean or dry bean harvest. In these cases, appropriate burndown herbicide programs should be considered.

No-tillage wheat. No-tilling wheat into soybean or dry bean stubble, generally does not present any major weed control challenges. If no weeds are present at wheat planting, or if small seedlings of spring-germinating weeds that do not overwinter (summer annuals) are present at low numbers then the field can be planted without special weed control measures. Typically, there is very little emergence of summer annual weeds in the fall and plants that do emerge will likely be killed by freezing temperatures. However, any winter annuals, biennial or perennials present in the field prior to or at wheat planting need to be controlled with a burndown herbicide application.

Glyphosate (i.e., Roundup PowerMax) can be used prior to or soon after wheat planting to control existing weeds. If applying glyphosate after planting, it is important to make these applications prior to wheat emergence. Waiting too long puts wheat at greater risk to exposure from glyphosate resulting in reduced wheat stands.

There is one caveat to just using only glyphosate: The presence of glyphosate-resistant horseweed (marestail). If horseweed is present, it's important to apply a herbicide that will control glyphosate-resistant horseweed. Options for controlling horseweed include adding 1 to 2 fluid ounces/acre of Sharpen to the glyphosate application. This application needs to be made before wheat emergence. The use of Gramoxone (paraquat) is another option to control emerged weeds, including glyphosate-resistant horseweed, prior to planting. However, larger horseweed will be more difficult to control. Dandelion is another weed challenge that no-till wheat farmers often have at planting. Established dandelions are very difficult to control in emerged wheat; therefore, it's important to control this weed before planting. Currently, tillage or glyphosate applications prior to wheat emergence are the best options for dandelion control. 2,4-D and dicamba are not labeled for applications before planting wheat and can result in substantial wheat injury.

Weed control with POST herbicides in fall

Over the last five years, there has been increased interest in applying postemergence (POST) herbicides in the fall for weed control in winter wheat. Fall POST herbicide applications, generally take place after wheat emergence and depending on the herbicide(s) selected, wheat may need to have 2- to 3-leaves (Feekes 1.2-1.3) prior to application. Typically, these herbicide applications are made to control winter annual weeds that emerge with the wheat crop. However, many of the herbicides used do not provide long enough residual activity to control summer annual weeds that emerge in the spring. While this may be one downfall to fall POST herbicide applications, there are certain instances where these fall herbicide applications are useful.

Controlling winter annual broadleaf weeds. Winter annual weeds can flourish in wheat planted in early fall. While early planting helps with wheat establishment and growth, fall's warmer temperatures also increase the germination and establishment of winter annual weeds like common chickweed and glyphosate-resistant horseweed (marestail). Fall applications of Huskie, Talinor or Quelex can control them.

Other broadleaf wheat herbicides can be applied in fall, but it's important to ensure the herbicides used are effective at controlling the weeds present in the field. For example, most horseweed populations in Michigan winter wheat fields are resistant to glyphosate (Group 9) and also the ALS-inhibiting (Group 2) herbicides. If Group 2 resistant horseweed is present in a field a fall application of the Group 2 herbicide premixture Affinity BroadSpec will not control it.

Additionally, not all herbicides labeled for spring applications can be applied in the fall. 2,4-D is an example of a herbicide that can cause major developmental problems leading to reduced wheat yields if it is fall applied. While many fall herbicide applications will only control weeds present at the time of application, vigorous wheat stands from early planted wheat may outcompete spring emerging weeds, preventing the need for another herbicide application in spring.

Controlling hard-to-manage winter annual grasses.
One area with tremendous advantage for fall POST herbicide applications is managing hard-to-control winter annual grass species, like common windgrass. MSU research plots have demonstrated effective control of common windgrass with fall POST applications of Osprey, Osprey Xtra and PowerFlex HL. These herbicide applications must be made to emerged windgrass and emerged winter wheat. They should typically occur in early- to mid-November when winter wheat has at least three leaves.

Other hard-to-manage grasses, (i.e., annual bluegrass and roughstalk bluegrass) can benefit from fall applications. However, in some cases an additional spring herbicide application will be needed for complete control due to continued grass emergence in spring. Osprey, Osprey Xtra and PowerFlex HL will control annual bluegrass, while Osprey, Osprey Xtra and Axial Bold are effective at controlling roughstalk bluegrass
(Figure 3).

Figure 3. Roughstalk bluegrass not effectively controlled in a Michigan winter wheat field.

Fall herbicide applications on winter wheat to be frost-seeded with red clover. One of the benefits of fall POST herbicide application, is it provides farmers another option for weed control if they will frost-seed red clover in winter wheat. Currently, spring herbicide options are limited if a farmer wants to frost-seed clover. However, if applied in the fall clover can tolerate Affinity BroadSpec, Huskie, Clarity, MCPA and Axial Bold. Frost-seeded clover can also tolerate fall-applied Osprey and PowerFlex HL, although there may be some slight injury and small reductions in the clover stand.

Weed control in spring

There are several POST herbicide options available in spring for selective weed control in winter wheat. Before applying any of them, there are several factors that farmers should consider: Proper identification of weed species, weed size, wheat growth stage and herbicide cost.

The earlier a weed emerges, the more competitive it will likely be. Larger winter annual weeds are usually more competitive with wheat than spring-germinating weeds, and therefore must be treated early to minimize crop impact. Early spring herbicide applications can be affected by several factors including the weather.

Cold temperatures. Remember that most herbicides labeled for weed control in winter wheat have specific instructions that applications should be made when *weeds are actively growing.* Herbicides should not be applied when the crop is under stress from very cold temperatures, when there are wide fluctuations in day/night temperatures, when a frost has occurred or when temperatures are below freezing prior to/at/immediately following the application. *A good rule of thumb* is to only apply herbicides to winter wheat when the daily temperature is 50° F or higher. Following this rule of thumb helps avoid wheat injury and improves weed control.

Spring herbicide applications on winter wheat frost-seeded with red clover. As mentioned, frost-seeding red clover in winter wheat has regained prominence for many Michigan farmers. However, one of its greatest challenges is finding a herbicide that can be applied for weed control without damaging the clover. While there are several herbicides that can be applied in the fall with little impact on frost-seeded clover (Figure 4), the only broadleaf herbicide that can be applied in the *spring* without negatively impacting clover is MCPA. Axial Bold is the only POST grass wheat herbicide that can be applied in the spring without affecting frost-seeded clover.

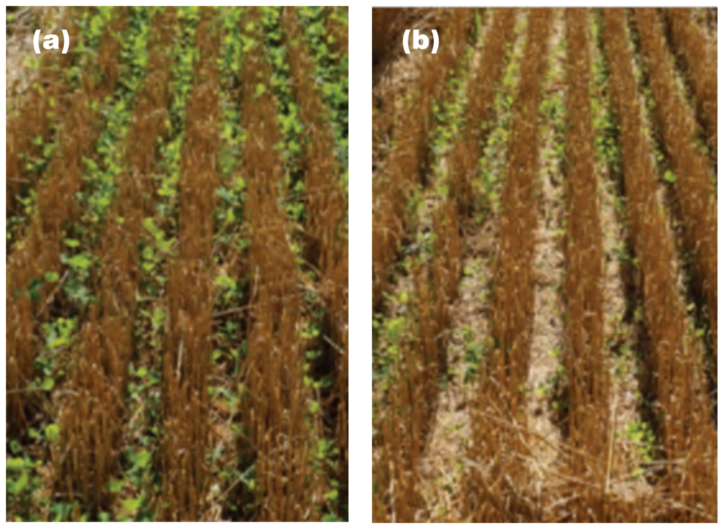

Figure 4. Frost-seeded red clover establishment after (a) fall and (b) spring applications of Huskie.

Horseweed (marestail) control in the spring. Herbicide-resistant horseweed (marestail) is quickly becoming one of the greatest weed control challenges in winter wheat in Michigan. While a good stand of wheat can go a long way in suppressing horseweed, it's important to spray an effective herbicide as well. There are several options that provide effective horseweed control, yet farmers should be aware that most horseweed populations in Michigan are resistant to the ALS-inhibiting or Group 2 herbicides. So, it will be important to use non-Group 2 herbicides. As farmers look to control herbicide-resistant horseweed, the herbicides Huskie, Talinor or Quelex are all effective options. Also keep in mind horseweed is best controlled when small.

Herbicide applications with liquid nitrogen fertilizer. Combining herbicide and nitrogen applications in winter wheat reduces the number of trips across the field. However, this practice has two major limitations:

1) the optimal timing for herbicide and nitrogen applications often do not overlap, and
2) when combining the two there is a greater risk for crop injury.

The ideal time for a single spring nitrogen (N) application is before wheat green-up. However, herbicides are best applied between Feekes stages 5 and 6. Applying herbicides too early – the ideal time for N application – would miss the optimal target for spring-germinating weeds. Delaying N application to the time of the herbicide application, Feekes stages 5 or 6, would likely reduce wheat yield. However, unfavorable spring weather including high precipitation could delay or increase the loss of N from early spring N application. In these instances, farmers may be forced to apply N later to larger wheat or may decide to split the N application.

Liquid 28% urea-ammonium nitrate (UAN) fertilizer is a common carrier for herbicides in wheat. Applications of herbicides with 28% UAN can cause leaf burn from the N, especially under hot, humid conditions. The risk for injury increases with later wheat growth stages, since there is more leaf area exposed and a shorter time to recover. Additionally, the use of adjuvants, such as surfactants or crop oil concentrates, increases the risk for leaf burn. To address these crop injury concerns from N and herbicide combinations, research was conducted at MSU and the following recommendations were formulated:

- 2,4-D amine or 2,4-D ester at 1 pint/acre can be applied with liquid N fertilizer solutions (28% UAN) as the spray carrier at 100% or a 50:50 28% UAN: water mixture. 2,4-D ester formulations generally mix easier with fertilizer solutions than 2,4-D amine formulations. When applying 2,4-D products with 28% UAN as the spray carrier, do not include surfactant. The addition of other herbicides or fungicides to these mixtures will likely increase the risk for crop injury.

- MSU does not recommend applying Affinity BroadSpec or Huskie with 100% (56 pounds actual N) 28% UAN as the spray carrier. The risk of crop injury and potential yield reductions is higher with these combinations. The full load of surfactant at 0.25% volume/volume (v/v) used in these combinations was likely the cause for increased injury (Figure 5).

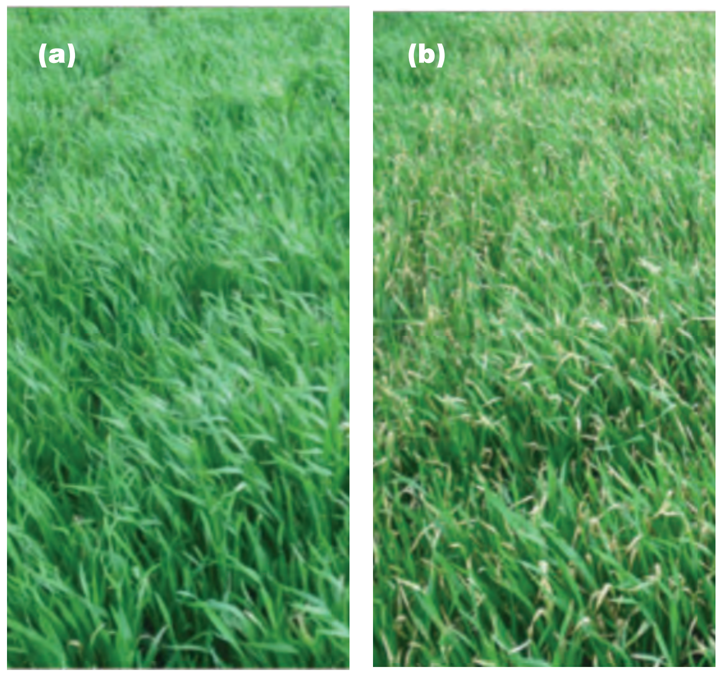

Figure 5. Wheat treated in the spring with Huskie (13.5 fl oz/A) + nonionic surfactant (0.25% v/v) + AMS (3 lb/A) applied with the spray carrier as (a) water and (b) 28% urea ammonium nitrate (UAN).

• **Affinity BroadSpec and Huskie can be applied with 50:50 ratio of liquid N fertilizer solutions (28% UAN) and water (28 pounds actual N).** Reducing the surfactant rate in these mixtures to 0.125% v/v will also reduce the risk for crop injury. Wheat tolerance is also greater if applications of these combinations are made prior to wheat jointing (Feekes stage 6).

• **A word on Quelex.** Quelex is a newer herbicide that can be applied in spray solutions containing N. While this herbicide was not available for MSU's spray carrier research, previous trials with Quelex with 100% UAN showed a slight increase in injury to wheat compared with Quelex applied alone. However, this injury was only temporary and did not impact wheat yield. If using this practice, it's important not to add more than a 0.25% v/v surfactant.

• **Talinor and 28% UAN.** MSU has never applied Talinor using 28% UAN as a carrier. However, since the use of ammonium sulfate (AMS) is prohibited on the label, our recommendations would be do not apply Talinor with 28% UAN as the herbicide carrier.

• **PowerFlex HL and 28% UAN.** Label recommendations state that PowerFlex HL can be applied 50:50 ratio of liquid N fertilizer solutions (28% UAN) and water, if the actual N rate is <30 pounds/acre, and the surfactant rate is reduced to 0.25% v/v.

• **Osprey and Osprey Xtra mixtures with 28% UAN.** For these applications only up to 15% of the spray solution can be N fertilizer solution. Additionally, independent N fertilizer applications should not be made within 15 days before or after application of these herbicides.

Winter wheat growth stage and weeds controlled. All herbicides have maximum wheat growth stages for application listed on the label. Late herbicide applications can lead to excessive crop damage that can cause kernel abortion and reduce wheat yield.

Some of the more restrictive herbicides that are used in winter wheat are the plant growth regulator herbicides. 2,4-D (Figure 6), dicamba (Clarity), MCPA and tank-mixtures that contain these herbicides need to be applied prior to winter wheat jointing (Feekes stage 6). These herbicides are typically good at controlling summer annual weeds such as common lambsquarters, pigweed and common ragweed, but vary in their control of some of the more common winter annual weeds including common chickweed. 2,4-D and MCPA will not control common chickweed.

Figure 6. Wheat damage from late-applications of 2,4-D.

Other herbicides that need to be applied prior to Feekes stage 6 are the grass herbicides, Osprey, Osprey Xtra and PowerFlex HL. They are effective at controlling annual bluegrass prior to flower and also common windgrass. However, Osprey and Osprey Xtra have been more effective at controlling roughstalk bluegrass. PowerFlex HL also has good activity on many broadleaf weeds including common chickweed. If winter wheat is at jointing these herbicides should no longer be used. Axial Bold is another herbicide that has good control on many grasses, including roughstalk bluegrass. However, Axial Bold can be applied up to the preboot stage of wheat (Feekes stage 8).

The herbicides, Affinity BroadSpec, Harmony Extra, Harmony, Express, Huskie, Talinor and Quelex are not as restrictive as many of the plant growth regulator herbicides. These herbicides can be applied to wheat until just before the flag-leaf is visible (Feekes stage 7.9). Talinor can be applied up to Feekes stage 8. All of these herbicides also have better control of common chickweed than many of the growth regulator herbicides. Peak, another herbicide, is also an option for common chickweed control, however longer rotation restrictions (22 months) to many crops including soybean often restrict its use.

Buctril, Stinger, Starane and Widematch (Stinger + Starane) are other herbicides that will control broadleaf weeds in winter wheat. These herbicides have the longest application window. They can all be applied to winter wheat up to the boot stage (Feekes stage 9). However, many of them have a fairly narrow spectrum of weed control. Buctril provides better control of summer annual weeds and is not very effective against winter annuals. Starane has a very narrow weed control spectrum, but is excellent in controlling hemp dogbane. Stinger, on the other hand, provides excellent Canada thistle control.

Preharvest weed control (harvest aids)

Currently, there are five different herbicides labeled as harvest aids for winter wheat. They are applied to desiccate or suppress weeds that can hinder wheat harvest. They will not improve wheat yield nor greatly reduce weed seed production.

Glyphosate, 2,4-D amine/ester, Aim, Clarity and Sharpen are harvest aid options for Michigan wheat farmers. The effectiveness in weed desiccation and improving wheat harvestability varies by each of these herbicides. In MSU research, glyphosate and glyphosate tank-mixtures have been the most effective for weed desiccation, except for glyphosate-resistant horseweed (marestail).

End-user concerns. However, buyers and consumers have voiced concerns about glyphosate residues in harvested grain. While glyphosate applications are legal once wheat is past the hard-dough stage (>30% grain moisture), glyphosate residues can still be detected even though they are below maximum residue levels (MRLs). In MSU research, the highest glyphosate residue detected was 37.5 times lower than the CODEX MRL of 30,000 ppb. To avoid consumer concerns, if a preharvest treatment is needed farmers should consider using one of the other herbicides labeled for preharvest use in winter wheat including 2,4-D, Aim, Clarity and Sharpen. Of these, Sharpen has been the most effective for desiccating common ragweed and glyphosate-resistant horseweed.

For more information on specific weed control recommendations, the *Weed Control in Small Grains* chapter in the *MSU Weed Control Guide for Field Crops (E0434)* should be consulted. This guide can be purchased from the MSU Extension Bookstore or accessed through www.MSUWeeds.com or www.canr.msu.edu/weeds/.

Using Red Clover for Crop Cover

Paul Gross, *Field Crops Educator,*
Michigan State University Extension

Spring is the ideal time to frost seed red clover into your winter wheat crop. Frost seeding is the practice of broadcasting red clover into winter wheat just prior to green-up. In most years, the ideal time is between mid-March and early-April.

It is important the snow melts prior to frost seeding. Deep snow will cause the seed to move to the lower areas of fields as the snow melts and can result in poor stands. Seasonal freeze-thaw cycles cause the soil to repeatedly develop small cracks on the surface, allowing the clover seed to achieve good soil contact for germination.

Seed inoculation is highly recommended in fields where red clover has not been grown within the last several years. Make sure the label states the inoculant contains *Rhizobia trifolii*.

The Michigan State University Extension Cover Crops Program has had excellent results frost seeding mammoth and intermediate red clover in winter wheat. Seeding rates range from 6 to 18 pounds per acre. The most consistent stands of red clover have resulted when seeding at 12 pounds to the acre. Many farmers are using ATVs with spinners to seed red clover into wheat, covering a lot of ground without rutting or causing compaction.

Uniformity of the stand is important to get the full benefits of the red clover. One effective strategy to ensure uniformity and avoid skips is set the spreader at half the intended seeding rate, spread the seed, then go over the field a second time applying the second half of the rate driving halfway between the tire tracks left by the first application. Many ATVs are equipped with GPS systems that can also be used to ensure accurate coverage.

A red clover cover crop has several benefits, including:

- Contributing 30 to 100 pounds of soil N/acre
- Reducing soil erosion and surface water pollution.
- Increasing soil organic matter, improving soil health and increasing water holding capacity.
- Reducing weed pressure.
- Serving as a forage and pasture for livestock.

What nitrogen credit can I expect?

According to MSU researchers, a 1.8 ton/acre red clover cover crop will have approximately 100 pounds of N in the top growth and 50 pounds in the roots. With good management, a farmer can expect that half of those 150 pounds should be available to the next crop; the rest will gradually be released over time. The actual N available depends on variables such as soil temperature, precipitation, soil texture, tillage and the maturity of the red clover.

For more detailed information on red clover, read the MSU publication, *Using red clover as a cover crop in wheat.* [https://bit.ly/3tPnrPP.




*Clockwise from top left, MSU wheat team **Dr. Martin Chilvers,** Associate Professor for Field Crop Pathology, Department of Plant, Soil and Microbial Sciences, Michigan State University, **Mikaela Breunig**, PHD Student, Department of Plant, Soil and Microbial Sciences, Michigan State University, **Martin Nagelkirk,** Retired Wheat Educator, MSU Extension, and **Dr. Jan Byrne,** Plant Pathology Diagnostician, Plant and Pest Diagnostics, Department of Plant, Soil and Microbial Sciences, Michigan State University*

Developing a disease management plan

When developing a disease management plan, it's important to understand that disease development requires three elements:

susceptible host + pathogen + environment favorable for disease = disease expression

A change in one of these factors can influence disease development (Figure 7). For example, selection of a wheat variety with high levels of resistance to head scab make it less likely to develop disease than a variety that is susceptible. Yet the environment can have a profound effect on disease development.

Cool wet conditions during flowering are ideal for the head scab pathogen to release spores and infect the head, as opposed to warm and dry conditions. And of course, the pathogen must also be present for disease to occur.

The *Fusarium* species that causes head scab overwinters well on corn stubble; so, planting wheat into corn stubble greatly increases the risk for head scab development.

In developing an integrated disease management plan all three of these factors should be considered as they will dictate disease potential and management choices.

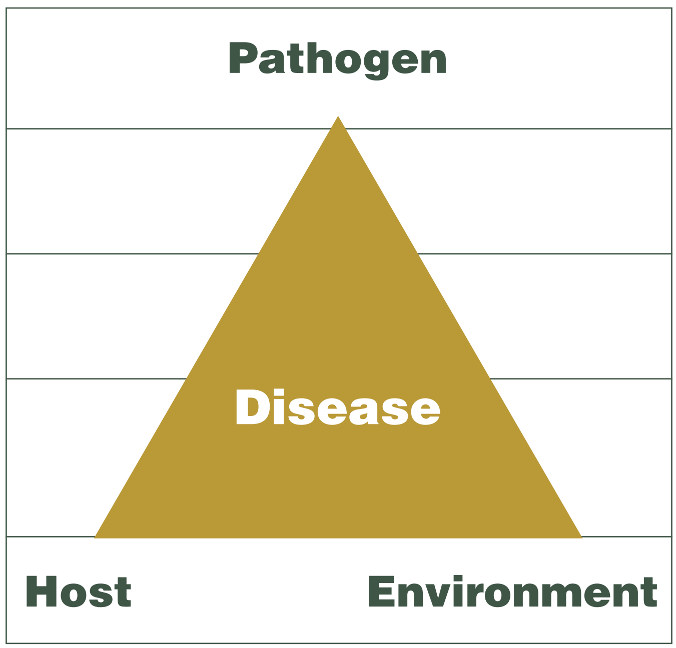

Figure 7. The plant disease triangle is a key concept in understanding disease development and management. The existence of disease by pathogen requires the interaction of a susceptible host, a virulent pathogen and an environment favorable for disease.

Managing seedborne, seedling diseases

Seed treatments are valuable for plant establishment, reducing the impact of soil-borne diseases. However, they also dramatically reduce the impact of seed-borne smuts, which historically caused tremendous yield and quality reductions.

A professional should apply seed treatments in a treatment facility to ensure complete coverage of the seed. The use of certified seed will also help reduce the chances that any seedborne pathogens are introduced with the seed.

Bacterial disease

Bacterial diseases such as bacterial mosaic, bacterial streak, black chaff and basal glume rot show symptoms on foliage or on heads late in the season, but have their beginnings in contaminated seed. Care should be taken to use disease-free seed.

Smuts and bunts of small grains

Seedborne smuts and bunts of grain may reduce yield dramatically and also result in rejection at the grain elevator. These diseases are relatively rare in Michigan, but do occur occasionally. Dwarf bunt (*Tilletia controversa*) and common bunt caused by *Tilletia caries* and *Tilletia laevis*, are soil borne fungi that cause "bunt balls" to produce in the head (Figure 8). These diseases cause a fish-like off-odor in harvested grain.

Tilletia fungi infect young plants and grow systemically in the plant, replacing tissue of the young ovary during seed development and filling the grain with teliospores. These spores then contaminate grain and soil, where they can survive for many years and initiate disease again.

Figure 8. Smutted wheat grain. Note that the ovary tissue of the seed is replaced by fungal spores.

Grain graders often refer to "stinking smut" meaning dwarf bunt or common bunt. Loose smut (*Ustilago tritici*) shares the smut common name but is a very different disease, causing yield losses but no effect on grain quality and does not produce the tell-tale odor.

It appears as though most seed treatments containing a triazole (DMI) fungicide are very effective against dwarf smut and common bunt, particularly if every kernel is completely covered by the treatment. However, 100% control is unrealistic and it may still be possible for some infections to occur.

Grain known to have stinking smut should not be used for seed. The use of certified seed will help ensure that the pathogen is not introduced with the seed.

The other potential source of infection will come from infested ground. The Tilletia controversa dwarf bunt pathogen in particular is able to survive in soils for several years. In addition, infested grain should not be used as cover crop seed as it can potentially increase the inoculum load in the field. Infected grain can be used as livestock feed. Grass weed species can be infected by species of Tilletia that cause smut/bunt issues, so wheat fields should be kept free from grass weed species.

Root and stem rots

There are a number of organisms that can cause root rot, foot rot or stem rot such as *Fusarium* spp., *Pythium* spp., and *Rhizoctonia* spp.. *Gaeumannomyces graminis* var. *tritici* is another organism that can cause a severe disease called take-all. Symptoms can suddenly appear at heading, when wheat plants begin dying prematurely and turn white.

Crop rotation is the most effective way to prevent and reduce take-all and other soilborne root and stem rots. Tillage can also reduce residue that may harbor these diseases. The MSU Plant and Pest Diagnostics Lab can aide in identification of root issues and provide more detailed recommendations.

Managing common fungal leaf diseases

Managing leaf (foliar) diseases is critical for Michigan growers who have set their sights on improving wheat yields. These fungal diseases can cause losses beginning in the early vegetative stages and extending through grain-fill.

The first rule is to scout, scout, scout! Knowing the growth stage and what disease pressure exists is essential to making the most profitable disease management decisions.

Varietal resistance is the first line of defense against diseases. *MSU's Wheat Performance Trial Report* provides information on each variety's susceptibility to common foliar diseases (http://varietytrials.msu.edu/wheat).

Cultural practices affect the development of diseases as well. For example, planting wheat following a small cereal grain can encourage fungal disease development.

In addition, excessive rates of nitrogen fertilizer can lead to overly dense, lush stands that tend to encourage leaf diseases.

Fungicide applications tend to be more cost effective where:

1) the variety is susceptible to the disease(s);
2) the disease is found at a relatively high level;
3) a damp weather pattern is predicted; and
4) the crop has a high yield potential.

The current fungicides available for wheat and their relative effectiveness are provided in Table 9 (p.24) and updates will be available at www.cropprotectionnetwork.org.

When attempting to manage wheat diseases, the priority should be to protect the flag leaf. This can be achieved by applying fungicide from the time the flag leaf emerges until early flowering. Strategically, there can be an advantage to waiting until the tail-end of this window when the first flowers (anthers) appear, as this can be effective timing for an application that targets both leaf diseases and Fusarium head scab (Figure 9). Where this strategy is employed, growers should consult Table 9 and ensure the fungicide is effective for head scab management (such as Prosaro, Caramba, Miravis Ace or Folicur).

Based on research in Michigan, this flowering application often results in yield protection of 5 bushels/acre or more due to suppressed leaf disease pressure (Figure 10). An exception to using a single application to manage head scab and leaf diseases is when a disease such as stripe rust has been detected. This fast-moving disease often requires a fungicide application to protect the flag leaf. Waiting until flowering may see rust levels explode and significant yield loss as seen in the 2016 stripe rust epidemic.

Disease Management Decision Tree

Full flag Feekes 9

- If significant foliar disease is present, consider a foliar fungicide to protect flag leaf, typical economic products such as twinline and folicur are listed in the Fungicide Efficacy table (p. 24).
- If no disease present, hold spray until head scab timing, which will also protect the flag leaf.

Boot Feekes 10

- Do not apply fungicides containing strobilurins at or after the boot stage as this can increase DON accumulation.

Beginning Flowering Feekes 10.5.1

- If scab risk factors are present make application from the beginning of flowering until 6 days after the beginning of flowering.
- Preference should be given to applying fungicides 4 days after the beginning of flowering as this results in the best scab reduction and DON suppression. Applying 4-6 days post flowering also widens the window of protection if an application was made at Feekes 9 (Zadoks39) to protect the flag leaf.

Figure 9. Decision tree for foliar fungicide applications.

Some growers are inclined to also use a fungicide at full-tillering under high-yield environments. With the inherent resistance levels of modern varieties, this early application is usually not cost effective. However, where this application may be warranted is where there is:

1) a lush stand of a variety particularly susceptible to powdery mildew and/or *Septoria* leaf spot;
2) scouting reveals unusually severe cases of fungal disease;
3) the fungicide only costs a few dollars per acre; or
4) the cost of an extra trip across the field can be avoided by combining with a predetermined herbicide application.

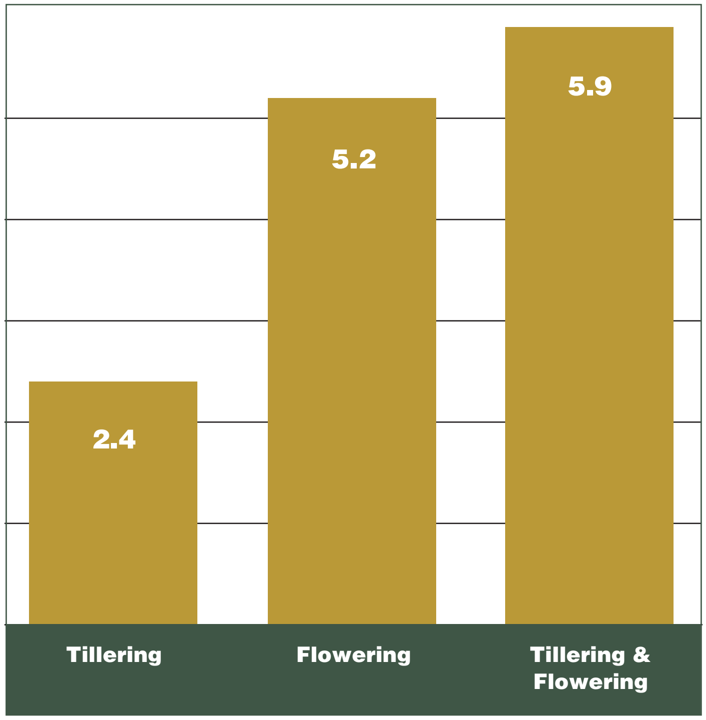

Figure 10. Chart illustrates the average yield response (bu/acre) to fungicide use across three years of a disease susceptible variety in Michigan's "thumb" region. The results suggest that, even in the absence of head scab, applications at flowering were most cost effective. It should be noted that in environments less favorable for disease or use of varieties with better resistance the chance of ROI is diminished.

Common wheat diseases visual guide

Leaf rust can survive Michigan winters to a limited extent, but most infections are due to spores that originated in Southern states and are blown here. This means disease development is usually delayed until after flag leaf emergence. Infections appear as reddish-orange spore masses on the upper surface of leaves. Leaf wetness and temperatures between 60-80°F promote its development.

Powdery mildew can often be found in fall or early spring, if conditions remain favorable it can eventually spread to the flag leaf and even the heads. The disease is favored by wet and cool temperatures (59-72°F), and humidity above 85%.

***Septoria* leaf spot** (also referred to as *Septoria tritici* blotch) is usually first seen in early spring as tiny yellow flecks on the lower leaves. It expands to become an angular patch, with tan to brown lesions containing black specks (pycnidia). As the season progresses, the disease can readily spread to the flag leaves in susceptible varieties. *Septoria* prefers wet and cool temperatures (50-68°F).

***Stagonospora* leaf blotch** has lesions similar to Septoria leaf spot, except they tend to be more lens-shaped, may have yellow halos, and its pycnidia are more brown in color. Unlike leaf spot, leaf blotch often spreads to wheat heads (called glume blotch). It is favored by wet conditions and warm temperatures (68-81°F).

Stripe rust may be able to survive Michigan winters, according to recent evidence. But typically spores originate in Southern states and blow here in the wind on storm fronts. Stripe rust pustules on young plants in early spring or late fall will tend to be light yellow in color and not in the typical stripe pattern. On older plants, the stripe rust pustules will form in stripes along the leaf.

There are a number of other foliar diseases occasionally found in Michigan wheat, including bacterial spot, tan spot and stem rust. See the American Phytopathological Society publication *A Farmer's Guide to Wheat Diseases* for a comprehensive list and www.cropprotectionetwork.org. Contact the Michigan Wheat Program office if you would like to receive a free hard copy.

Viral disease management

There are several viral diseases affecting wheat, including barley yellow dwarf and wheat streak mosaic.

An important management practice for virus prevention is controlling volunteer wheat that can act as a reservoir for virus particles and the insects that may carry them. Any volunteer wheat should be destroyed at least two weeks before emergence of the next crop, by tillage or herbicides.

Varietal resistance is also a key management strategy, take care to select varieties that list resistance to the virus prominent in your location or which have been seen in the field previously.

Managing Fusarium head blight

Fusarium head blight (FHB), commonly called scab, is the single most important wheat disease. Risk of the disease cannot be totally avoided, but knowledge of it, use of improved varieties and appropriately timed fungicides can substantially reduce the risk of financial losses to scab.

Figure 11. Fusarium head blight at varying levels of incidence on wheat spikes.

FHB can lead to a reduction in wheat yields. However, the greatest financial threat is when a mycotoxin called deoxynivalenol (DON or vomitoxin) is produced in FHB-infected kernels. Infected spikelets may appear bleached (Figure 11) and the kernels may be shriveled, lightweight and, sometimes, chalky-white or pink in color. It should be noted, however, that kernels might exhibit few to no visual FHB symptoms and still contain the pathogen and a significant DON level. If DON is a significant issue, the FHB management plan should be reevaluated, including variety selection and fungicide application.

Weather. The environment has the greatest influence on disease development. Damp conditions and moderately warm temperatures at the time of flowering are most advantageous to the pathogen. FHB is also favored by wet weather several days prior to flowering which encourages spore production and dissemination. Damp weather during grain fill favors both disease development and the production of DON.

A Fusarium head blight *FHB Risk Assessment Tool* (www.wheatscab.psu.edu), based on an FHB forecast model, is available to help assess local disease risk.

Variety Susceptibility. Wheat varieties vary significantly in their susceptibility to scab. Plant breeding efforts have significantly improved FHB resistance. In some cases, simply selecting a more FHB-resistant variety could potentially cut a field's FHB level in half. FHB and DON ratings are available at Michigan State University's annual variety performance report which may be accessed by clicking here. (https://varietytrials.msu.edu/wheat/). These sources also include ratings for foliar diseases.

Soft white and soft red wheat, as subclasses, are generally comparable in their susceptibility to FHB. However, soft white has a disadvantage in that the market is more sensitive to DON levels due to end-use requirements. While market discounts for DON vary, soft white wheat value is often docked when levels exceed 1 ppm, whereas discounts for soft red often begin at 2 ppm.

Management. Crop rotations matter, as residues from the previously infected crop can harbor *fusarium* and, thereby, increase the chance for infection. The greatest risk is associated with residue from corn and, to a lesser extent, wheat, barley and some hay crops. Using tillage to incorporate the residue from these crops will reduce the amount of inoculum generated within the field, although the risk of *fusarium* spores from outside the immediate field remains.

Fungicides such as Caramba, Miravis Ace and Prosaro, often reduce FHB severity by 50-60% and DON levels by 30-50%, although the actual reductions are highly variable. Conversely, the use of strobilurin fungicides (e.g., Quadris, Headline, Aproach), when used during heading stages, may lead to elevated DON levels. Using fungicides against FHB offers the additional benefit of reducing yield losses from foliar diseases (e.g., leaf rust and leaf spots).

Successful fungicide applications against FHB depend on the use of:

1) *Recommended fungicides.* Table 9 (p.24). To date, the most effective products are Prosaro, Caramba, Proline and Miravis Ace. Tebuconazole (sold under various product names) is less effective on FHB but, because of lower product cost, might be considered where the risk of FHB is relatively low and yet the threat of foliar diseases remains.
2) *Proper application timing.* For best results, apply fungicides for scab within 3-6 days following the beginning of flowering. Here, flowering is defined as 50% or more of heads have emerged anthers. Figure 12.
3) *Application adjustments:*
    a. Adjust boom height to target the wheat heads (generally 8-10 inches above heads);
    b. Use dual flat fan nozzles configured both forward and backward, and 30 degrees down from horizontal. A single, forward-directed spray may be sufficient at higher ground speeds;
    c. Select flat fan nozzles that provide a droplet size between a large fine to small medium (300-350 microns);
    d. Calibrate sprayer to deliver 10-15 gallons of volume/acre.

Figure 12. Anthers on wheat head at flowering.

At harvest. As grain begins to ripen and bleached spikelets become visible, it may be possible to get a sense of the amount of head scab in the field. However, visual head scab is not always a good predictor of final DON levels.

If a field has been identified to have head scab, combine settings can be adjusted in an attempt to remove scabbed kernels from the grain. Combine settings such as increased fan speeds may aid in discarding lighter weight scabbed kernels to reduce overall DON levels. Scab may also vary throughout a field. For example, field edges can flower earlier, leading to much higher or lower DON values. These portions of the field may be harvested separately to avoid contamination of low DON grain.

MSU Plant and Pest Diagnostics Lab - Free Analysis

To manage any disease it's essential to know the enemy! If in doubt as to the cause of a disease or disorder submit a sample of it to the MSU Plant and Pest Diagnostics Lab.

The Michigan Wheat Program has had a special relationship with the Lab since 2013, that allows farmers to submit samples free of charge to obtain a diagnosis of general crop health, a culture of fungal and disease pathogens, virus and nematode tests, and insect pest identification. Results and some crop improvement strategies are emailed directly to farmers for rapid implementation.

Visit the Michigan Wheat Program's website under Farmer Perks for sample submittal directions and forms, as well as a video by Dennis Pennington on good sample collection. miwheat.org/farmer-perks/wheat-diagnostics/

Table 9: Fungicide Efficacy for Control of Wheat Diseases
The North Central Regional Committee on Management of Small Grain Diseases (NCERA-184) has developed the following information on fungicide efficacy for control of certain foliar diseases of wheat in the US. The fungicide efficacy ratings were determined by field testing the materials over multiple years and many locations.

Efficacy is based on proper application timing to achieve optimal effectiveness of the fungicide as determined by labeled instructions and overall level of disease in the field at the time of application. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and are based on a single application at the labeled rate listed. Table 9 (p.24) includes most widely marketed products, and is not intended to be a list of all labeled products.

For updates see www.cropprotectionnetwork.org.

Table 9. Efficacy of fungicides for wheat disease control based on appropriate application timing Fungicide(s)

	Fungicide(s)	
Class	Active ingredient	Product
Strobilurin	Picoxystrobin 22.5%	Aproach SC
	Pyraclostrobin 23.6%	Headline SC
Triazole	Metconazole 8.6%	Caramba 0.75 SL
	Tebuconazole 38.7%	Folicur 3.6 F[5]
	Prothioconazole 41%	Proline 480 SC
	Prothioconazole19% Tebuconazole 19%	Prosaro 421 SC
	Propiconazole 41.8%	Tilt 3.6 EC[5]
Mixed modes of action[6]	Tebuconazole 22.6% Trifloxystrobin 22.6%	Absolute Maxx SC
	Cyproconazole 7.17% Picoxystrobin 17.94%	Aproach Prima SC
	Prothioconazole 16.0% Trifloxystrobin 13.7%	Delaro 325 SC
	Pydiflumetofen 13.7% Propiconazole 11.4%	Miravis Ace SE
	Fluxapyroxad 2.8% Pyraclostrobin 18.7% Propiconazole 11.7%	Nexicor EC
	Fluoxastrobin 14.8% Flutriafol 19.3%	Preemptor SC
	Fluxapyroxad 14.3% Pyraclostrobin 28.6%	Priaxor
	Propiconazole 11.7% Azoxystrobin 13.5%	Quilt Xcel 2.2 SE[5]
	Prothioconazole 10.8% Trifloxystrobin 32.3%	Stratego YLD
	Benzovindiflupyr 2.9% Propiconazole 11.9% Azoxystrobin 10.5%	Trivapro SE
	Flutriafol 18.63% Azoxystrobin 25.30%	Topguard EQ

[1] Efficacy categories: NL=Not Labeled; NR=Not Recommended; P=Poor; F=Fair; G=Good; VG=Ver
[2] Product efficacy may be reduced in areas with fungal populations that are resistant to strobilurir
[3] Efficacy may be significantly reduced if solo strobilurin products are applied after stripe rust infe
[4] Application of products containing strobilurin fungicides may result in elevated levels of the my
[5] Multiple generic products containing the same active ingredients also may be labeled in some s
[6] Products with mixed modes of action generally combine triazole and strobilurin active ingredier
[7] Based on application timing at the beginning of anthesis (Feekes 10.5.1)

Rate/A (fl. oz)	Powdery mildew	Stagonospora leaf/glume blotch	Septoria leaf blotch	Tan spot	Stripe rust	Leaf rust	Stem rust	Head scab[4]	Harvest Restriction
6.0 – 12.0	G[1]	VG	VG[2]	VG	E[3]	VG	VG	NL	Feekes 10.5
6.0 - 9.0	G	VG	VG[2]	E	E[3]	E	G	NL	Feekes 10.5
10.0 - 17.0	VG	VG	—	VG	E	E	E	G	30 days
4.0	NL	NL	NL	NL	E	E	E	F	30 days
5.0 - 5.7	—	VG	VG	VG	VG	VG	VG	G	30 days
6.5 - 8.2	G	VG	VG	VG	E	E	E	G	30 days
4.0	VG	VG	VG	VG	VG	VG	VG	P	Feekes 10.5.4
5.0	G	VG	VG	VG	VG	E	VG	NL	35 days
3.4 - 6.8	VG	VG	VG	VG	E	VG	—	NR	45 days
8.0	G	VG	VG	VG	VG	VG	VG	NL	Feekes 10.5 35 days
13.7	VG	VG	VG	VG	VG	VG	VG	G7	Feekes 10.5.4
7.0 - 13.0	VG	VG	E	E	E	E	VG	NL	Feekes 10.5
4.0 - 6.0	—	—	VG	VG	E	VG	—	NL	Feekes 10.5 40 days
4.0 - 8.0	G	VG	VG	E	VG	VG	G	NL	Feekes 10.5
10.5 - 14.0	VG	VG	VG	VG	E	E	VG	NL	Feekes 10.5.4
4.0	G	VG	VG	VG	VG	VG	VG	NL	Feekes 10.5 35 days
9.4 - 13.7	VG	VG	VG	VG	E	E	VG	NL	Feekes 10.5.4
4.0-7.0	VG	NL	VG	VG	E	E	VG	NL	Feekes 10.5.4 30 days

ry Good; E=Excellent; — = Insufficient data available
n fungicides.
ection has occurred.
cotoxin deoxynivalenol (DON) in grain damaged by head scab.
states.
nts. Miravis Ace, Nexicor, Priaxor and Trivapro include carboxamide active ingredients.

Wheat Insect Management

Dr. Chris DiFonzo, *Professor and Field Crops Entomologist*
Department of Entomology, Michigan State University

Because insect pressure in Michigan wheat is sporadic and varies from year to year, so scouting is important to identify any fields which are over threshold. Three common insects in Michigan wheat are discussed below. Additional information on insect pests of wheat and their management can be found on the MSU Field Crop Entomology website at https://www.canr.msu.edu/fieldcropsent/extension/.

True armyworm

True armyworm (or simply armyworm) is the most common caterpillar infesting wheat in Michigan. Armyworm does not overwinter in Michigan. Moths colonize the state from the south each season, so infestations are sporadic, varying from year-to-year and field-to-field. Moths are attracted to areas of dense grassy vegetation for egg laying, including wheat and other small grains, ditch banks, turf, grass hay and weedy areas in crop fields.

Identification. Full grown larvae are 1.5 or more inches in length, with stripey bands of brown, tan, white and orange. Each proleg has a distinct black bar. The brown head capsule has a net-like, reticulated pattern (Figure 13).

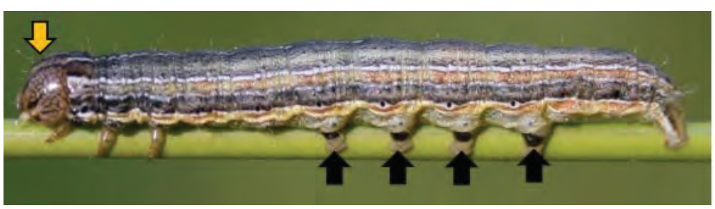

Figure 13. An armyworm, with distinctive bars on its prolegs and a reticulated head capsule. (picture taken by S. Gower)

Signs of Infestation. Small armyworms initially feed on leaves, moving up the plant and consuming more as they grow. Large larvae defoliate plants, in severe cases stripping the plant up to and including the flag leaf (Figure 14). Larvae sometimes clip leaves and grain heads, and these litter the ground between rows (Figure 14). Cylindrical frass (excrement) pellets on the ground are another sign that armyworms are present. On sunny days, the larvae usually hide at the base of plants, so these signs of infestation are an important clue to look for larvae on the ground.

Figure 14. Left, a field stripped of all leaves by armyworm. Middle, an armyworm just finished chewing through a stem and clipping a head. Right, clipped heads and larvae on the ground.

Because populations vary considerably from year to year and field to field, checking wheat stands for small caterpillars and their leaf feeding is key to protecting yield, because smaller larvae are easier to control. In the last few larval stages larvae do the most feeding and damage, especially head clipping. A field that looks fine from the road can seemingly be defoliated or clipped overnight, as big larvae become common. Scouting involves examining plants, but more importantly the ground, to find and count larvae.

Treatment thresholds.

Before heading: 4 or more larvae per square foot
At heading: 2 or more larvae per square foot

Treatment tips.

- Protect the flag leaf from defoliation. But if the flag leaf is gone, it may still be worth treating if the stem is still green and photosynthesizing to fill the head. It may also be worth treating if heads are being clipped.
- If possible, spray later in the day. Larvae will crawl across the freshly-treated surface that evening as they climb plants to feed.
- In a thick canopy, coverage may be difficult. Aerial application sometimes fails to drive product down into the canopy, whereas a ground rig may have better luck. However, better coverage is balanced by yield loss from wheel tracks in the field.
- Know your preharvest intervals (PHIs). They can range from 7 to 30 days depending on the insecticide.
- Know your crop. While there are many insecticides registered for wheat, some products cannot be used on barley, oats, or rye.
- If armyworms are marching out of a field towards another wheat or corn field, a barrier treatment is a cost effective way to stop the movement. Note that soybeans are a non-host and do not need to be protected.
- If larvae are already large (over 1.5 inches), they are ready to pupate and will stop feeding shortly. Spraying probably will not pay at this point.

Cereal leaf beetle

The cereal leaf beetle (CLB) is a native of Europe. It was first found in North America in Berrien County, Michigan, in 1962. After its introduction, CLB was a key pest of small grains until the USDA and land grant universities released several parasitoids in the 1970s. These natural enemies controlled CLB in many parts of the Midwest, so it became a non-issue for most growers. However, in the last few years CLB numbers seem to be trending upward, suggesting that this biocontrol is being disrupted, possibly because of the trend to add an 'insurance' insecticide to fungicide applications on wheat.

Life cycle. CLB adults are distinctive, with dark-blue wing covers, a red thorax and reddish legs (Figure 15). They overwinter in crop residue and along field edges under tree bark or vegetation. Beetles emerge in late March-April to feed on grasses. In late April-May, females lay 1-2 eggs at a time on the upper leaf surface of small grains. They prefer younger grasses, so infestations in oats and spring wheat tend to be greater than in winter wheat. Larvae are yellow, fat and hump-backed, but appear black and slimy because of a unique defense mechanism: a fecal shell covering the body (Figure 15). This slimy covering reduces water loss and deters predators.

Figure 15. Cereal leaf beetle adult (top) and a larva covered with feces (bottom).

Larvae pupate underground in late May-June for 2-3 weeks. New adults emerge in June. They briefly feed on grasses, small grains, or corn, but move to field edges to spend the rest of the summer in an inactive state. They overwinter in the same locations. Thus, there is only one generation per year, with larval damage occurring in May and June.

Signs of Infestation. Larvae feed for 2-3 weeks, with peak populations occurring in late-May into early June. Larvae feed by scraping the leaf surface (Figure 16); when defoliation is severe, plants or parts of fields appear white or frosted. Larvae do not feed on the grain head directly, but damage to the flag leaf after boot stage reduces grain fill. While severe defoliation across an entire field is rare in Michigan, hot spots can be impressive. Infestations tend to be greater along field edges and near tree lines where adults overwintered.

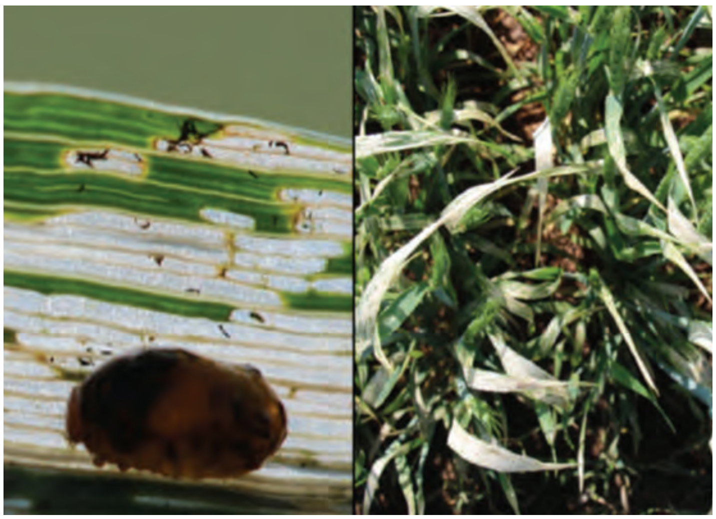

Figure 16. Leaf scraping by a CLB larva (left) can result in a frosted appearance of the canopy (right)

Treatment thresholds. Early-season (to reduce general defoliation): 3 or more eggs or larvae per stem
At heading (to protect the flag leaf): 1 larva per flag leaf

Treatment tips.

- CLB larvae feed on upper leaves, thus exposure to insecticide isn't a problem.
- If an infestation coincides with disease pressure, most insecticides can be tank-mixed with fungicides. However, conventional insecticides sprayed for CLB kill beneficial insects, including the parasitoids specific to CLB. Do not add an insecticide to a fungicide spray simply as a form of insurance.
- Since infestations typically start at the field edge, it is often possible to treat only the part of the field over-threshold. This balances the need to treat with preserving the local parasitoid population.

Aphids

Aphids are typically first detected in wheat fields in late April or early May. By June, three different species are common. These same species infest corn, sorghum and grasses along field margins. Most do not overwinter in Michigan. *Oat bird-cherry aphid* is usually the first species to colonize fields in April or early May. It is olive green with a rusty-orange patch on its butt-end (Figure 17), visible with the naked eye. It may overwinter in Michigan in the egg stage, which could explain why it is typically found so early. *English grain aphid* colonizes Michigan from the south in mid-May, in the same timeframe as armyworm. It is a large green aphid with long black cornicles ('tailpipes') and long legs (Figure 17). It is common in Michigan wheat fields. *Corn leaf aphid* is blue-green, with short black cornicles and short antennae (Figure 17). It is less common in wheat, but it is the primary species infesting Michigan corn fields.

Signs of Infestation. Aphids feed by sucking juices from the phloem cells of plants. A few aphids per tiller do not cause a problem, and there are no obvious signs or symptoms of infestation other than the aphids themselves. A heavy infestation can stress plants by removing water and nutrients, but this type of damage is rare in Michigan wheat because fields rarely reach threshold. This is because beneficial insects such as lady bugs, lacewings, and syrphid flies tend to be

Figure 17. Aphids in Michigan wheat: oat bird-cherry (left), English grain (middle) and corn leaf (right)

present. In fact, natural enemies in Michigan field crops often build first in wheat fields, largely by consuming aphids, before moving into neighboring crops later in the season.

The three species discussed here can transmit barley yellow dwarf virus (BYDV) in wheat, barley and oats. Transmission in the fall is more important than transmission in late spring, because the virus infects the plant for a longer time period. For fall transmission, the virus source likely is grasses outside the field. Once wheat is heading, the impact of BYDV is negligible. Rates of BYDV infection tend to be low in Michigan compared to states to the south, because aphids do not survive freezing temperatures in the fall. Wheat is typically planted after the Hessian fly-free date when grain aphid populations are already declining. Cold weather wipes out aphids so that very little transmission takes place during the winter months, and new aphids must recolonize in the spring.

Treatment thresholds.

A direct sampling method of determining treatment involves recording the number of aphids per tiller on 100 tillers, then calculating the average. The aphid species does not matter, only the number per stem. This method can be used in the fall or in spring as aphids are colonizing fields, but before heading. The threshold is 12 or more aphids per tiller.

A presence/absence sampling method involves determining the number of tillers with at least one aphid (= presence). Aphid species does not matter. The total number of aphids per tiller does not matter, only the presence or absence of aphids. The advantage of presence/absence sampling is that a quick decision can be made in fields with very low or very high aphid populations. Presence / absence sampling starts with picking 25 tillers, determining how many are infested, then consulting a decision table (Table 10). In this first round of sampling, if 18 or fewer tillers are infested, stop sampling and scout again in a week the field is below threshold. If 25 (100%) of the tillers are infested, stop sampling; the field is over threshold and a spray might be justified. But if 19 to 24 tillers are infested, a decision isn't clear and more information is needed. Five more tillers must be picked and examined. Now the decision is based on the second line in the table for 30 total tillers. Sampling of groups of 5 tillers continues until a decision is reached or a maximum of 100 tillers are examined.

Table 10. Presence/ absence decision table for aphids in wheat.

	Cumulative number of infested tillers:		
Total number of tillers examined	Stop sampling: Do Not Spray	Keep sampling: Pick 5 more tillers	Stop sampling: Spray
25	< 18	19 - 24	25
30	< 22	23 - 29	30
35	< 27	28 - 34	35
40	< 31	32 - 39	40
45	< 35	36 - 43	44 - 45
50	< 40	41 - 48	49 - 50
55	< 44	45 - 53	54 - 55
60	< 48	49 - 58	59 - 60
65	< 53	54 - 62	63 - 65
70	< 57	58 - 67	68 - 70
75	< 61	62 - 72	73 - 75
80	< 66	67 - 77	78 - 80
85	< 70	71 - 81	82 - 85
90	< 75	76 - 86	87 - 90
95	< 79	80 - 91	92 - 95
100	< 84	84-100 Tillers = treat	

Wheat Harvest

Dennis Pennington, *wheat specialist, Michigan State University*

Physiological maturity is the point at which the grain fill period ends and dry down begins. It is also the point at which no additional grain yield will accumulate. Physiological maturity is when the peduncle (stem just below the head) starts to turn yellow (see Figure 19). Grain moisture at this stage is around 35-40%. It usually takes 10-14 days to dry down for harvest, depending on weather conditions.

Figure 19. Progression of wheat towards physiological maturity. The stem below the head (peduncle) on the left is still green and grain fill is still occurring. The head on the right has reached maturity and the end of the grain fill period.

This is a good time to go and scout your fields. Check for Fusarium head blight (head scab). Make note of which fields and which varieties are the most infected. Check the lower leaves in the canopy for disease. Assess the level of lodging and potential lodging. These notes will help you to make decisions about what fields to harvest first and also for variety selection for next year's crop.

Harvest considerations

Here are a few harvest suggestions:

1. Harvest fields with the highest lodging potential first. Check headlands and places where N overlap can occur for signs of lodging.
2. In fields where varieties were planted that are susceptible to Fusarium head blight and you have found infection – start harvesting these fields at 20% moisture, turn the fan speed up on the combine to blow shriveled/scabby kernels out the back and dry the grain. Some elevators will pay the drying charge if you start harvest early as that will increase grain quality.
3. Be sure to calibrate your yield monitors using the multi-point calibration. While this does take some time, it will provide you with much higher quality yield maps that you can use to make other decisions on your farm such as variable rate nutrient application. Monitors should be calibrated once per year for each crop. www.canr.msu.edu/news/yield_monitor_calibration_procedure provides the steps necessary to do this.
4. Last, and most important – be safe. Accidents happen when we rush to get our work done. Take the time necessary to be safe and teach your kids and employees how to safely operate your equipment. Tragedy can happen in a split second: don't let it happen to your family.

Harvesting straw

Baling wheat straw is becoming more and more popular in Michigan. Much of the straw harvested in Michigan is used as bedding for livestock. Dairy farms are increasingly using straw as a fiber source in cattle rations. Many wheat growers are now selling wheat straw as a secondary income stream from the wheat crop.

Straw Yields

Biomass yield for straw is dependent upon a number of factors including variety, fertility, rainfall/irrigation, temperature, soil type, weed pressure, combine header cutting height and varies between fields and from year to year. A good long-term average is 1 ton of dry matter/acre per year. This can range from 0.5-2.0 tons of dry matter/acre based on variety, weather and combine harvest conditions.

Straw Value

The value of straw varies with normal market conditions and is strongly influenced by supply/demand. Areas of the state with a large concentration of dairy cattle tend to have higher prices. Areas of the state with low wheat acreage also drive local prices higher.

When valuing wheat straw, two things must be considered:

1) value of the fertilizer nutrients being removed with the straw and
2) value of the potential organic matter contribution to the soil.

One ton of dry matter wheat straw removes 14 pounds of nitrogen, 6 pounds of phosphate and 29 pounds of potassium/acre. Current nutrient prices can be obtained from a local elevator, but if we assume the following: $0.50/pound N, $0.40/pound phosphate (P) and $0.45/pound potassium (K), then removing and selling 1 ton of wheat straw would require $22.45/acre [Math = (14x0.50)+(6x0.40)+(29x0.45)] plus the application cost to apply the nutrients. This does not take micronutrients into account.

From personal communications with farmers plus past experience purchasing straw from wheat growers, straw prices in the field range from $60-$75/ton of straw. In the last 10 years, straw prices have increased steadily.

Michigan Wheat-the importance of our crop

Michigan is a strong wheat production state. In fact, Michigan usually ranks about 10th in wheat production nationally, which is remarkable given that wheat is produced in 42 of the 50 states.

One advantage for Michigan wheat farmers is being in the Great Lakes growing region. There are times when the weather is a challenge, but overall, the climate is well suited for wheat production. Michigan's record yield is an average of 89 bushels per acre, set in 2016. Compare that with the US record average production of 50 bushels per acre set in 2016.

Michigan's current average production is about 500,000 acres planted annually which yields about 34 million bushels.

Six classes of wheat are grown in the US. Michigan is one of the few areas left with a strong white winter wheat presence. While the white wheat presence is very strong, Michigan is now primarily a red wheat state. This is a flip from more than 10 years ago when Michigan farmers were 60-70% white wheat and 30-40% red wheat.

Many other white wheat growing areas such as Ontario and New York have lost most of their white wheat production as red wheat has gained those acres.

Michigan white and red wheat are used primarily in cookies, cakes, cereals, pastry, donuts, crackers and as a thickening agent. The wheat for pasta and bread, which many people think of when you mention wheat, is a different variety and is grown in the Western states.

In addition to a good growing climate, Michigan wheat farmers also benefit from close proximity to many wheat millers, processors and end markets. Michigan is home to six major wheat millers along with several value-added processors that need wheat to make cereals, crackers and other baked goods.

Michigan has a long history of wheat production and that legacy is standing strong. As new information and innovations come to the market-place and the farm field, our future is as bright as our history is long.

Check out more about wheat from the Michigan Wheat Program and MSU Extension by following us, watching us or liking us!

Michigan Wheat

MSU Extension Field Crops

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