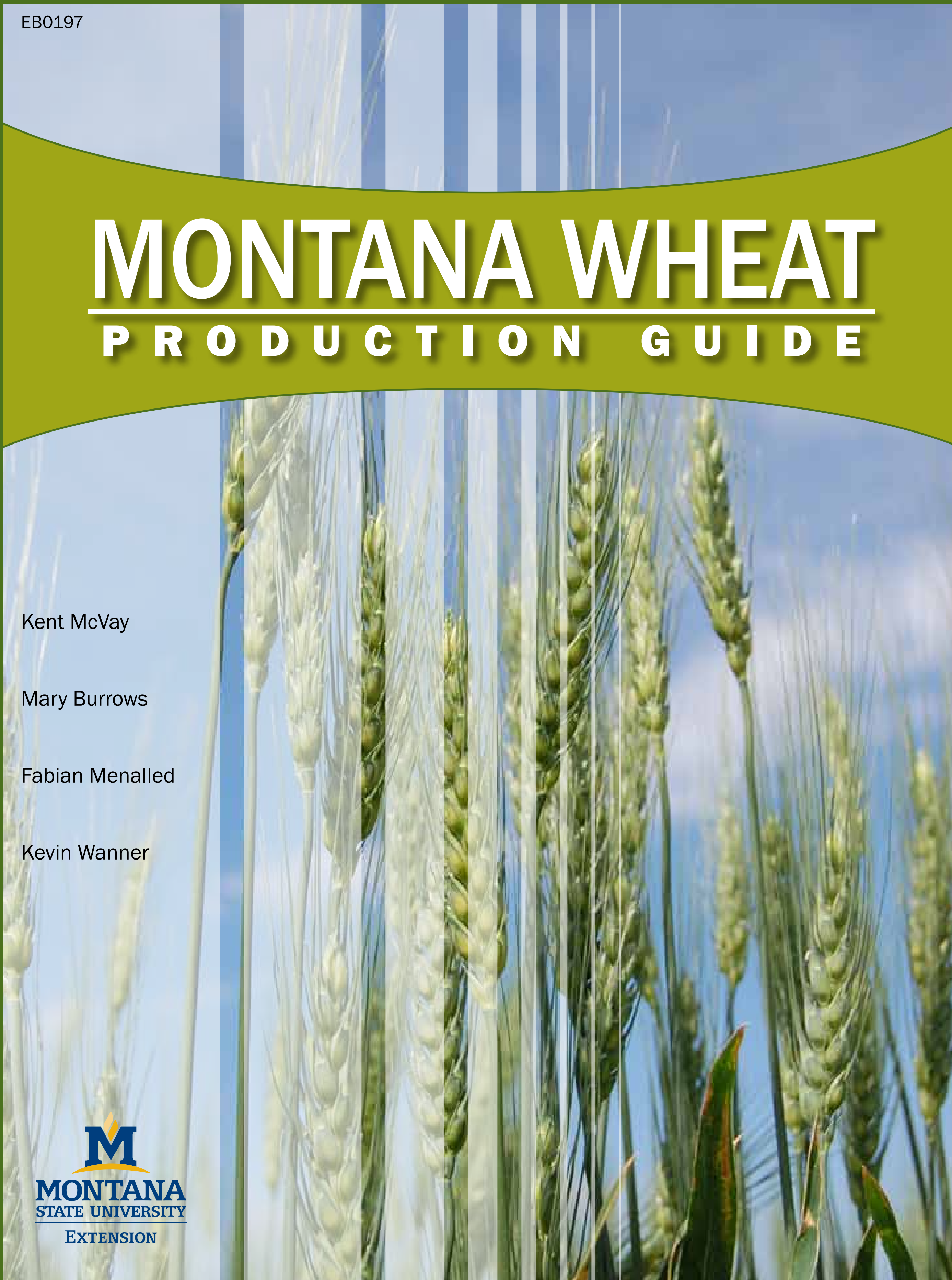
EB0197

MONTANA WHEAT

PRODUCTION GUIDE



Kent McVay

Mary Burrows

Fabian Menalled

Kevin Wanner

MONTANA STATE UNIVERSITY
EXTENSION

Cereal Grain Development Scales

Growth Stage	Description	Zadoks	Feekes	Haun
Germination	Dry seed	00		
	Start of imbibition	01		
	Imbibition complete	03		
	Radicle emerged	05		
	Coleoptile emerged	07		
	Leaf at coleoptile tip	09		0.0
Seedling Growth	First leaf through coleoptile	10	1	
	1st leaf unfolded	11		1.+
	2 leaves unfolded	12		1.+
	3 leaves unfolded	13		2.+
	4 leaves unfolded	14		3.+
	5 leaves unfolded	15		4.+
	6 leaves unfolded	16		5.+
	7 leaves unfolded	17		6.+
	8 leaves unfolded	18		7.+
	9 or more leaves unfolded	19		
Tillering	Main shoot only	20		
	Main shoot and 1 tiller	21	2	
	Main shoot and 2 tillers	22		
	Main shoot and 3 tillers	23		
	Main shoot and 4 tillers	24		
	Main shoot and 5 tillers	25		
	Main shoot and 6 tillers	26	3	
	Main shoot and 7 tillers	27		
	Main shoot and 8 tillers	28		
	Main shoot and 9 or more tillers	29		
Stem Elongation	Pseudo stem erection	30	4-5	
	1st node detectable	31	6	
	2nd node detectable	32	7	
	3rd node detectable	33		
	4th node detectable	34		
	5th node detectable	35		
	6th node detectable	36		
	Flag leaf just visible	37	8	
	Flag leaf ligule/collar just visible	39	9	

Growth Stage	Description	Zadoks	Feekes	Haun
Booting	Boot Initiation	40		
	Flag leaf sheath extending	41		8-9
	Boots just swollen	45	10	9.2
	Flag leaf sheath opening	47		
	First awns visible	49		10.1
Inflorescence Emergence	First spikelet of inflorescence visible	50	10.1	10.2
	¼ of inflorescence emerged	53	10.2	
	½ of inflorescence emerged	55	10.3	10.5
	¾ of inflorescence emerged	57	10.4	10.7
	Emergence of inflorescence complete	59	10.5	11.0
Anthesis	Beginning of anthesis	60	10.51	11.4
	Anthesis half-way	65		11.5
	Anthesis complete	69		11.6
Milk Development	Kernal watery ripe	71	10.54	12.1
	Early milk	73		13.0
	Medium milk	75	11.1	
	Late milk	77		
Dough Development	Early dough	83		14.0
	Soft dough	85	11.2	
	Hard dough	87		15.0
Ripening	Kernel hard (difficult to divide by thumbnail)	91	11.3	
	Kernel hard (no longer dented by thumbnail)	92	11.4	16.0
	Kernel loosening in daytime	93		
	Overripe, straw dead and collapsing	94		
	Seed dormant	95		
	Viable seed giving 50% germination	96		
	Seed not dormant	97		
	Secondary dormancy induced	98		
	Secondary dormancy lost	99		

Modified from Growth Staging of Wheat, Barley and Wild Oat

Preface

The intent of this publication is to provide current information on wheat production for producers within the state of Montana. The authors have attempted to provide all the basic information necessary for the establishment and management of a wheat crop. More detailed information can be found on certain topics by following the links to the referenced web sites. If you are viewing this document online, all links should be live and documents or web sites can be accessed directly. Hard copies of many of the references in this publication are available through MSU Extension Publications, as well as through your local county Extension office. ©2010

Editor

Kent A. McVay, assistant professor and extension cropping systems specialist, Department of Research Centers, Montana State University, located at the Southern Agricultural Research Center, Huntley, MT.

Contributing Authors

All authors are faculty members of Montana State University. Kent McVay is the principle author, assisted by Mary Burrows, an assistant professor and extension plant pathology specialist in the department of Plant Sciences and Plant Pathology; Fabian Menalled, an assistant professor and cropland weed specialist in the Department of Land Resources and Environmental Sciences; and Kevin Wanner, an assistant professor and extension entomology specialist in Plant Sciences and Plant Pathology.

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Designed by Sara Adlington and David Ashcraft of Montana State University Extension.

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Introduction

Nearly six million acres of wheat is harvested annually in Montana, representing a market value greater than $1 billion. For the past 10 years approximately 56 percent of this acreage was spring wheat, 33 percent winter wheat, and the remainder was durum. For the past decade, winter wheat acreage has increased at the expense of spring wheat. Montana provides an excellent environment for growing wheat as evidenced by our reputation for producing a high protein product.

Experienced wheat growers may not think they need a comprehensive production guide, but access to a quality reference helps both new and experienced growers and agricultural specialists provide science-based advice when time is short and a management decision must be made. Our goal with this publication is to provide answers and connect you to other relevant literature for further information.

Growth and Development

Wheat is an annual grass with both winter hardy and spring cultivars developed for production in Montana. Winter wheat generally has greater yield potential than spring wheat, especially when moisture is adequate. Yields reported by National Agricultural Statistics Service (Anonymous) for the past 10 years (2000-2009) show spring wheat averaged 25 bu/acre while winter wheat averaged 36 bu/acre, statewide. As a general rule, in any given year spring wheat yield will be about two-thirds that of winter wheat. In years like 2001, where environmental conditions were less than ideal, yields of spring and winter cultivars may be nearly equal.

In Montana, winter wheat is more likely to be grown following fallow than spring wheat. For some regions of the state like the northeast, it is difficult for winter wheat to survive due to low winter temperatures. A significant acreage of durum wheat is produced in Northeast Montana where breeding efforts, industry, and sufficient summer rains have historically supported this crop.

It is important to understand growth and development of the wheat plant in order to correctly use fertilizers, plant growth regulators, and pesticides for crop production. Many pesticide labels restrict application to when the crop is at certain growth stages referred to either Feekes or Zadoks growth scales (see front inside cover). Applications of nutrients, herbicides, plant growth regulators, fungicides, and irrigation water should be based on the stage of crop development rather than calendar dates. Poor timing of these operations can reduce effectiveness or result in crop injury and yield loss. Crop growth rates will vary depending on variety, planting date, and growing conditions, including nutrient and water availability.

Variety Selection

One of the most important management decisions a producer makes is the choice of variety. Take for example the 2009 variety performance evaluations. In these trials the top winter wheat variety yielded 150 percent more than the lowest yielding variety averaged across 17 locations. This implies that for the same management, choosing the right variety for your specific environment can result in half again as much yield as growing the wrong one. Montana State University has long-standing breeding programs for winter and spring wheat. Each program conducts replicated trials across the state at each of the Agricultural Research Centers. Results are published annually by the Agricultural Experiment Station, as Annual Performance Evaluation and Recommendations which are available through the Department of Plant Sciences and Plant Pathology. Results for all these trials are also compiled into an online database that can be accessed on the web at Variety Trial Selection Tool for Montana.

Choosing the right variety requires more than just choosing last year's local top yielder. Select a variety that yields well across many environments. Look for a variety that places in the top 5 percent over multiple years at one location, or for a variety that is in the top tier for one year over many locations. Both year and location can be considered different environments. Choose a variety that shows consistency in yield where the environments have varied by as much as the environment where you farm.

Yield is only one parameter to evaluate. In Montana's Golden Triangle region, spring wheat can be very susceptible to sawfly damage. Where sawfly pressure is high, our current best management recommendation is to grow a solid-stem or semi-solid stem variety of wheat to provide some resistance to damage. Use the variety selection tool to 'drill down' to just those varieties with some measure of solid stemness, and pick a better yielding variety from those solid stem varieties that have been evaluated.

Winter wheat varieties vary in their tolerance to frost and winter kill. If significant winter kill occurs some years where you farm, this may be an important characteristic to evaluate. Winter wheat variety descriptions include a winter hardiness score. Use this parameter in concert with yield potential to help you decide on the right variety for your operation.

An increasing number of herbicides are being labeled for control of downy and Japanese brome in winter wheat. These herbicides have specified conditions for use to insure winter wheat tolerance and effective control of the annual bromes. 'Clearfield' wheat varieties are specifically bred for tolerance to the herbicide Beyond (imazamox). For fields infested with downy brome, using a 'Clearfield' wheat may be the best option to regain control of this pest.

A significant effort goes into developing and maintaining disease resistance in cereal grain varieties. Often diseases require specific environmental conditions to grow. These conditions are not common across all diseases. Therefore cereal cultivars rarely have a high degree of resistance against all diseases pertinent to an area. If you have had particular fields where a wheat disease has severely impacted yield, you may want to use disease resistance ratings as part of your selection criteria when choosing a new wheat variety.

The important point to remember is that variety development continues today with new varieties released each year. Over the years, yield levels have steadily increased, end use qualities have been improved, and pest resistances broadened through efforts of breeders. If you haven't changed varieties for several years, you should compare how your variety is faring in these trials. Evaluate the new varieties that are available and if the time is right, upgrade your variety.

Tillage

Wheat can be successfully produced under any tillage system. As no-till and reduced till systems have become the norm for Montana dryland wheat production, the questions have changed from "Will using no-till reduce my yield?" to "Will an occasional tillage operation improve my wheat yield?" The benefits of reduced till systems include: lower labor and fuel costs, reduced soil loss from wind and rain, less time in the field, and more efficient use of stored soil moisture. The trade-off is a greater need for herbicide use, greater potential for disease or insect damage when in continuous cereal production systems, and more expensive planting equipment.

In most instances the benefits of no-till systems outweigh the costs. Comparing overall herbicide programs of no-till and conventional till systems reveals that the increased cost in a no-till system occurs primarily during the fallow period, as in crop herbicide use in each tillage system is likely to be similar. Risk of greater disease or insect pressure in no-till can be offset by adopting appropriate crop rotations and by choosing varieties with better disease and insect resistance. And finally, the cost of replacing planting equipment is one that all producers must address at some point if they continue to farm. When the time comes to replace your grain drill, consider choosing equipment that provides you with greater ability to seed in diverse and difficult seedbeds, has more choices in fertilizer placement, and provides greater ease in seeding rate calibration. Choose equipment capable of no-till seeding to increase your management options.

In irrigated wheat production, the high levels of straw associated with greater yields must be managed in order to prepare the field for the next crop. Options include tillage, either by plowing or with multiple disk ripping passes, or baling or burning the straw. When the straw is to be left on the field and worked into the soil, short-statured semi-dwarf varieties should be utilized to reduce straw bridging in equipment. Also, there are varietal differences for straw persistence. Harvest equipment can be equipped with straw choppers to accelerate straw break down. Annual burning of straw is not considered a sustainable practice as soil organic matter content will decline under sustained burning. If irrigation is by flood, removal of most of the previous crop residue is necessary to ensure good irrigation water distribution.

Tillage is not necessary for optimum crop growth in any production system, but it may be necessary for management of crop residues to ensure the successful establishment of a next crop. Tillage can be used as a management tool to bury crop residues for disease control, but in most cases, rotating crops to break the disease cycle can accomplish the same result with a better economic outcome.

Planting Dates and Rates

Winter wheat should be planted early enough in the fall as to have four to six weeks of growth prior to dormancy. This provides ample time for plants to establish a root system and produce tillers. Tillers will form during the fall, but produce most of their growth in the spring. Planting too early can result in rank growth in the fall, increase the potential for the infestation by diseases dependent on a "green bridge" for spreading, and inefficient water use that can leave the crop more susceptible to winter kill. Planting too late can result in small plants with few tillers and shallow root systems that place the wheat plant at risk to winter kill. However, dormant seeding is a viable practice for winter wheat in some environments and may be the ideal method in some situations.

For dryland winter wheat, a planting rate of 40 to 60 lbs/acre (15 to 21 seeds per square foot) of pure live seed (PLS) is usually sufficient to establish the crop. In high residue no-till systems, planting 60 to 80 lbs/acre PLS is recommended to compensate for some poorly placed seeds that won't germinate. Seeding rate should be increased if seeding is delayed past optimum period to compensate for the reduced opportunity of tillering. As a rule, don't drill if the seedbed is still green. First either spray or harrow the field prior to planting so that the seedbed is weed-free. Try to plant into moisture. Seeds should be placed at least 1 inch below the surface, but if moisture is deeper, set your drill to place seeds up to 3 inches deep. It's best to plant into moisture to get the crop established on time rather than to drill into dry soil and be dependent on subsequent precipitation to establish the crop. If time is running out, wheat can be successfully dusted in and will establish after moisture is received.

Spring wheat should be planted when average soil temperature at 2 inches exceeds 40°F. Planting earlier can delay germination resulting in weaker, less vigorous plants. If a pre-plant herbicide has been applied, for example a triallate, delayed emergence can increase seedling mortality from herbicide poisoning. Both spring and winter wheat will continue to grow into the summer season as long as soil moisture is available and maximum daily air temperatures remain below the 90s°F. For this reason, delayed planting of spring wheat typically results in lower yields because of a shortened grain filling time.

Soil temperature is affected not only by air temperatures, but also by residue levels. Soil temperatures in tilled environments, and in fallow soils where much of the residue has decomposed, will warm more quickly in the spring than soils that have high levels of residue. Crop sequence can cause a similar effect. Where the previous crop was peas or lentils, lower levels of residue will remain the following spring. This allows soils to warm more quickly compared to fields where the previous crop was a cereal like wheat or barley, due to snow catch, stubble shading, and stubble reflectance.

If planted on-time for your region, seeding rates for spring wheat should be 60 lbs/acre PLS. If spring wheat planting is delayed, increase the seeding rate to 90 lbs/acre. Since spring wheat tillers less than winter wheat, you must provide a high enough population through seeding to optimize yield potential. Producers in NE Montana might gain from the high seed rates due to late seeding.

Many producers will wait for a flush of downy brome (also called 'cheatgrass') to occur so that they can spray these spring weeds prior to planting. This is a good management practice as long as the delay in planting isn't great. Another option is to use a 'Clearfield' wheat variety so that Beyond is available for chemical control of downy brome as a post-emergence herbicide. This allows timely planting of spring wheat but retains a method for downy brome weed control after crop establishment.

Seeds should be placed at 1 to 2 inches below the soil surface into good soil moisture. Shallow planted seed typically emerges quicker. A minimum planting depth of 1 inch will insure that the crown of the plant develops and remains below the soil surface.

Cropping Systems

Many acres of wheat in Montana are grown following fallow. The fallow period is designed primarily to reduce the risk of crop production in semi-arid environments where yields are dependent on limited precipitation. Fallow cropping is most successful where soils are deep and capable of holding greater amounts of water. Most silt loam to clay loam soils can hold two inches of available water per foot of soil depth. A soil with a profile of five feet can theoretically store ten inches of water during the fallow period for the next crop. Winter wheat will utilize water from up to five feet of depth. Spring wheat will root down to approximately four feet of soil depth, so the same soil could provide eight inches of stored water for a spring wheat or durum crop.

Stored water can be lost during the fallow period to transpiration from weeds. It is important to keep the soil weed-free during the fallow period. Tillage can be used but increases evaporative loss.

Precipitation storage efficiency (see Box) varies through the year and by the amount of water stored in the soil. During the summer, when evaporation potential is highest, PSE is typically lower than during the winter. In fact PSE can actually be negative, meaning more water is lost than is gained through precipitation. This occurs regularly during the second summer of a fallow period as shown in Figure 1 (Nielsen, Unger, & Miller, 2005).

Designing cropping systems to minimize fallow during the low efficiency period of May through September is one way to improve water use efficiency.

Precipitation Storage Efficiency (PSE)

Definition: the amount of water stored in the soil as a percentage of the total amount of precipitation received.

Example. Assume your field receives 12 inches of precipitation over the course of 1 year. If soil moisture is determined at the beginning of this period, and again at the end, the total amount of water stored can be calculated. Assume we can account for an increase of 9 inches of soil moisture.

$$PSE = 9/12 \times 100$$
$$= 75\%$$

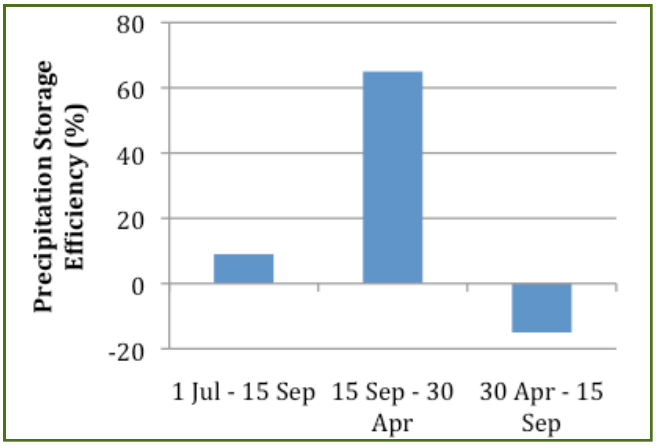


Figure 1. Precipitation storage efficiency in three time intervals in the fallow period of a wheat–fallow system in NE Colorado.

In a wheat-fallow system, 51 percent of the non-crop period occurs during the highly efficient fallow period directly following harvest while a significant 31 percent occurs in the second summer when fallow efficiency is low. By using a more intense rotation of wheat—corn—proso millet, Colorado researchers were able to shift the periods of fallow or non-crop time so that 79 percent of the fallow was in the high-efficiency period directly following a crop while only 5 percent remained in the low-efficiency period. This practice improved precipitation storage efficiency, which in return improved profitability.

In Montana, it's difficult to successfully grow warm-season grasses like corn and millet in dryland production systems, but there are cool-season crop options that may be used to improve water use efficiency. For example, alternating wheat with pulse crops such as peas or lentils in continuous crop production can make better use of stored moisture from the fall and winter non-crop period following wheat harvest. Pulses are shallow rooted, using moisture only from the upper three feet of soil. They grow quickly and mature early as compared to wheat, providing a short but highly efficient fallow period following harvest. Summer rains can recharge the surface soil for fall or spring planting while deep moisture is retained for the wheat crop that can be used the following spring.

With the advent of no-till production systems, the need for fallow has been lessened. It is no longer necessary to perform tillage operations prior to planting to prepare a seedbed. Most modern day equipment can plant through high levels of residue. And when the land is continuously cropped, yields and the accompanying residue are more manageable as compared to the high level of residue that can occur in a wheat-fallow system. In fact when a producer makes the move from fallow systems to continuous cropping, rather than working the soil to reduce residue levels, management to maintain residue on the soil surface to help harvest moisture becomes the key to success.

Crop rotation is a great way to help manage residue. Crops such as spring pea, mustards, canola, and camelina can be rotated with small grains in continuous crop systems to reduce the amount of residue present at wheat planting time. Since peas are a legume, the low C:N ratio of pea residue helps this residue breakdown quicker than wheat straw, which reduces the total amount of residue on the ground at wheat planting time. Crops like canola and mustard produce less residue at harvest so alternating these crops with wheat, a high residue producing crop, is a good management practice.

Nutrient Management

Wheat must acquire adequate nutrients in order to produce maximum economic yield. Evaluating the soil's nutrient availability begins with a soil test. Ideally, fields should be sampled each year, and over time a predictable history of soil fertility levels will emerge. Mobile nutrients such as nitrogen (N) and sulfur can vary greatly from year to year, depending on fertilizer applications, precipitation (leaching), crop type, and crop yield. As such, fertilizer recommendations for these nutrients may fluctuate more for crop selection and yield goal than they will for nutrients such as phosphorus (P) and potassium (K), which are considered non-mobile in the soil. Other soil properties like pH and organic matter are also fairly stable and over time will either decline or rise at a slow rate depending on the field's annual fertility program. Because of inherent variability, both in soils, and in sampling patterns, greater faith can be placed on a running average for these soil parameters rather than results from any single soil test.

Table 1. Nutrients removed in wheat grain and straw.

Nutrient	Grain	Straw
	Lbs/bushel	Lbs/ton
Nitrogen, N	1.25	14.5
Phosphate, P_2O_5	0.62	3.6
Potash, K_2O	0.38	25.0
Sulfur, S	0.08	3.7
Calcium, Ca	0.025	4.4
Magnesium, Mg	0.15	0.11
Copper, Cu	0.0008	0.0007
Manganese, Mn	0.002	0.11
Zinc, Zn	0.0035	0.03

Nutrient removal can be significant for wheat, especially if straw is harvested (Table 1). Typically in Montana the three nutrients that need to be supplied within a fertility program are N, P, and K while the rest of the essential nutrients are usually adequately supplied by the soil. Potassium is a comparatively large component of straw, so soil K levels should be monitored especially when haying or removing straw. Pictures and descriptions of nutrient deficiency symptoms can be found in Extension bulletin EB0043, Diagnosis of Nutrient Deficiencies in Alfalfa and Wheat (Jacobsen & Jasper, 1991).

Nitrogen is the nutrient needed in the greatest quantity, and its application typically provides the biggest yield boost. Montana State University recommendations are based entirely on yield goal using a factor of 2.6 lbs total N/bushel for winter wheat and 3.3 lbs total N/bushel for spring wheat. Credit is given for any available nitrate present in the profile as well as adjustments for soils with low or high organic matter content. There are two excellent tools available online to help calculate fertilizer needs. The Fertilizer Recommendation Tool requires user input of soil test information, crop and yield goal, and then calculates the MSU recommendation as specified in Extension Bulletin EB0161 "Fertilizer Guidelines for Montana Crops" (Jacobsen, Jackson, & Jones, 2005). Another tool that takes into account prices for fertilizer, grain, and protein is the Economic Calculator. This tool provides an MSU N recommendation as well as an interactive graph revealing the sensitivity of input variables.

When wheat follows pulses such as peas or lentils, Montana research shows the rotation benefit averages approximately 10 lbs N/acre, but can vary from 0 to 20 lbs N/acre. If wheat is drilled into plowed down alfalfa stubble or sweet clover, 35-50 lbs N/acre should be credited. If growers want higher protein in winter wheat, MSU recommends using the spring wheat fertilizer guidelines or the Economic Calculator.

Nitrogen sources are considered by MSU to be equal per pound of N. Differences lie in the form of N, either nitrate, ammonium, or urea, and in the stability of the compound. The majority of N currently sold in Montana is urea or UAN solution. Urea is stable when dry, but is readily converted by soil micro-organisms once added to the soil. Urea is first hydrolyzed to ammonia and then converted to the stable form of ammonium. If this process occurs on the soil surface through multiple wet and dry cycles, there is risk of loss of N to the atmosphere as ammonia. Significant losses can result in N deficiencies later in the growing season. Producers should manage urea and UAN by banding within the soil, or by broadcasting and incorporation either with tillage or through irrigation or precipitation. A minimum of at least 0.5 inch of precipitation will move urea into the soil and greatly reduce the risk of gaseous N loss. Further discussion can be found in Extension bulletin EB0173, Management of Urea Fertilizer to Minimize Volatilization (Jones, Koenig, Ellsworth, Brown, & and Jackson, 2007).

Fall applications of N are at greater risk to leaching and immobilization loss. Fertilizer applied closer to the time of maximum nutrient accumulation leads to better nutrient use efficiency. For irrigated production where potential yield is high, split applications and timing can be important. Extension publication EB0191, Nutrient Uptake Timing by Crops (Jones, Olson-Rutz, & Dinkins, 2009), provides a detailed assessment of nutrient accumulation by crops with guidance on fertilization application decisions.

Fertilizer application timing is less important for dryland production. Minimize the chance of N loss by fertilizing during cool periods in either fall or spring (<50°F) when microbial activity is low to reduce the movement of N into the biological pool.

Nitrogen deficiency symptoms are characterized by an overall yellowing of the plant followed by generally stunted growth (Wiese, 1996). Since N is mobile within the plant, under N stress conditions, younger leaves will utilize N from the lower leaves causing chlorosis in older tissues. Reduced cell growth and cell division as well as slowed protein synthesis can result in smaller plants and conditions more favorable for the development of disease.

Phosphorus is important for healthy root growth and is important for tillering. If soil test levels are below an Olsen test of 16 ppm P, wheat yields can respond to P applications. Below this soil test level it is a good practice to add P fertilizer with the seed or in bands adjacent to the seed, especially for spring and durum wheat when soils are cold and root growth can be slow.

What about banding fertilizer? (Mengel & Rehm, 2000)

Advantages:

- A zone of enhanced nutrient availability is created by minimizing contact between the fertilizer and soil.
- It is a simple and efficient method of applying small amounts of fertilizer.
- Efficiency of volatile products like urea is enhanced.

Disadvantages:

- Only a limited portion of the root system has a high probability of coming in contact with the fertilizer
- Damage to germination can occur when high rates of some products are placed close to the seed.
- Higher cost of equipment for banding.

Most research on fertilizer banding of non-mobile nutrients such as P and K indicates that the chance of positive response is greatest where the soil test level of those nutrients is in the low or responsive category (see Box).

The primary P fertilizer sources in Montana are monoammonium P (MAP; 11-52-0), diammonium P (DAP; 18-46-0), and liquid ammonium P (10-34-0). All sources are considered equal on a lbs P/acre basis, although MAP is the preferred source since it has a lower ammonium content which allows a greater amount to be placed with the seed when drilled.

Phosphorus deficiency in wheat is expressed as slow growing and late maturing plants (Wiese, 1996). As contrasted to N deficiency, plants are not chlorotic. Rather plants can be darker bluish-green than normal. Leaf tips may die back, and the foliage of some cultivars will turn red or purple in color. Phosphorus deficiency is more likely in cold wet soils when P release from organic matter is reduced due to low microbial activity and P movement is slow.

Potassium deficiency is rare for crops in Montana but can occur in sandy coarse-textured soils, or in fields where grain and straw are both removed. Fertilizer source is primarily potash (KCl, 0-0-60) and is best utilized when banded. If banded with the seed, limit the total amount so as to not cause salt problems (See Starter fertilizer discussion below).

Deficiency symptoms show first on lower leaves as K is quite mobile (Wiese, 1996). Leaves showing K deficiency may appear scorched, bronzed, or blighted along the leaf edges. Since K is such an important component of straw, deficiency may lead to weak straw and increased lodging. Diseases such as powdery mildew may be accentuated on K deficient plants.

Starter fertilizer can help wheat get off to a quicker start, especially in no-till fields which have higher levels of residue and where soils are typically colder. Phosphorus fertilizer is quickly removed from the soil solution by soil activity and therefore can be mixed with the seed at high rates without causing salt problems for germination. Nitrogen and K fertilizers remain in solution longer and when added as starter can create high salt conditions which are toxic to seedlings. Limit applications to a total of 20 lbs of N + K_2O when fertilizer is mixed directly with the seed and when drilled in 6-7 inch rows. If the N source is urea there is an additional risk. Urea placed in the soil will quickly hydrolyze to ammonia, which is highly toxic to seedlings. If N is formulated as urea or UAN solution, limit the total amount of N + K_2O to 10 lbs/acre in 6-7 inch rows. If drilling wider rows, do not place any N+K_2O directly with the seed. A separation of seed and fertilizer by 1 to 2 inches eliminates any restrictions. Air seeders which mix the seed and fertilizer also reduce the risk to seedlings by diluting the fertilizer across a wider band. Little fertilizer research has been completed using air seeders, so start with these guidelines and increase fertilizer amounts at your own risk. Seedling damage from fertilizer occurs less frequently in wet years as these salts move with water and will quickly move away from the seed row when water is abundant.

Micronutrients are rarely needed for wheat production in Montana. Exceptions include soils low in organic matter, or those recently leveled for irrigation where topsoil has been buried or diluted with deeper soils. A recommendation table for micronutrient levels and fertilizer rates is available at the Fertilizer Recommendation Tool and in “Fertilizer Guidelines for Montana Crops” (Jacobsen, Jackson, & Jones, 2005).

Enhanced Efficiency Fertilizer (EEF) products are available for use by producers. These include additives like NBPT, a urea stabilizing product which is designed to delay hydrolysis (the conversion of urea to ammonium) once the fertilizer is applied to the soil. This product may have value for producers that top-dress urea and want to reduce the potential volatilization of urea to ammonia. Other additives such as sulfur or polymer-coatings place a physical barrier around the fertilizer granule to slow or prevent dissolution until a significant precipitation or irrigation event is received that will dissolve the coating and move the nutrient safely into the soil profile. Since these coatings typically dissolve and break down slowly in cool soil temperatures, their use for spring crops like wheat and barley is limited in Montana.

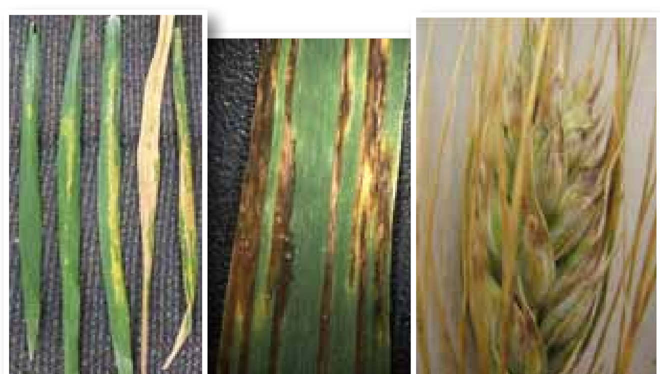
An EEF for P which uses an exchange resin to bind cations in the soil near the fertilizer granules has been shown to slow the mineralization process of fertilizer P, keeping it more available for plant uptake. Limited Montana research on these new products has been completed to be able to fairly evaluate their effectiveness. Further discussion and recommendation on the use of these and other products can be found in Extension publication EB0188 Enhanced Efficiency Fertilizers (Olson-Rutz, Jones, & Dinkins, 2009).

Plant diseases of importance in Montana wheat

Plant diseases can severely impact wheat yields. Management to prevent occurrence is preferable to treatment. In most cases (but not all), crop rotation to reduce the amount of disease organisms (inoculum) present and alteration of the host (crop, variety) or environment so the disease is not favored is the best management practice for wheat production. When diseases do occur, rapid identification is needed so proper management decisions can be implemented. The following section describes common diseases in wheat in Montana, their identification and management recommendations. When in doubt, submit a sample to the diagnostic lab through your county extension agent. A proper sample consists of entire plants (including roots) showing symptoms, a 'healthy' comparison where available, and if possible, photographs of the field to illustrate the pattern of the problem. Submission forms can be found at the Schutter Diagnostic Laboratory Web site. Diagnosis can often be accomplished remotely with a good description of the problem and a photograph, but submitting a physical sample is often required. Pictures of the following disorders can be found on the Wheat Diseases of Montana Web site.

Leaf Diseases

Bacterial leaf blight and bacterial stripe (both commonly known as black chaff) are caused by *Xanthomonas campestris pv. translucens* and *Pseudomonas syringae pv. syringae*. The leaf symptoms begin as small, water-soaked spots on leaves which elongate into linear streaks that become necrotic tan or brown. Often the tips of the leaves become shredded. Leaf tip shredding can also be caused by drought stress, but in the case of drought stress, the leaf lesions characteristic of bacterial leaf diseases will not be seen on the leaves. Bacterial-caused symptoms can also be confused with spot or net blotch, or Septoria leaf spot, diseases which are caused by fungi (see below).



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Bacterial leaf blight and black chaff symptoms.
Left, tan to brown lesions; center, bacteria oozing from lesions; and right, discoloration of the glume.

The leaves of bacterial-infected plants often have a varnished or 'slick' feel, whereas leaves infected by fungi do not. Under very wet conditions, beads of bacteria will be exuded from leaves or glumes infected by the bacterial pathogen. Symptoms often appear late in the season or after a hail storm or heavy, driving rain which wounds the plant.

When bacteria infect the head of wheat or barley, it is known as black chaff. Symptoms include pink, tan, or black streaks on the glumes, and discolored and shriveled seed. Under wet conditions, an exudate can develop on the glume and seed surfaces, forming tiny yellow droplets or a glassy or shellacked appearance. Seed symptoms include discoloration of the embryo end of the kernel and can be confused with black point, which is caused by a number of different fungi. Both bacterial kernel blight and black point are encouraged by moisture during heading and seed filling. The best method of control is to use clean seed and to cut irrigation during this period. Do not save seed from affected fields. There are no effective pesticides for control of bacterial diseases of wheat.

In order to distinguish between bacterial and fungal leaf diseases, one can put leaves in a moist chamber and check for fungal structures (little black dots in the lesions) after two to three days. Also, bacterial lesions will be 'water-soaked' or 'glassy' before they dry up, particularly if the environment is moist. When in doubt, submit a sample to the Plant Disease Diagnostic Clinic through your county extension agent.

Dry seed decay is caused by *Penicillium spp.* and other soil-inhabiting fungi. Any soil condition that prevents rapid germination and emergence of winter wheat seed increases the possibility of seed decay. This includes dusting winter wheat into dry soil. Light showers that are sufficient to germinate seed but not sufficient to sustain growth can cause poor stands if adequate moisture does not follow. Dry seed decay is often misdiagnosed as winterkill or Rhizoctonia root rot (below). Seed treatments will prevent dry seed decay for 3-4 weeks after planting. Imazilil gives the best control of dry seed decay, but other seed treatments are also effective.

Damping off and root rots can be caused by a number of different fungi including Pythium and Rhizoctonia. They are favored by wet, cool soil conditions. Symptoms include decreased seedling emergence (seed rot/damping off), poor seedling vigor, decreased number of lateral roots, shorter roots, browning or necrosis of roots, chlorotic leaves, small heads, and sometimes white heads at maturity. The subcrown internodes and first few nodes may also be discolored. Damping off can be controlled using a seed treatment. Consult the Small Grain Seed Treatment Guide (Dyer, Burrows, Johnston, & Tharp) for current recommendations. Seed treatments are generally effective for 3-4 weeks after planting, and do not protect the entire root system from fungal pathogens.

Root rot (bare patch) can be partially controlled by seed treatment but crop rotation, good weed control, and eliminating the 'green bridge' are all important management techniques. There is research from Oregon showing that glyphosate (Roundup) application to volunteer cereals and grassy weeds can increase the amount of Rhizoctonia in these plants and increase the risk of bare patch when seed is planted into a field with green plants remaining. Eliminating the green bridge by planting 2-3 weeks after herbicide application is the most important control method in this case.

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Root rot caused by Pythium and Rhizoctonia (left). 'Spear-tip' symptoms of bare patch (right).

Crown rot fungi are both soil- and residue-borne, and can also infect grassy weeds. Fusarium crown rot is caused by *Fusarium spp.*, common root rot by *Cochliobolus sativus*, and take-all by *Gaeumannomyces graminis var. tritici*. Crown rots are commonly present but are often not noticed until they significantly decrease yield. Symptoms include discoloration of the crown and/or subcrown internode, reduced seed weight and size, and white heads at maturity.

These diseases can be difficult to control in a continuous wheat cropping system. Recommendations include crop rotation, variety selection, proper fertilization, irrigation management to maintain continuous (not fluctuating) moisture, and tillage where practical to reduce residue levels. Seed treatments are of limited efficacy for crown rot control since they only last 3-4 weeks after planting, but are recommended for plant health during seedling establishment.

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Fusarium crown rot (left), common root rot (center) and take all (right).

Eyespot diseases can be difficult to distinguish in the field as they cause similar symptoms as crown rot including reduced yield, white heads at maturity, and lodging. Cool moist conditions near the base of the plant favor infection. Either soil- or residue-borne spores can infect through the leaf sheath at the base of the plant. The lesions of the two diseases are distinct. Sharp eyespot *(Rhizoctonia cerealis)* causes circular to elliptical light brown lesions surrounded by a thin, necrotic, dark brown border. Eyespot *(Pseudocercosporella herpotrichoides)* causes eye shaped lesions, initially white to tan-brown and developing to dark brown lesions that cannot be stripped off by peeling off the leaf sheaths. Lesions of both fungi may girdle the plant.

Control is generally not economical but if infections are serious, management may be recommended. Spring wheat and late-seeded winter wheat are less exposed to conditions favoring infection. Reduction in seeding density reduces moisture in the canopy. Crop rotations of two or more years and fungicide application at tillering can be helpful. No resistant varieties are available.

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Sharp eyespot (left) and eyespot or strawbreaker foot rot (right).

Tan spot *(Pyrenophora tritici-repentis)* and **Septoria leaf blotch** *(Septoria spp.)* are residue-borne and encouraged by continuous cereal cropping, minimum or no tillage, and irrigation. They can be distinguished based on their symptoms, but controlled using similar techniques. Yield and quality reductions are proportional to the amount of leaf area affected, particularly the flag leaf.

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Tanspot (left) on leaf showing typical eye-shaped spots with halos. Septoria leaf blotch symptoms (right) are usually more diffuse shaped, grey or tan colored and lack the yellow halo.

Symptoms will vary according to variety, pathogen isolate, and environmental conditions, but generalizations can be made. Symptoms begin as small spots on leaves or stems and expand. Tan spot symptoms are similar to spot blotch but the lesions are initially lens-shaped with a yellow halo and often a dark spot in the center of the lesion under moist conditions. Septoria leaf blotch symptoms are also similar to spot blotch but consist of grey or tan colored lesions that lack the yellow halo. Septoria can cause a glume blotch of the head and shriveling of the seed. Periods of warm dry sunny weather inhibit spread of disease to new leaves.

Management can be achieved by crop rotation, fungicide application, variety selection, irrigation management, tillage to reduce residue, and good grassy weed control.

Powdery mildew *(Blumeria graminis f. sp. tritici)* is commonly observed on lower leaves of winter wheat, particularly in irrigated fields or cool, humid weather. Signs include white to gray fluffy fungal mycelia on the leaves, often in patches that expand to cover the entire leaf. Old infections appear brown and powdery. Small black fungal structures called cleistothecia may also form in the hyphal mass. It is generally not economical to control, but many fungicides are effective.

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Powdery mildew on a wheat leaf.

Snow mold occurs when winter wheat is covered by snow for extended periods, particularly if the snow falls on ground that is not yet frozen. It often occurs in areas of the field which are the last to thaw. Pink snow mold is caused by Microdochium (synonym Fusarium) nivale. The fungus attacks plant parts during wet, cool weather, but is not dependent upon snow. Speckled snow mold is caused by Typhula idahoensis and the similar T. ishikariensis. Both species are restricted to areas with deep snow.

T. Murray, WSU

Snow mold has reduced this stand, and has weakened the remaining plants.

Less serious is T. incarnata, which has a wider geographical range and is found even in areas without prolonged snow cover. Pink snow mold produces pinkish mycelium and conidia that cover dry yellow or dead leaves. Leaves attacked by speckled snow mold appear scalded or bleached-white or tan in color and have a tendency to crumble. Fungal structures called sclerotia are scattered on leaves and give the disease its common name. Plant vigor may be markedly reduced, and in severe cases, the crowns are killed. Surviving plants recover slowly and are sensitive to additional stress.

Fungicide applications have not been effective since residual efficacy is only 3-4 weeks after application. Crop rotation to legumes or other non-cereal crop is effective. Attempts have been made to hasten snow melt by using blackening agents, but cost, difficulties of application, and unpredictability of post-application snowfall make this method unreliable.

Cephalosporium stripe invades through roots and causes symptoms on leaves. Only winter wheat is susceptible, particularly continuously cropped dryland winter wheat. The fungus *(Cephalosporium tritici)* enters roots through wounds induced by freezing and thawing (frost heaving) of the soil. During jointing and heading, affected plants appear dwarfed with continuous yellow stripes on leaves. Normally, only one or two stripes and discolored veins are present on each leaf. Darkened stripes on stems appear during crop maturity, and nodes may be darkened. At heading and during grain filling, the awns of diseased plants tend to turn outward and the heads turn white. White heads are either empty or filled with shriveled kernels. Plants in severely-infected fields may mature early. Delayed fall seeding reduces root volume reducing, potential for root breakage and number of potential infection sites.

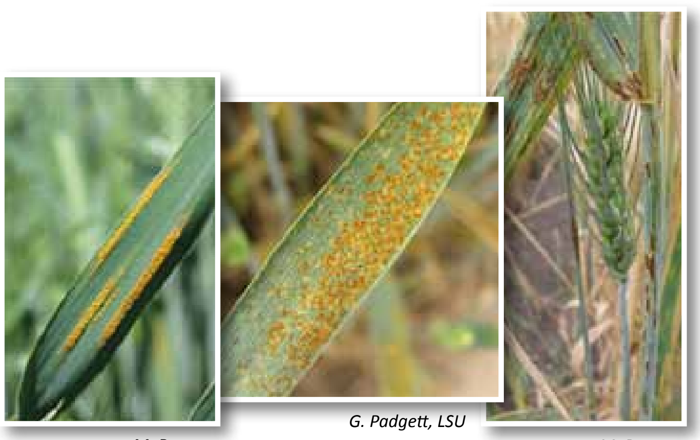
J. Johnston, MSU

Cephalosporium stripe.

Rusts *(Puccinia spp.)* are dependent on the host for survival, and generally blow in on weather systems each year from other wheat-growing areas. The exception is stripe rust *(Puccinia striiformis)*, which can overwinter on wheat and grassy weeds in Montana. Rust spores occur in spots or stripes called 'pustules' and they will rub off on your finger.

The rusts can be distinguished based on their appearance and preferred environmental conditions. Stripe rust, also called yellow rust, is a 'cool-season' rust, preferring temperatures of 41 to 59 °F. Symptoms include yellow to orange spores occurring in stripes. It is most common on winter wheat but can infect spring wheat. Leaf rust spores are red to brown and occur in discrete pustules unless the infection is very advanced and the pustules have merged together. Stem rust spores are red to brown/ black and occur on both leaves and the stem. The edges of the pustules have frayed edges from the leaf epidermis (skin) where the pustule erupted. Infections of rusts are favored by at least 6-8 hours of dew, which allows the spores to germinate and infect the leaf. Leaf rust prefers temperatures of 60 to 80 °F for infection, and stem rust is favored by warm days of 77 to 86 °F and cool nights of 59 to 68 °F.

Yield loss will depend on variety resistance and the time of infection. Control is achieved through the use of resistant varieties and fungicide application. For best control when using a fungicide, apply at the first appearance of symptoms. See the fungicide efficacy table for more details.



G. Padgett, LSU

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Stripe rust (left), will occur in distinct stripes. Leaf rust spores (center) will be red to brown, and occur as scattered pustules on leaf surface. Stem rust can occur on both leaf or stem (right) and is red to black in color.

Bunts and smuts are seed-borne, and have greatly decreased since the invention of systemic fungicide seed treatments and deployment of resistant cultivars. The fungus replaces the seed, and forms a powdery black substance which is a mass of fungal spores. You can distinguish smut from ergot by trying to crush the black substance: ergot is a solid mass of fungal hyphae and not powdery like smut or bunt. Yield loss due to smut is proportional to the number of heads infected. Affected plants can be stunted before the head symptoms are obvious. The different kind of smuts can be distinguished based on the symptoms on the head.

Common bunt, also called stinking smut and covered smut *(Tilletia tritici or T. laevis),* has a membrane that remains around the smutted seeds until the plant is mature. Most people will detect a distinct fishy odor associated with common bunt. Bunt spores released during threshing are combustible. Most inoculum originates with contaminated seed, but soil-borne spores can infect winter wheat seedlings. Soil-borne spores do not survive the winter. Seed treatments can provide control.

Dwarf bunt *(T. controversa)* is very similar to common bunt and has the same distinct odor. However, it is caused by a different species, has unique requirements for spore germination and infection, infected plants are stunted, and spores can live in the soil for years. A prolonged period of very low-intensity light accompanied by temperatures between 32 and 40 °F is necessary. These conditions generally exist in late fall. Infection can occur at the snow-soil interface when snow falls on unfrozen ground and stays there for several months. The spores germinate best when soil or seedbed temperatures are in the range of 40 to 60 °F. Then, the fungus grows within the growing point of the infected shoot and completes its life cycle by growing into the ovaries and producing smut balls in place of kernels. The seed treatment difenoconazole (Dividend) is the only effective product for dwarf bunt management. Resistant varieties may be available.

Loose smut *(Ustilago tritici)* is strictly seedborne. Symptoms appear at crop maturity. Infected heads emerge before healthy heads. A thin membrane covering the spores ruptures and spores are dispersed by the wind, leaving a naked rachis (center of the head). Spores infect the open flowers of neighboring plants, infecting the seed embryo and perpetuating the disease cycle. To prevent smut, use a systemic fungicide seed treatment.

MSU Plant Pathology Slide Collection

Loose and covered smut (left); Dwarf bunt (right); Seed replaced with common bunt spores called 'bunt balls' (bottom).

Head Diseases

Ergot *(Claviceps purpurea)* is a fungus that forms compounds that are toxic to animals and humans. The source of the fungus is the sclerotia, a hard mass of fungal hyphae and a survival structure for the fungus. Ergot is introduced into a field by contaminated grain, grassy weeds or wild grasses. The fungus infects during the flowering period, so moist conditions at flowering favor this disease. Light frost during flowering increases the incidence of ergot.

The first symptom of ergot is honeydew, a moist sticky substance which occurs during flowering under moist conditions. Insects can be attracted and feed on this substance. As the disease progresses, the fungus replaces the seed and forms an ergot body. This black structure can be up to 4 times as large as the original seed and protrude from the head.

If you suspect the grain has ergot, do not feed it to animals. Ergot contamination of 0.05 percent by weight can be toxic. Ergot can be controlled by cutting wheat for hay before flowering, tillage to bury the sclerotia, mowing contaminated headlands or roadways before the wheat matures, and rotating out of small grains for at least one year.

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Ergot replaces the seed (left) and is generally larger than the grain it replaces. Ergot bodies, or sclerotia (above) contaminate grain and are toxic to livestock at very low levels.

***Fusarium* head blight or scab** *(Fusarium spp.)* is important because the fungus produces toxins including deoxynivalenol (DON). The disease also causes yield and quality losses. Scab on wheat has been reported sporadically in Montana, primarily in irrigated spring wheat but also in winter wheat and barley.

The primary symptom of scab is partial bleaching of the heads. This disease is residue-borne and the fungus infects through the flower, much like ergot (above). If environmental conditions are very moist, a pink fungal growth may be seen on the head. This can also be seen if the heads are put into a moist chamber for a few days (a Ziploc bag with a wet paper towel). Seed symptoms include ‘tombstones’ or shriveled seed sometimes with crusty white fungal growth. They are lighter than non-affected seeds and can be blown out of the combine while harvesting by increasing the fan speed. However, this practice has the downside of providing inoculum for the following crop.

Since this is a residue-borne disease, reducing grassy residue via crop rotation or tillage will reduce the amount of inoculum in the field. Irrigation management, or limiting irrigation 10 days before head emergence to let the canopy dry out can reduce fungal infection. Another option includes spraying a systemic fungicide at head emergence or slightly before head emergence (see fungicide efficacy table). Variety resistance is available for spring wheat. Seed treatments are not effective against scab since the inoculum comes from the crop residue, but seed treatments are routinely recommended to protect against soil-borne pathogens.

Symptoms of Fusarium head blight include partial bleaching of the head. Whole heads can also be bleached.

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Sooty mold is caused by a number of different fungi. The fungi are favored by wet weather, particularly after heading through harvest. Sooty mold is noticed particularly when harvest is delayed. Heads that are shaded, weakened, undersized, prematurely mature, deficient in nutrients, lodged, or damaged by other diseases also are prone to sooty molds. In some cases, plants weakened by other diseases such as take-all or Cephalosporium stripe are more prone to sooty mold development. Sooty mold may decrease grain quality by causing a black point or kernel smudge. There are no fungicides available for control of sooty mold after flowering; the best control is to harvest early and dry the grain.

Sooty mold is favored by wet weather, particularly after heading through harvest.

T. Murray, WSU

Virus diseases

Wheat streak mosaic virus (WSMV), **Wheat mosaic virus** (WMoV, formerly known as *High Plains virus*), and **Triticum mosaic virus** (TriMV) are wheat curl mite-transmitted viruses found in Montana. Symptoms include yellow to white streaks on leaves, stunting, and delayed maturity. The three viruses cannot be distinguished based on symptoms, but when multiple viruses are infecting one plant, symptoms can be more severe. Yield loss will depend on the virus species, virus strain, wheat variety, time of infection, and environmental conditions.

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Three distinct virus diseases have similar symptoms which include white to yellow streaks on leaves, stunted plants, and delayed maturity. Laboratory tests are required to determine which virus is present. These viruses are transmitted by the wheat curl mite (right).

The best method of control is avoiding the green bridge. The virus and the mite are dependent on green tissue for survival. They survive on wheat, barley, oats, corn, rye and grassy weeds, but volunteer or cultivated wheat is the ideal host for both the virus and the mite. Eliminating the green bridge by destroying volunteer wheat and grassy weeds using herbicides or tillage during August (2-3 weeks before planting) is the most important control method. Herbicides don't kill weeds immediately. Volunteers and grassy weeds must be completely dead in order to no longer serve as a pathogen source. This means an extended period is needed in order to break the green bridge prior to planting. Fields managed as large blocks rather than strips minimize the field edges that are exposed to mite-infested volunteer wheat or grasses. No effective seed or foliar acaricides are registered for use. Delayed planting in the fall will minimize exposure of seedlings to mite infestations due to cool temperatures which reduce mite activity.

A delicate balancing act exists for managing WSMV by use of planting date. Early planting to establish a vigorous plant for yield potential must be weighed against planting late enough to avoid the transmission of WSMV by the wheat curl mite. Although planting date is no guarantee to avoid disease, cooler fall temperatures will minimize mite migration and virus transmission. General guidelines for winter wheat planting date is after September 5 in northern Montana, September 15 in central Montana, and September 20 in southeastern Montana. Fall planting depends on local weather conditions. If it is unseasonably warm when fall planting should begin, it may be necessary to postpone seeding as warm weather keeps mites active for a longer time and wheat may become infected. Spring wheat crops should be planted as early as possible; no later than the end of April. Late-seeded spring wheat does expose susceptible seedlings to an active population of the mite with the higher temperatures. Spring wheat should not be planted near winter wheat with symptoms of WSMV, or in fields that were heavily infested with the wheat curl mite the previous fall. Spring control of volunteer winter wheat with glyphosate up wind from emerging spring wheat has resulted in severe spring wheat mortality from WSMV infection.

Barley yellow dwarf virus (BYDV) is an aphid-transmitted virus. Aphids generally arrive on weather systems from other cereal-growing areas or from adjacent grasslands like CRP or rangeland. Incidence is higher in late seeded spring wheat and early seeded winter wheat. This disease is sporadic in nature. There are several species of aphids which transmit different species of BYDV. The interaction between the aphid and the virus is very specific, and not all aphid species will transmit all species of BYDV. The severity of the disease will depend on how many plants are infected, the species of BYDV infecting the plant, and the growth stage at which the plant becomes infected.

Symptoms vary by virus, plant variety, environmental conditions and time of infection. Yellowing of the leaves can be confused with nitrogen deficiency or stress. The flag leaf is sometimes purple or red in color. Plants are stunted or dwarfed, and leaves may be shortened or curled and sometimes have serrated edges. This disease is generally not economical to control in Montana and occurs sporadically.

Barley yellow dwarf virus causing yellow to purple discolored leaves.

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Abiotic Disorders

Frost injury is caused by freezing temperatures after plant emergence. The worst damage occurs when wheat is damaged at the 2-leaf stage or at heading. If injury occurs during heading or pollination, symptoms will include white heads, sterility, white awns and watersoaking and shriveling at the base of the head.

Hail injury is most damaging from heading through harvest. Hail kinks and severs plant parts randomly. Other symptoms include drying and bleaching of damaged tissues, white heads, stem lesions, and spike bruising (circular white patches on the glume).

Melanism occurs as brownish-black to dark purple spots, streaks, or blotches on the leaf sheaths, stems, and/or glumes. It is caused by production of melanoid pigments, and is common in some varieties. The dark brown color usually develops on the glumes and peduncles. The symptom may be confused with black chaff or stagonospora blotch, but no leaf symptoms of those diseases will be present.

Physiological leaf spots often resemble leaf spots caused by pathogens, but with no pathogen present. They are caused by plant physiology or by genetics. Leaf spotting has also been associated with chloride deficiency in some wheat varieties in Montana. Often the margin of the spot is very distinct, not diffuse. Spots will occur uniformly on all leaves of the plant, and will not be more severe towards the base of the plant, as is expected with a stubble-borne leaf spot disease such as tan spot or Septoria leaf spot. If leaves are placed in a moist chamber (plastic bag with a wet paper towel) for 2-3 days, no fungal structures (black dots) will develop. Send samples to the diagnostic lab if you are not certain. Varieties vary in their susceptibility to physiological leaf spotting.

Nutrient deficiency symptoms include stunted or uneven growth, yellowing, poor vigor, reduced tillering, and low yield and seed quality. Most symptoms occur between tillering and heading when there is high demand for nutrients. Diagnosis can be obtained from plant or soil analyses. In Montana the most common nutrient deficiencies are nitrogen, sulfur, phosphorous and potassium. (For more details see the Nutrient Management section.)

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 for use by the grain production industry in the U.S. Efficacy ratings for each fungicide listed in Table 2 were determined by field testing the materials over multiple years and locations by the members of the committee. Efficacy is based on proper application timing to achieve optimum 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 of the labeled rate as listed in the table. Table 2 includes most widely marketed and labeled products, and is not intended to be a list of all labeled products. Comments on stem rust are based exclusively on trials in Bozeman in 2009.

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CIMMYT, http://greengenes.cit.cornell.edu/gifs/wheat_diseases/091.gif

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Wheat can show abiotic, or non-disease disorders in the field. From left to right, damage symptoms include frost injury, hail, melanism, and physiological leaf spots.

Table 2. Efficacy of fungicides for wheat disease control based on appropriate application timing

Fungicide(s)				Powdery mildew	Septoria leaf blotch	Tan spot	Stripe rust	Leaf rust	Stem rust	Head scab	Harvest restriction
Class	Active ingredient	Product	Rate/A (fl. oz.)								
Strobilurin	Azoxystrobin 22.9%	Quadris 2.08 SC	6.2 - 10.8	F(G)[1]	VG	E	E[2]	E	--	NR	45 days
Strobilurin	Pyraclostrobin 3.6%	Headline 2.09 EC	6.0 - 9.0	G	VG	E	E[2]	E	G	NR	Feekes 10.5
Triazole	Metconazole 8.6%	Caramba	10.0 - 17.0	--[3]	--	--	E	E	E	G	30 days
Triazole	Propiconazole 41.8%	Tilt 3.6 EC PropiMax 3.6 EC Bumper 41.8 EC	4.0	VG	VG	VG	VG	VG	--	P	40 days
Triazole	Prothioconazole 41%	Proline 480 SC	5.0 - 5.7	--[3]	VG	VG	--	VG	E	G	30 days
Triazole	Tebuconazole 38.7%	Folicur 3.6 F [4] Embrace 3.6 L Monsoon Muscle 3.6 F Orius 3.6 F Tebucon 3.6 F Tebustar 3.6 F Tebuzol 3.6 F Tegrol Toledo	4.0	G	VG	VG	E	E	--	F	30 days
Triazole	Prothioconazole 19% Tebuconazole 19%	Prosaro 421 SC	6.5 - 8.5	G	VG	VG	E	E	E	G	30 days
Mixed mode of action	Metconazole 7.4% Pyraclostrobin 12%	Multiva TwinLine	6.0 - 11.0	G	VG	E	E	E	VG	NR	Feekes 10.5 and 30 days
Mixed mode of action	Propiconazole 11.7% Azoxystrobin 7.0%	Quilt 200 SC	14.0	VG	VG	VG	E	E	VG	NR	Feekes 10.5
Mixed mode of action	Propiconazole 11.4% Trifloxystrobin 11.4%	Stratego 250 EC	10.0	G	VG	VG	VG	VG	--	NR	35 days

[1] Efficacy categories: NR=Not Recommended; P=Poor; F=Fair; G=Good; VG=Very Good; E=Excellent. Efficacy designation with a second rating in parenthesis indicates greater efficacy at higher application rates.

[2] Efficacy may be significantly reduced if solo strobilurin products are applied after stripe rust infection has occurred.

[3] Insufficient data to make statement about efficacy of this product.

[4] Generic products containing tebuconazole may not be labeled in all states.

Integrated management of weeds in wheat

Growing a successful wheat crop requires close attention to weed management. If left unmanaged, weeds have potential to reduce wheat yields as they compete with the crop for light, nutrients, and water. Furthermore, weeds can interfere with harvest, contaminate harvested grain, and can harbor diseases, nematodes, or insects that attack wheat.

Research and experience shows that the integration of cultural and mechanical practices with careful use of herbicides is at the core of a successful integrated weed management (IWM) program in wheat fields. In essence, IWM combines the use of different control practices to manage weeds, so that reliance on any one weed management technique is reduced. Selecting the proper combination of management strategies requires an understanding of the following:

- time at which both the wheat crop and weed grow
- size and growing stage of the wheat and the weeds
- kind of weeds present in the field and their relative abundance
- cropping system
- environmental conditions (soil type, moisture, nutrient availability, temperature)
- management goals
- availability of resources (time, labor, and equipment)

More information on IWM can be found in Integrated Strategies for Managing Agricultural Weeds (Smith & Menalled, 2006).

Prevention. Reducing the spread of weeds is an important step in weed management. This can be achieved through careful sanitation practices such as use of clean equipment before entering a field, keeping field borders clean, and use of certified seeds. Seeds of jointed goatgrass, downy brome, Persian darnel, kochia, and prickly lettuce are common contaminants of noncertified wheat seeds that can create problems for many years. Removing weeds before they produce seeds, either through spot spraying, tillage or mowing, and cleaning combines prior to entering a field, and collecting weed seeds in chaff wagons pulled behind the combine, can help reduce the spread of weeds within and among fields.

Crop rotation. When wheat is grown continuously, weeds which are well-adapted to compete with the crop thrive. Examples include wild oat, Persian darnel, jointed goatgrass, and downy brome. Planting different crops is one of the most powerful tools in the development of an IWM program. Properly selected crop rotations prevent the buildup of problematic weeds. Not only can different herbicides be used in each phase of the rotation, the crop itself can act as an excellent barrier to prevent the spread of certain weeds (Fig. 2).

When designing a crop rotation, producers should select crops that physically out-compete problematic weeds, which will result in the gradual weed population decline. Diverse rotations, including small grains, forages, and annual broadleaf crops, provide the full benefit of crop rotation. For example, in Montana, wheat and peas are generally sown as early as possible, while canola is usually planted later to avoid spring frost. Not only is the occurrence of a specific herbicide associated with each crop lower in a diversified rotation, which can delay the selection of herbicide resistant biotypes, but changing the yearly seeding and herbicide application date means that specific weeds cannot adapt to changing environmental conditions. Winter wheat provides greater suppression of wild oats than spring wheat. Spring wheat production provides more control of downy brome seed production. Less diverse rotations which include only winter and spring wheat will be marginally beneficial.

Producers interested in developing a diversified crop rotation should pay special attention to reduce the risk of crop damage due to herbicide carryover (Fig.3).

Preventing seed production and dispersal reduces the spread of weeds across fields. A case study: Wild oat

Limit seed production

Wild oat is usually found in patches. Minimizing seed production can reduce patch expansion. For example, a 6-year study monitored wild oat patch expansion in farmers' fields. Wild oat patches that were treated to prevent seed production and dispersal increased by 35 percent; while untreated patches increased by 330 percent.

Limit seed dispersal

Wild oat seeds are heavy and do not disperse more than 6 to 9 feet from the parent plant. However, seeds can be moved long distances (>450 feet) when taken up by a combine harvester and returned to the ground with chaff. Methods that reduce seed dispersal during harvesting operations can reduce the spread of wild oats within and across fields. For example, chaff collection removes up to 74 percent of wild oat seeds that would otherwise be dispersed by the combine.

For example, the labeled rotation restrictions of wheat herbicides such as Assert, Ally, Glean, and Finesse range between 10 and 34 months when rotating to peas, lentils, canola, sunflower, or safflower. A field bioassay is required following the use of some herbicides before seeding the rotational crop. Herbicide labels list harvest intervals to reduce the risk of crop injuries due to herbicide residues.

Resource availability. Adequate fertility is required to establish a highly competitive wheat stand. Excess fertilizer, especially N, can enhance weed competitive ability resulting in decreased yields. For example, downy brome has been shown to be more responsive to N, reaching maximum size at lower N availability than wheat. Also, wild oat is better able to use added N than wheat, thus gaining a competitive advantage and decreasing crop yields (Fig 4).

Banding fertilizer near the crop row and applying at the appropriate time enhances the ability of wheat to compete with weeds. For example, band placement of fertilizer in the root zone has been shown to increase early wheat growth and grain yield, while decreasing weedy grass. Effects are particularly pronounced in reduced tillage cropping systems.

Crop establishment and growth. Decreasing row spacing and/or increasing seeding rates enhances the competitiveness of wheat relative to the weeds so that fewer resources are available to support weed growth. Using tall wheat varieties with high leaf area have been shown to be more competitive than short varieties with low leaf area. For example, an analysis of 13 winter wheat cultivars found that there was a 40 percent yield difference between the two most weed-suppressive cultivars (Mason, 2006).

Chemical weed control. Several foliar- and soil-applied chemical options exist to manage grassy and broadleaf weeds commonly infesting wheat fields. However, not all selective products provide control for all weed species. Therefore, the proper selection of herbicides is critical for effective weed management. An online Herbicide Selection Tool for selecting post emergence herbicides for small grain production has been developed for use at Montana State University. This tool narrows the choices of registered herbicides by using user inputs of current crop, weeds present, and planned crop rotations for specific fields.

The selection of an herbicide or combination of herbicides should be based on several factors. Among them:

- Label approval for use
- Weed abundance and spectrum
- Crop and weed application timing
- Crop rotation restrictions
- Ground and surface water pollution concerns
- Potential for drift and soil carryover damage
- Weather conditions
- Herbicide cost
- Presence of herbicide resistance weeds
- Soil texture, soil pH, and soil organic matter content

The effectiveness of an herbicide and the potential for crop damage is governed by the interaction of environmental factors such as temperature and rainfall, managerial factors such as depth of planting and time of application, and biological factors such as weed species and wheat variety present in the field.

Fate, effectiveness, and persistence of soil-applied herbicides

Soil-applied pre-plant incorporated (PPI) and pre-emergence (PRE) herbicides are valuable tools: they control early season weeds and, if they have residual activity, can provide extended weed control. They are especially useful when wet weather delays post-emergence spraying or cultivation. However, miscalculations in the use of soil-applied herbicides could cause crop injury or fail to control weeds.

To minimize risk of crop damage due to soil-applied herbicides, it is important to understand the factors affecting their fate (Fig. 5). After spraying, the concentration and persistence of soil-applied herbicides depends on the herbicide properties, the weather conditions, and soil factors such as texture, pH, moisture and organic matter. Further, delayed emergence, due to cold weather, can result in fatal poisoning of the wheat seedling by some soil active herbicides (for example: triallate).

Knowing the length of time that an herbicide persists in soil can help reduce the risk of crop injury and determine the expected weed control period. For herbicides with residual activity, the label will list the crop rotation interval based on the chemical's half-life, defined as the length of time it takes for 50 percent of the herbicide to break down to inactive compounds. Herbicide adsorption and breakdown varies with soil temperature, soil pH, and soil moisture. For example, Montana's producers recently added Spartan (sulfentrazone) as a way to manage kochia, Russian thistle, buckwheat, common lambsquarter, pigweed species, and green foxtail in dry pea production. Unfortunately, farmers and researchers at Montana State University have reported wheat, barley, and dry pea injury due to Spartan carryover. Although it is unclear why Spartan carryover can be seen in some locations but not in others, it is likely due to a combination of soil factors, climate conditions, and seeding depth.

More information on approaches to reduce the spread and impact of herbicide resistance weeds can be found in Getting the Most from Soil-Applied Herbicides (Menalled & Dyer, 2004).

The overreliance on chemical control practices has lead to the selection of herbicide resistant weed biotypes. Herbicide resistance is the innate ability of a weed biotype to survive and reproduce after treatment with an herbicide dose that would normally be lethal. Producers should be aware that the selection of herbicide resistant weed biotypes threatens the long-term sustainability of this approach for weed control. In Montana, biotypes of wild oat, Persian darnel, kochia, and Russian thistle have been found to be resistant to several herbicides commonly used by wheat growers. Also, it is highly suspected that herbicide resistant green foxtail biotypes have developed in Montana.

To reduce the risk of selecting herbicide resistant biotypes, producers should rotate among herbicides with different sites of action, applied either as tank mixes, premix formulations or sequential applications. Also, producers should rotate management practices, such as the incorporation of timely cultivation. Finally, the development of an IWM program is an excellent tool to reduce the selective pressure on herbicide resistant weeds.

More information on approaches to reduce the spread and impact of herbicide resistant weeds can be found in Preventing and Managing Herbicide-Resistant Weeds in Montana (Menalled & Dyer, 2005).

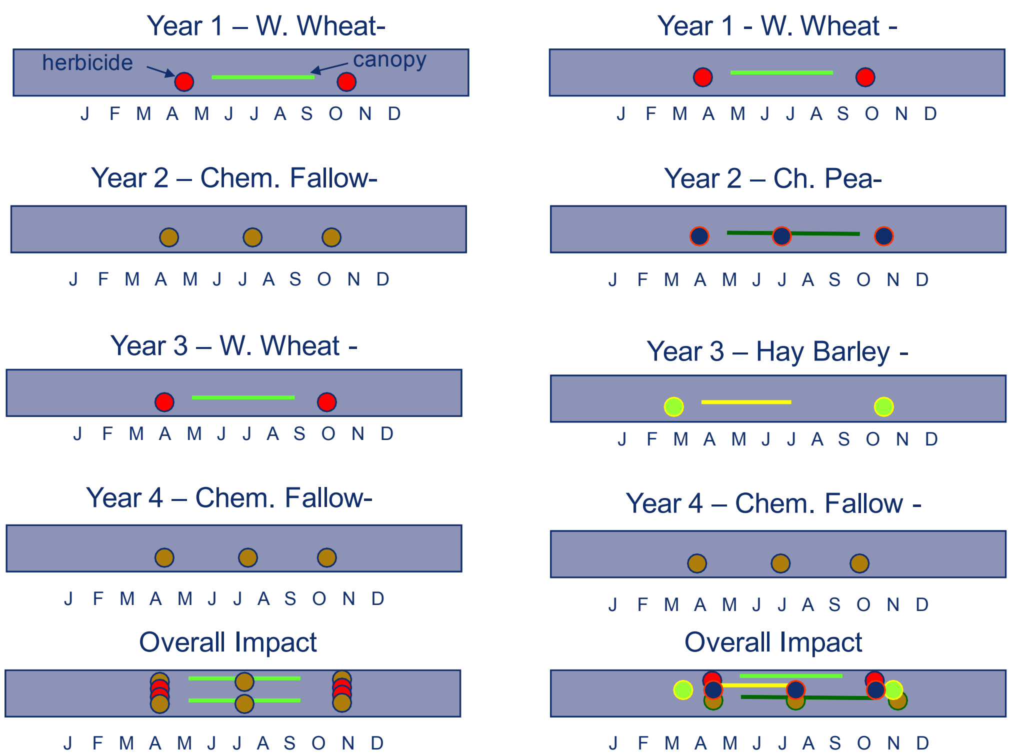

Figure 2. Conventional (left) and diversified (right) crop rotations differ in the type and timing of seeding dates, canopy closure times (lines) and herbicide applications (symbols). In the diversified rotations, variations in management practices and in crop type make it very difficult for a specific weed to adapt to the changing environmental conditions.

F. Menalled

Figure 3. Herbicide damage on lentils (left) and untreated control (right).

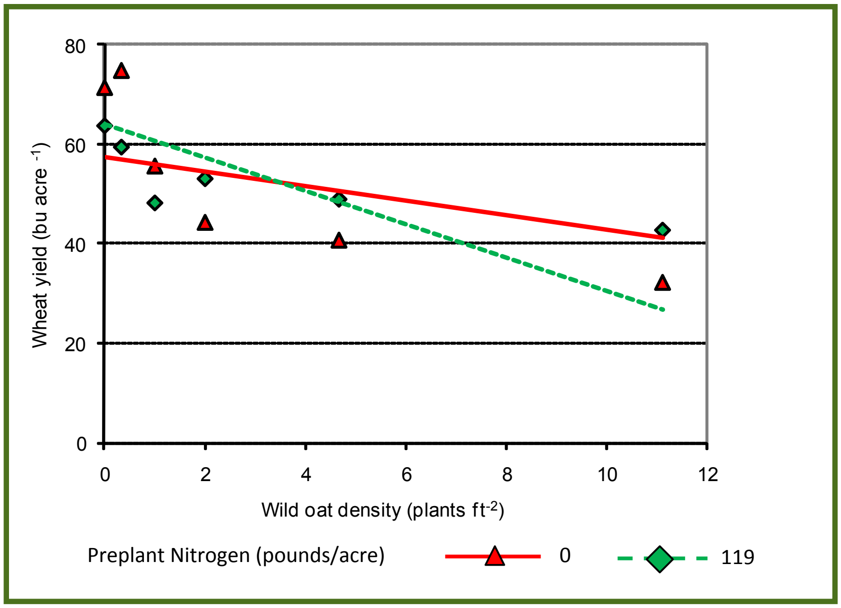

Figure 4. Impact of wild oats on wheat yield increases with nitrogen availability (Carlson & Hill, 1986)

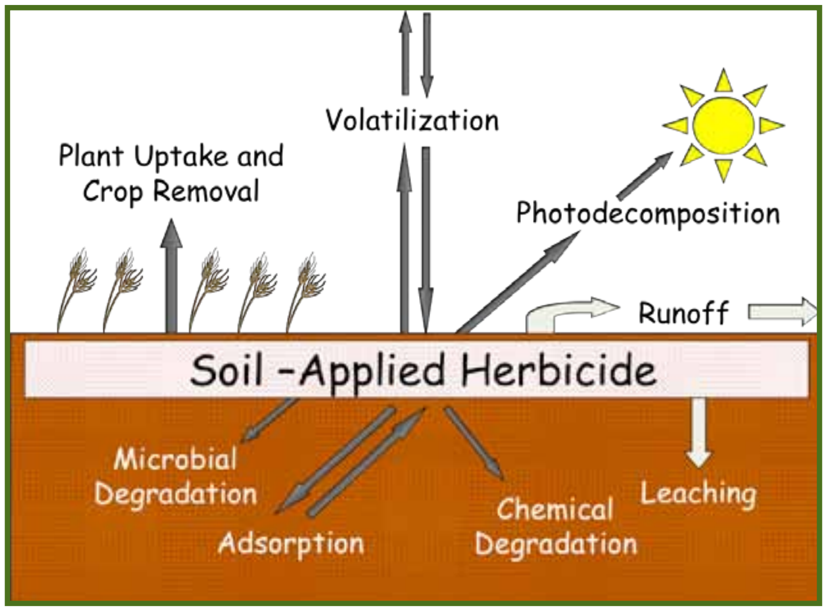

Figure 5. Factors affecting the fate of soil-applied herbicides.

Insect Management

The wheat stem sawfly (WSS), (*Cephus cinctus* (Hymenoptera:Cephidae)), is the most important insect pest of wheat in Montana, and probably the most difficult to manage. The WSS is a small ¾ inch long elongate insect with a black and yellow banding on the abdomen. It has chronically infested wheat in the Northern Great Plains region since the beginning of the last century and causes grower-estimated crop losses of $25 to $100 million annually in Montana.

RKD Peterson, MSU

Wheat stem sawfly

After mating, female sawflies lay their eggs within developing wheat stems, typically during June. The elongated, whitish larvae that superficially look like small caterpillars feed and complete their development within the wheat stem. The duration of the overall flight period of the emerging adults (3-5 weeks) and the internal feeding behavior of the larvae make their control with contact insecticides highly unreliable. Eggs and larvae within the wheat stem are protected from insecticide sprays. Controlling adults is unreliable because it is difficult to time adequate spray applications and modern insecticides do not persist for the duration of the flight period. To date, new systemic insecticides applied as seed treatments have not been effective. Both spring and winter wheat can be heavily infested and damaged.

Damage is caused in two ways. The feeding activity of the larvae within the stem reduces the flow of nutrients to the developing seed head, resulting in yield loss exceeding 20 percent under some circumstances. However, the most obvious yield loss is caused when the wheat breaks, falls over and lodges just before harvest. As the larvae mature, they cut a V-shaped notch around the stem, weakening it at the base. The stub is plugged by the larvae that overwinter within the stem, close to ground level. During the following spring the larvae continue developing to the next generation of adults that typically emerge and fly during June.

A variety of management options are available, some of which can be integrated together. One primary recommendation is the use of solid stem wheat varieties that were first developed in the 1940s. Solid stem varieties are not immune to damage, particularly at very high sawfly populations, but the solid stem can cause larval mortality up to 50 percent and it is also more resistant to lodging. An alternative strategy is to plant high yielding but susceptible hollow stem varieties, and reduce crop loss by swathing before significant lodging begins. This approach has no effect on the size of the sawfly population that will overwinter, it only conserves crop yield. Other management recommendations involve a variety of cultural practices that reduce sawfly numbers but not enough to impact population size the following year. Oats are resistant to sawflies and if used in a large-scale crop rotation, may aid in the reduction of sawfly populations.

RKD Peterson, MSU

Bracon cephi **(top), and *Bracon lissogaster* (bottom) are small parasitic wasps important for biological control of wheat stem sawfly.**

Another approach is to conserve natural enemies of the WSS. Two related species of small parasitic wasps, *Bracon cephi* and *B. lissogaster*, are the two most important natural enemies of WSS. These wasps have two generations per year as opposed to one for the WSS. The success of the second generation, which has much greater numbers, depends on the maturation of the wheat. Therefore, spring wheat typically has more parasitoids than winter wheat. Female parasitoid wasps lay their eggs through the wheat stem placing them directly onto sawfly larvae that they paralyze. The parasitoid larvae feed and develop within the sawfly larvae resulting in their death before they cut notches in the base of wheat plants. The parasitoid larvae then form pupae (the last stage before adults) within a cocoon located higher up in the stem, where they overwinter. The following spring, new adults emerge a few weeks after the sawflies begin flying. Traditional harvesting methods remove more of the parasitoids that are overwintering higher up in the stems, compared to sawfly larvae that overwinter closer to ground level. One recommendation is to cut the crop at one-third of its standing height, to conserve the natural enemies for the following season. Burning crop residue, grazing and heavy tilling can also kill the parasitoids, while light tilling or weed control with herbicides has no effect.

As the most important pest of wheat in the Northern Great Plains region, the WSS is also the most researched insect pest of wheat in this region. Research reviews were written as early as 1917. Research at MSU continues to investigate a variety of new management techniques. Ongoing research includes investigating the nature of resistance that oats have to sawfly larval feeding, pheromone traps, degree day models for monitoring, and planting attractive trap crops around less attractive varieties. More information about WSS biology and its management can be found at the MSU Department of Land Resources and Environmental Sciences wheat stem sawfly Web page.

Grasshoppers. More than 70 species of grasshoppers can be found in the Northern Great Plains Region but only a handful attack and damage small grain crops. Grasshopper populations tend to increase over a 2-4 year period and one or a few species make up the majority of the outbreak. Species that feed on a variety of host plants tend to move into small grain crops from the surrounding borders, including the two-striped *(Melanoplus bivittatus)*, migratory *(M. sanguinipes)*, clearwinged *(Camnula pellucida)*, differential *(M. differentialis)* and redlegged *(M. femurrubrum)* grasshoppers. Most grasshoppers complete their life cycle (egg, nymph, adult) during a single season.

Grasshopper Control in Gardens & Small Acreages

In Montana there are five grasshoppers of economic importance in small grain production. Clockwise from upper left: Clearwinged, migratory, redlegged, two-striped, differential.

Eggs hatch in the spring and the juveniles go through a series of molts to become adults later in the summer. Grasshoppers develop to adults by incomplete metamorphosis, meaning the juveniles resemble the adults in appearance. Nymphs are distinguished by their wing buds that increase during each molt, only becoming full-sized and functional for flying in the adult stage.

The Northern Plains Agricultural Research Laboratory (NPARL) in Sidney, Montana, maintains a Grasshopper Web site with extensive information on grasshopper identification, biology and management: Resources on this website include grasshopper Survey and Hazard Maps and a Lucid Electronic Key for identification.

Grasshoppers will move into small grain cropland as the summer progresses and emerging winter wheat can be at risk in the fall. Grasshopper densities should be visually estimated within the fields and along the field margins. Several estimates should be averaged. Monitoring methods including the 'Visual 18 ft^2 Method' are provided in "USDA Grasshopper Guidebook". When threshold levels are reached, chemical control is warranted.

Threshold levels of grasshoppers for Spring Wheat*

Number of Grasshoppers Per Square Yard		Treatment Required
Within Field	Field Border	
0-2	5-10	No, Non Economic
3-7	11-20	Light, Treatment Questionable
8-14	21-40	Moderate, Likely Economic
> 15	>41	Heavy, Requires Treatment

*For winter wheat, larger adult-stage grasshoppers moving into emerging fields are more difficult to control. Therefore thresholds for emerging winter wheat are lower at 3-7 grasshoppers per square yard within the field, or 11-20 per square yard within the field border.

Management

Spring Wheat. Grasshoppers typically move into small grain crops as the summer progresses. Early scouting to determine the source and density of grasshopper in the crop border is important. If required, treating the crop margin or the border area (150 feet wide) surrounding the crop may be adequate for control. If grasshopper densities are high, control may require up to a quarter-mile border treatment. Under extreme pressure, control may be difficult and multiple border treatments may be required. Border areas and crop margins should be monitored after treatment to ensure that grasshoppers do not re-enter the field. For larger areas such as rangeland, a "skip pass" tactic can be used, also termed the Reduced Agent/Area Treatment Program (RAATs). Ground or aerial equipment can be used to alternate treated and untreated strips in the target area reducing the cost of application. Control is achieved because grasshoppers are exposed to the insecticide as they move from untreated to treated areas. Insecticides such as zeta cypermethrin (Mustang Max), carbaryl (Sevin) and diflubenzuron (Dimilin – an insect growth regulator) are commonly used to control grasshoppers. Semaspore bait is a biological insecticide containing *Nosema locustae*, a microsporidia pathogen that infects and kills grasshoppers. Semaspore and Dimilin need to be applied earlier in the season and are not effective against adult grasshoppers.

Winter Wheat. Border treatments applied as insecticidal sprays or seed treatments are the main recommendation for protecting emerging winter wheat. Typically, spraying 150 feet beyond the edge of the crop or 1-2 passes with treated seed around the perimeter of the field is a sufficient border. Adult grasshoppers are more difficult to control, and the higher end of label rates are recommended. If grasshopper populations are very high they are difficult to control, borders up to ¼ of a mile and repeated applications may need to be considered. When applying border sprays, timing is critical. Border sprays need to be applied just before the wheat emerges; if it is applied too early there may not be enough residual, if it is applied too late, the damage may have already occurred. Systemic seed treatments eliminate the timing concern, but systemic insecticides require consumption, so some feeding damage will occur, but it should be reduced considerably. Carbaryl and pyrethroid insecticides are commonly used as sprays and imidacloprid is used for seed treatments. Dimilin and Semaspore bait are not effective against adult grasshoppers. In general, baits may not be as effective at controlling adults compared to the juvenile nymphs.

The Pale Western Cutworm *(Agrotis orthogonia* (Lepidoptera: Noctuidae) is a subterranean soft bodied caterpillar. It is grayish-white without spots or stripes with two distinct vertical brown bars on the front head capsule. A fully developed larva is about 1½ inch long.

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The adult moths emerge from the soil in late summer to early fall. The moths lay their eggs in loose soil. Some eggs may hatch in the fall, but the majority hatch in the spring. The pale western larva feeds underground on newly emerging plants, tillers, and roots. Because the pale western cutworms cut stems, they can destroy the plant's growing point resulting in plant or tiller death. Field damage many times appears as poor or spotty stands. Larvae can be found by scraping the soil surface and either passing the soil through a fine screen or looking for the small larvae against a white board or paper. Treatment may be justified if 2 to 3 small larvae (< ½ inch) per foot of row are present. Large larvae indicate near completion of feeding, and treatment may be too late to be cost effective.

The Army cutworm (*Euxoa auxiliaris* (Lepidoptera: Noctuidae)) larvae can periodically cause significant damage in wheat fields. The adult moths lay eggs beginning in late August just beneath the soil surface.

Army cutworm larvae *High Plains IPM*

These eggs hatch in the fall, and the cutworm species overwinters in the larval stage. The larvae are greenish-brown to greenish-gray with the dorsal (top) side darker than the ventral (underside). A narrow, pale mid-dorsal stripe is usually present. The head is pale brown with dark brown freckles.

Plant damage occurs as feeding on plant leaves and stems in early spring. They feed during the night and can occasionally be found feeding on overcast days. The small (1/16 inch) size of the early instar larva coupled with their nocturnal behavior makes them difficult to detect even though foliar damage is quite apparent. Treatment may be warranted when 4 to 5 army cutworm are found per square foot. More information on both species of cutworms can be found in the Pale Western and Army Cutworms in Montana (Blodgett, Johnson, Lanier, & Wargo, 2000). Also check the High Plains IPM Guide for relevant information on cutworms.

A cutworm activity monitoring program is conducted by Montana State University Extension. Volunteers, including many county agents, set and monitor pheromone traps specific for both the pale western and the army cutworm. Maps and model predictions of potential problems for these insects can be found online at Cutworm.org.

Wireworms (many different species) are slender, jointed hard-bodied insects that can sometimes cause significant damage in wheat and other small grains. Wireworms are the larval stage of click beetles. Early larval stages are white in appearance and feed on germinating seeds or young seedlings. Larvae have three pairs of legs located just behind the head, with their last abdominal segment flattened. Larvae may reach 0.5 to 1 inch in length. When fully grown, the larvae pupate in summer, and adults emerge the following spring. The females then lay eggs

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Juvenile wireworms (left) remain in this growth stage for several years. Adult stage (right) also known as click beetles are not of economic importance.

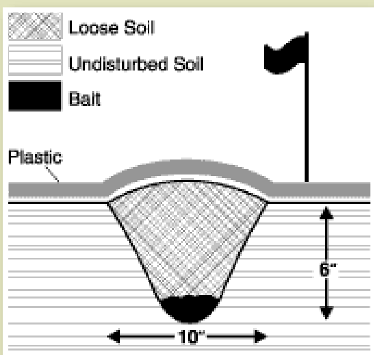
in loose or cracked soil. The young wireworms hatch and begin feeding on roots or germinating seeds. The larval stage can last anywhere from 2 to 5 years. This extended time as larvae can cause crop damage to recur in 'hot spots' over several years causing wheat stands to appear thin or as areas of poor germination.

Plant damage from wireworms can be confused with cutworm damage. With wireworms, damaged plants will be wilted and discolored, but the plant remains attached to the root. With cutworms, the plants are usually cut off completely at or near the soil surface. Topsoil down to approximately 6 inches should be sieved to look for wireworms, repeating the process at different areas of the field. When populations exceed an average of two larvae per bait station, insecticide seed treatment may be necessary. Generally, healthy, well-fertilized plants tend to outgrow wireworm damage. For wireworm control, seed treated with approved insecticides has proven effective. More information can be found at the High Plains IPM Guide.

Monitoring for wireworms

Wireworms can be monitored using a bait station. This is a good approach because wireworm impacted areas are not always consistent from one year to the next. To create a bait station: Bury ½ cup of wheat or a 50:50 mix of presoaked wheat or corn in a hole measuring 3-4 inches deep and 9-10 inches wide. Wireworms are attracted to the germinating seed. The seed should be covered with loose soil and slightly mounded in a dome shape, and covered with black plastic to warm the soil. Bait stations, marked with a flag so they can be easily located, should be deployed 2-3 weeks prior to planting. A threshold of two or more wireworms per bait station may warrant treatment with an insecticide.

Wireworm bait stations



graphic courtesy of www.ag.ndsu.edu/pubs/plantsci/pests/e199-1.htm

P. Glogoza, Univ. of MN

Orange wheat blossom midge.

Orange wheat blossom midge (*Sitodiplosis mosellana (Diptera: Cecidomyiidae)*) has a broad distribution in the Northern hemisphere. Economic damage to wheat by this insect has been reported in the Canadian prairies as well as North Dakota, Montana and Idaho. In Montana, economically damaging infestations have occurred in Flathead County around the Kalispell area. However, the insect has also been present in the northeastern part of Montana for some time.

The small orange-colored midge resembles a mosquito in appearance, but is about half the size. Adults emerge after pupating in the soil in late June or early July. After mating, the short-lived females lay their eggs on newly emerged wheat heads. The eggs hatch and the small orange larvae feed on the developing kernels, reducing yields and grain quality. The larvae then fall to the soil and overwinter in cocoons.

The crop is most susceptible to damage from early heading through pollination. Damage to the crop is not readily visible since the infested wheat heads have no external symptoms. As such, the only way of detecting their presence is to thresh the heads and inspect the kernels. The adult insect can be monitored by scouting fields at dusk, or by the use of pheromone traps and sticky traps. Several insecticides are labeled for control, but timing is critical. Economic threshold levels for Montana have not been established.

Researchers at MSU and the Northwestern Agricultural Research Center are currently evaluating spring wheat varieties for resistance to the orange wheat blossom midge. Insecticide efficacy trials are being conducted as well as temperature-based models to predict the development of the insect.

Aphids are small insects with sucking mouthparts which they insert into the host plant. Aphids can reproduce asexually and their populations can expand quickly if conditions permit. Damage to small grains can occur directly or indirectly from feeding. English grain aphids can move to the wheat head during the boot stage where they cluster around the bracts. If aphid numbers are high enough, the wheat kernels shrivel as a result of feeding damage.

Russian wheat aphid.

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Greenbug and Russian wheat aphids damage small grains by injecting toxic saliva into the plant as they feed. As they suck plant sap, the aphid injects toxic salivary secretions into the plant cells. Yellow or reddish stippling on the leaves is a result of the toxin that kills the plant cells. Aphids also damage crops indirectly by vectoring viruses. The greenbug and English grain aphids both can be vectors of the barley yellow dwarf virus that can infect wheat. For more information refer to Aphids of Economic Importance in Montana (Tharp, Blodgett, & Denke, 2005).

The High Plains IPM Guide lists management recommendations for aphid that periodically cause economic damage in Montana, such as the greenbug, Russian Wheat and English grain aphids which periodically cause economic damage.

Harvesting and Straw Management

Most modern harvesting equipment does an excellent job in threshing and harvesting grain. Follow the manufacturer's guidelines and watch for changing conditions during the course of the day to adjust the machine appropriately.

Management of the next crop begins with how straw is managed for this harvest. An even distribution of straw and chaff across the full cutting width of the combine helps reduce the chances of problems with direct seeding the next crop. Where straw is uniformly spread, chemical weed control is enhanced, reducing either application frequency or a need for tillage. For irrigated production, the large volume of straw can be difficult to manage. In some cases, baling, disk ripper tillage, or plowing may be necessary to remove straw. Burning straw is not a recommended practice and can lead to reduced soil organic matter levels if conducted frequently.

For dryland production, retaining tall stubble is important to prevent wind erosion and to help trap snow. Wheat should be cut as high as possible without leaving low-growing heads. Stripper headers which strip grain from the stem without cutting straw can be a good choice. A higher cutting height also reduces the amount of material passing through the combine, resulting in cleaner grain and less residue to spread. Conservation of standing residue is critical in sustaining wheat stem sawfly parasitoids. Unloading grain while moving will help prevent building straw piles. If you must stop, pull out and let the combine clear before unloading.

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