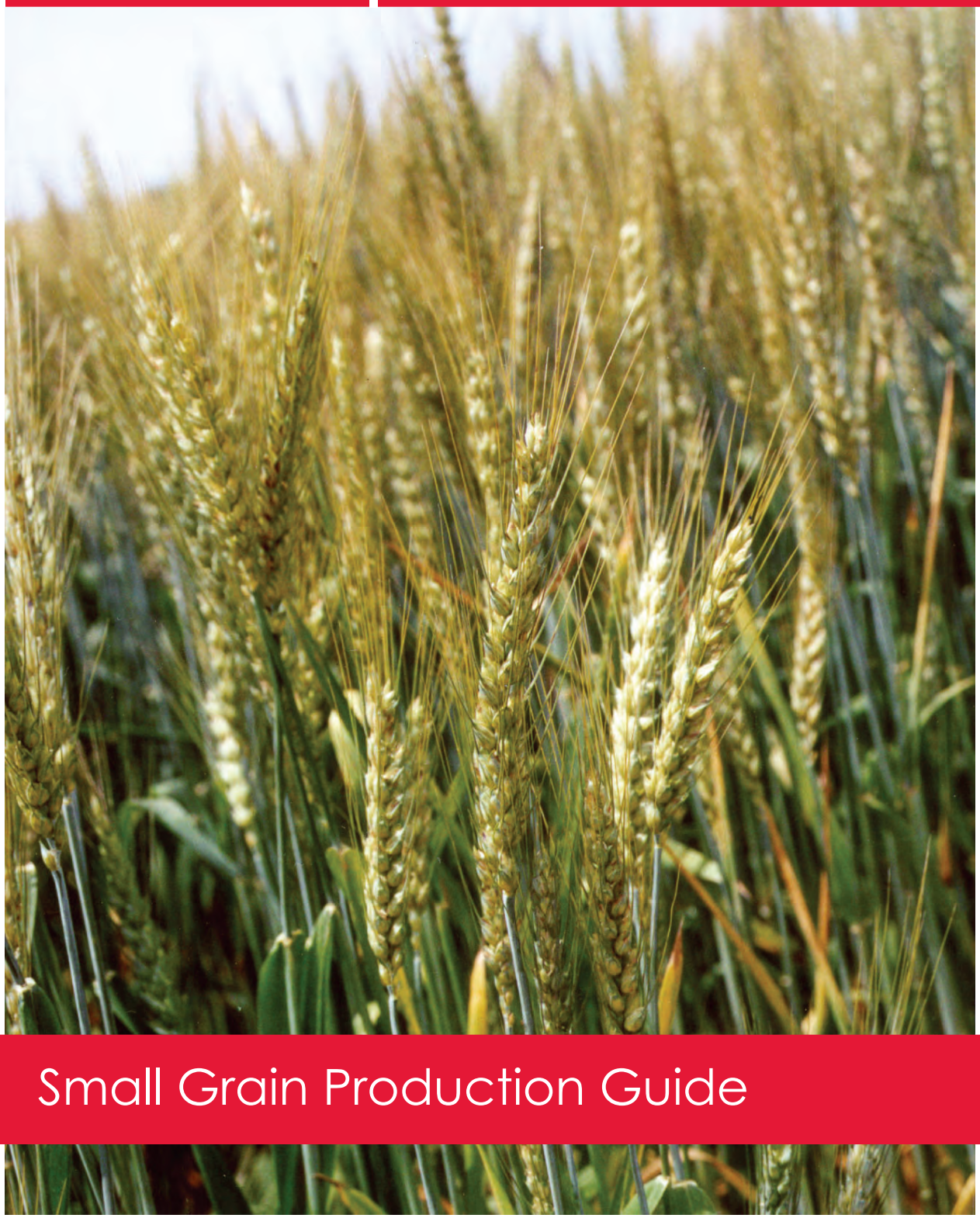
NC STATE UNIVERSITY

Revised March 2013



Small Grain Production Guide

North Carolina Small Grain Growers Association Inc. 1986

NC State University
A&T State University
COOPERATIVE EXTENSION
Empowering People · Providing Solutions

Small Grain Production Guide
Revised March 2013

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Published by

North Carolina Cooperative Extension Service

College of Agriculture & Life Sciences

North Carolina State University

Acknowledgments

This publication is supported in part by a grant from the NC Small Grain Growers Association, Inc. The association provides funds to supplement public appropriations and research programs at NC State University for the benefit of the small grain industry, general consumers, and the public at large.

Contents

1. Small Grain Growth And Development

By Randy Weisz

Small grains respond best to inputs when they are applied at specific growth stages. Therefore, it is important to understand how small grains develop so you can identify the different growth stages and properly time applications of pesticides, nitrogen, and other inputs. Small grain development can be divided into four phases: vegetative growth or tillering, stem extension, heading and flowering, and kernel formation and ripening. The specific growth stages associated with these phases have been described in several scales. The most popular scales are the Feekes and Zadoks stages of development (Table 1-1). Both scales will be described in this chapter, but we will use the Zadoks system in the rest of this production guide.

Vegetative Growth And Tillering

In NC, wheat is typically planted from mid-October through late November. Plants emerge about one week after planting (Feekes 1 or Zadoks 11, see Figure 1-1), and leaves begin to develop on the mainstem or shoot. When the fourth leaf unfolds, the first tiller starts to grow (Feekes 2 or Zadoks 21), and a new tiller is produced with every subsequent unfolding of a leaf on the mainstem. Tillering continues as long as the plants are healthy, unstressed, and the temperature is warm. Tillers are important because each tiller can only produce one grain head, and tillers that develop in the fall often produce the largest heads and contribute the most to crop yield. Tillering slows down or stops when winter weather turns cold. When the weather warms up again in late January or February, another brief period of further vegetative growth occurs when spring tillers can grow if nitrogen is available. In NC, tillering and vegetative growth usually end between late Febuary and mid-March (Feekes 4-5 or Zadoks 30).

Emergence
Feekes 1
Zadoks 11

Three leaves
Feekes 1
Zadoks 13

First Tiller
Feekes 2
Zadoks 21

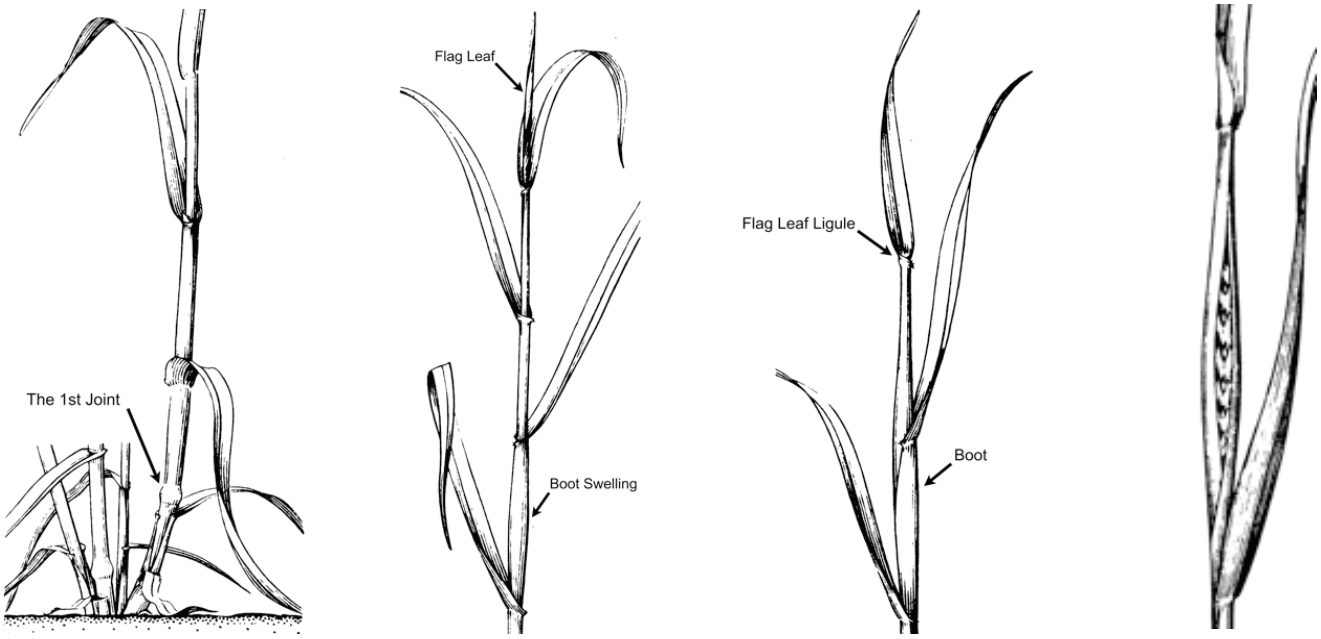
Three Tillers
Feekes 2
Zadoks 23

Tillering Ends
Feekes 4-5
Zadoks 30

Figure 1-1. Vegetative growth and tillering phase of wheat development. More details and pictures of these growth stages can be found online: http://www.wheatbp.net/cgi-bin/grain3.pl.

Stem Extension

During Feekes growth stage 4-5 or Zadoks 30, small grains switch from producing tillers to starting reproductive growth. In the first phase of reproductive growth, the stems extend and the plant grows taller. The *growing point*, which was below ground during tillering, moves upward through the elongating stem and begins the transition into what will become a head of grain. The first easily



First Joint
Feekes 6
Zadoks 31

Flag Leaf Visible
Feekes 8
Zadoks 37

Flag Leaf Ligule Visible
& Boot Swollen
Feekes 9 to 10
Zadoks 39 to 45

Boot Splitting
Feekes 10
Zadoks 47

Figure 1-2. Stem extension. More pictures of these stages can be found online at: http://www.wheatbp.net/cgi-bin/grain3.pl.

¾ Of Head Visible	Fully Headed	Flowering
Feekes 10.4	Feekes 10.5	Feekes 10.51 to 10.53
Zadoks 56	Zadoks 58	Zadoks 60 to 68

Figure 1-3. Heading and flowering. More pictures of these growth stages can be found online: http://www.wheatbp.net/cgi-bin/grain3.pl.

detected sign that this has started is the appearance of the first *node* or *joint* at Feekes growth stage 6 or Zadoks 31 (see Figure 1-2). The joint is a small swelling of the stem that somewhat resembles a joint on a human finger. As the stem continues to develop, several joints may appear. Knowing this is important for the small grain producer: the developing grain head is always inside the stem just above the highest joint. That means that if the stem is damaged by being driven over, a freeze, or lodging, the developing head is also likely to be damaged. Additionally if liquid nitrogen fertilizer is applied after jointing, the developing grain head is almost always burned, resulting in potential yield reductions.

The *flag leaf* is the last leaf to develop on the small grain plant. The growth stage when it first appears at the top of the stem is defined as Feekes 8 or Zadoks 37. As the flag leaf unfolds, the *ligule* or *collar* at the base of the leaf become visible at Feekes 9 or Zadoks 39. At this time the developing grain head is getting large enough that the stem containing it swells. This swelling is called the *boot*. As the grain head continues to grow it eventually causes the boot to split open at Zadoks 47.

Heading and Flowering

The plant starts the heading phase of development when the first spikelet has emerged from the boot at Feekes 10.1 or Zadoks 50. Over the next few days the grain head will fully emerge from the boot at Feekes 10.5 or Zadoks 58 (see Figure 1-3). About one week later, the head will begin to shed pollen as flowering begins.

Photo 1-1. Soft dough. Feekes growth stage 11.2 or Zadoks 85.

Kernel Formation

A few hours after pollination, grain kernels begin to form. Dry matter starts accumulating in the kernels, and a clear to milky fluid can be squeezed from them. This is known as the *milk stage* of kernel formation. Forage harvest during the milk stage results in the best combination of nutrient quality and yield. With continued growth and water loss, the kernel content changes from a milky fluid to a doughy or mealy consistency. This is called the *soft dough* stage. At soft dough, the green color of the head begins to fade (Photo 1-1) and harvesting forage at this time results in maximum dry matter

yield. When the water content of the kernels drops to about 30 percent, the plant loses most of the green color but the kernels can still be cut by pressing with a thumbnail. This is called the *hard dough* stage. This marks the end of all insect and disease pest management. When the kernels reach 13 to 14 percent moisture, the grain is *harvest ripe* (Photo 1-2).

Photo 1-2. Harvest ripe. Feekes growth stage 11.4 or Zadoks 92.

References

Some materials in this chapter were adapted from these references:

Alley, M. M., D. E. Brann, E. L. Stromberg, E. S. Hagood, A. Herbert, and E.C. Jones. 1993. *Intensive Soft Red Winter Wheat: A Management Guide* (Publication 424-803). Blacksburg: Virginia Polytechnic Institute, Cooperative Extension Service.

Hilfliger, E. (Ed.). 1980. *Wheat-documenta*. CIBA-GEIGY, Technical Monograph. Basle, Switzerland: CIBA GEIGY Ltd

Strand, L. 1990. *Integrated Pest Management for Small Grains* (Agricultural and Natural Resources Publication 3333). Oakland, CA: University of California Statewide IPM Project.

Table 1-1. Feekes and Zadoks scales of small grain development.

Feekes	Zadoks	General Description
Vegetative Growth & Tillering		
1	10	1st leaf through coleoptile
	12	2nd leaf unfolded
	13	3rd leaf unfolded
2	21	Main shoot and 1 tiller
	22	Main shoot and 2 tillers
	23	Main shoot and 3 tillers
3	26	Main shoot and 6 tillers
4-5	30	Tillering ended, leaf sheaths strongly erected
Stem Extension		
6	31	1st node detectable
7	32	2nd node detectable
8	37	Flag leaf just visible
9	39	Flag leaf ligule visible
10	45	Boots swollen
Heading and Flowering		
10.1	50	1st spikelet visible through split boot
10.2	52	¼ head emerged
10.3	54	½ head emerged
10.4	56	¾ head emerged
10.5	58	Head fully emerged
10.51	60	Start of flowering
Kernel Formation		
10.54	71	Milk stage - watery ripe
11.1	75	Milk stage - medium milk
11.2	85	Soft dough
	87	Hard dough
11.3	91	Dry matter accumulation ends
11.4	92	Harvest ripe

2. Wheat Enterprise Budgets

By Randy Weisz and Ron Heiniger

In NC, wheat is grown in a double-cropped soybean production system. This allows the risk of crop failure to be spread across two harvests and increases income potential. A full-season soybean budget is included for comparison with wheat double-cropped bean production. At the wheat and soybean prices that the market has been offering in 2012 and 2013 this double-cropped system is highly profitable. The wheat budgets presented here are based on practices outlined throughout this production guide. If you have a smaller farm, smaller equipment, or use more inputs than assumed in these budgets, costs will be higher than those shown in the following tables. Please note that these budgets are for planning purposes only.

Items for All Wheat Bean Budgets

- Wheat and soybeans are planted with a Great Plains 22-foot wide no-till drill.
- Pre-plant fertilizer to provide 27 pounds N, 70 pounds P_2O_5, and 100 pounds K_2O per acre is applied by a commercial applicator as 152 pounds of diammonium phosphate (18-46-0) and 167 pounds of potassium chloride (0-0-60).
- Lime is applied once every three years and is prorated across each season.
- All herbicides, fungicides, insecticides, and top-dress N-fertilizer are applied using a HiBoy with a 90-foot boom.
- A broadleaf herbicide is applied in February.
- Top-dress N (100 pounds per acre) is applied in March as 30% N solution.
- A fungicide is applied to the wheat between flag leaf and heading.
- An insecticide is applied to the wheat either in March tank-mixed with top-dress N, or in April tank-mixed with the fungicide.
- Wheat and beans are harvested by combine with a 30-foot wide header.
- All soybeans are Roundup Ready planted no-till.
- A herbicide application is made to the soybeans pre-plant to help prevent development of glyphosate resistance.
- Glyphosate is applied post-emergence.
- An insecticide is applied to all soybean acreage in August.
- One-fourth of the land in production is rented at $100 per acre.

Conventional-Till Wheat No-Till Beans Budget

- In the fall, field preparation is made with two passes of a 30-foot-wide disk harrow, and one pass with a 29-foot-wide field cultivator.
- Wheat is planted at 1.5 million seeds per acre (35 seeds per square foot) or about 2.4 bags of seed per acre.
- Soybeans are planted at 160,000 seed per acre.

No-Till Wheat No-Till Soybeans Budget

- In the fall, field preparation is limited to one application of glyphosate applied pre-plant.
- Wheat is planted at about 2.7 bags of seed per acre.
- Soybeans are planted at 160,000 seed per acre.

Full-Season No-Till Soybean Budget

- This budget is identical to the double-cropped soybean budgets except that soybeans are planted in May and expected to yield more, no pre-plant N is applied, and the rates of P_2O_5, and K_2O are reduced.

Table 2-1. No-till wheat and double-cropped no-till *Roundup Ready* soybean budget.

	Unit	Quantity	Price or Cost/Unit	Total per Acre	Your Farm
1. GROSS RECEIPTS					
Wheat	BU	55	$8.00	$440.00	_____
Soybeans	BU	30	$14.00	$420.00	_____
			TOTAL RECEIPTS:	$860.00	_____
2. VARIABLE COSTS					
Wheat seed	BU	2.7	$15.00	$40.50	_____
Soybean RR seed	THOU.	160	$0.36	$57.60	_____
Pre-plant fertilizer					
DAP	LBS	152	$0.36	$54.72	_____
Potassium chloride	LBS	167	$0.32	$53.44	_____
Commercial spreading	ACRE	1	$6.00	$6.00	_____
Top-dress N (30% solution)	LBS	90	$0.62	$55.80	_____
Lime (Prorated)	TON	0.33	$48.50	$16.01	_____
Herbicides for wheat	ACRE	1	$21.54	$21.54	_____
Herbicides for soybeans	ACRE	1	$33.65	$33.65	_____
Fungicides for wheat	ACRE	1	$10.80	$10.80	_____
Insecticides for wheat	ACRE	1	$4.63	$4.63	_____
Insecticides for soybeans	ACRE	1	$11.85	$11.85	
Crop insurance for wheat	ACRE	1	$6.00	$6.00	_____
Crop insurance for beans	ACRE	1	$10.00	$10.00	_____
Hauling wheat	BU	55	$0.15	$8.25	_____
Hauling soybeans	BU	30	$0.15	$4.50	_____
Tractor/Machinery	ACRE	1	$25.48	$25.48	_____
Labor	HRS	1.35	$7.25	$9.79	_____
Interest on Op. Cap.	DOL	$190.09	6.50%	$12.36	_____
			TOTAL VARIABLE COSTS:	$442.91	_____
3. INCOME ABOVE VARIABLE COSTS:				**$417.09**	_____
4. FIXED COSTS					
Tractor/Machinery	ACRE	1	$39.06	$39.06	_____
			TOTAL FIXED COSTS:	$39.06	_____
5. OTHER COSTS					
Land rent	ACRE	0.25	$100.00	$25.00	_____
General overhead	DOL	$442.92	4.5%	$19.93	_____
			TOTAL OTHER COSTS:	$44.93	_____
6. TOTAL COSTS:				**$526.90**	_____
7. NET RETURNS TO RISK AND MANAGEMENT:				**$333.10**	_____

Table 2-2. Full-till wheat and double-cropped no-till *Roundup Ready* soybean budget.

	Unit	Quantity	Price or Cost/Unit	Total per Acre	Your Farm
1. GROSS RECEIPTS					
Wheat	BU	55	$8.00	$440.00	_____
Soybeans	BU	30	$14.00	$420.00	_____
			TOTAL RECEIPTS:	$860.00	_____
2. VARIABLE COSTS					
Wheat seed	BU	2.4	$15.00	$36.00	_____
Soybean RR seed	THOU.	160	$0.36	$57.60	_____
Pre-plant fertilizer					
DAP	LBS	152	$0.36	$54.72	_____
Potassium chloride	LBS	167	$0.32	$53.44	_____
Commercial spreading	ACRE	1	$6.00	$6.00	_____
Top-dress N (30% solution)	LBS	90	$0.62	$55.80	_____
Lime (Prorated)	TON	0.33	$48.50	$16.01	_____
Herbicides for wheat	ACRE	1	$10.57	$10.57	_____
Herbicides for soybeans	ACRE	1	$33.65	$33.65	_____
Fungicides for wheat	ACRE	1	$10.80	$10.80	_____
Insecticides for wheat	ACRE	1	$4.63	$4.63	_____
Insecticides for soybeans	ACRE	1	$11.85	$11.85	
Crop insurance for wheat	ACRE	1	$6.00	$6.00	_____
Crop insurance for beans	ACRE	1	$10.00	$10.00	_____
Hauling wheat	BU	55	$0.15	$8.25	_____
Hauling soybeans	BU	30	$0.15	$4.50	_____
Tractor/Machinery	ACRE	1	$27.96	$27.96	_____
Labor	HRS	1.76	$7.25	$12.76	_____
Interest on Op. Cap.	DOL	$183.59	6.50%	$11.93	_____
			TOTAL VARIABLE COSTS:	$432.47	_____
3. INCOME ABOVE VARIABLE COSTS:				**$427.53**	_____
4. FIXED COSTS					
Tractor/Machinery	ACRE	1	$43.93	$43.93	_____
			TOTAL FIXED COSTS:	$43.93	_____
5. OTHER COSTS					
Land rent	ACRE	0.25	$100.00	$25.00	_____
General overhead	DOL	$432.47	4.5%	$19.46	_____
			TOTAL OTHER COSTS:	$44.46	_____
6. TOTAL COSTS:				**$520.86**	_____
7. NET RETURNS TO RISK AND MANAGEMENT:				**$339.14**	_____

Table 2-3. Full-season no-till *Roundup Ready* soybean budget.

	Unit	Quantity	Price or Cost/Unit	Total per Acre	Your Farm
1. GROSS RECEIPTS					
Soybeans	BU	37	$14.00	$518.00	_____
		TOTAL RECEIPTS:		$518.00	_____
2. VARIABLE COSTS					
Soybean RR seed	THOU.	160	$0.36	$57.60	
Fertilizer					_____
Pre-plant P_2O_5	LBS	65	$0.41	$26.65	_____
Pre-plant K_2O	LBS	83	$0.55	$45.65	
Commercial spreading	ACRE	1	$6.00	$6.00	_____
Lime (Prorated)	TON	0.33	$48.50	$16.01	_____
Herbicides for soybeans	ACRE	1	$33.65	$33.65	_____
Insecticides for soybeans	ACRE	1	$11.85	$11.85	
Crop insurance for beans	ACRE	1	$10.00	$10.00	_____
Hauling soybeans	BU	37	$0.15	$5.55	_____
Tractor/Machinery	ACRE	1	$10.72	$10.72	_____
Labor	HRS	0.61	$7.25	$4.42	_____
Interest on Op. Cap.	DOL	$98.14	6.50%	$6.38	_____
		TOTAL VARIABLE COSTS:		$234.48	_____
3. INCOME ABOVE VARIABLE COSTS:				**$283.52**	_____
4. FIXED COSTS					
Tractor/Machinery	ACRE	1	$17.69	$17.69	_____
		TOTAL FIXED COSTS:		$17.69	_____
5. OTHER COSTS					
Land rent	ACRE	0.25	$100.00	$25.00	_____
General overhead	DOL	$234.48	4.5%	$10.55	_____
		TOTAL OTHER COSTS:		$35.55	_____
6. TOTAL COSTS:				**$287.72**	_____
7. NET RETURNS TO RISK AND MANAGEMENT:				**$230.28**	_____

3. Small Grain Variety Selection

Randy Weisz, Paul Murphy, and Christina Cowger

Keep Up to Date!

Small grain varieties generally have the highest yields and milling quality during the first couple of years after their release. Consequently, the varieties grown on a farm should change over time. This makes it important to keep up to date on newly released varieties and how they are doing in NC. Plant newer varieties on small acreage to assess performance. Plant the most consistent performers on most of the available cropland, and phase out the older varieties showing signs of succumbing to disease and insect pressures.

Getting Unbiased Information

The best source of unbiased public and private wheat variety performance information for NC is the *Wheat Variety Performance and Recommendations SmartGrains Newsletter* (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf), which is released every July at NC State University and prepared by Randy Weisz (in the Crop Science Department at NC State) and Christina Cowger (USDA–Agricultural Research Service, Plant Pathology Department). This newsletter is based on the *Official Variety Test Report* or OVT (www.ncovt.com), and additional Cooperative Extension variety testing projects around NC. This newsletter groups wheat varieties into four categories: above average yielding, above average but less consistently yielding, average yielding, and below average yielding. It also gives heading date and pest resistance information about each wheat variety.

The best source of unbiased variety performance information for other small grains is the OVT (www.ncovt.com) produced annually by the Crop Science Department at NC State University. It is also updated every July.

Additionally, producers in counties adjacent to VA may find the *Virginia Official Variety Test Report* to be valuable (http://pubs.ext.vt.edu/category/grains.html).

Guidelines for Specific Variety Selection

Avoid Varieties Not Adapted to North Carolina

All small grain varieties that have been in the OVT for more than one year are usually good candidates for production. Avoid investing in varieties that have not been entered into these tests because they usually are not adapted to NC's growing conditions and may be highly susceptible to local diseases or mature too late to follow with double-cropped soybeans. Only varieties that have been in the OVT for at least two years are included in the *Wheat Variety Performance and Recommendations SmartGrains Newsletter*.

Plant at Least Three Varieties

Small grain variety performance can vary greatly from one year to the next. This makes it nearly impossible to pick a single best variety. Consequently, producers should plant three or more varieties every season. Growing at least three varieties will reduce the risk of freeze injury, pest damage, and other forms of crop failure and maximize the potential for a high-yielding crop.

Pick High Yielding Varieties

Using the *Wheat Variety Performance and Recommendations SmartGrains Newsletter*, the "Above Average Yielding" varieties are good first choices. The next to consider are the "Above Average but Less Consistent Yielders." These are varieties that on average had high yield but are more risky. Finally, the "Average Yielding Varieties" are likely to

produce acceptable yields but may not win a yield contest.

Avoid Spring Freeze Damage

Heading date is an important indication of how susceptible a variety will be to late-spring freeze damage. Early heading varieties are the most susceptible to freeze damage, while late heading varieties are the most likely to avoid yield loss due to spring freezes. Figure 3-1 shows how different varieties were damaged by the April 2007 freeze. Early heading varieties (shown in solid red) were severely damaged. Medium-early heading varieties (striped red) also tended to be more severely damaged. But late heading varieties (in black) were barely damaged at all. In 2008, spring freeze damage was observed at some locations and early and medium-early varieties were again the most damaged.

Heading date also indicates when a wheat variety should ideally be planted. Medium and late heading wheat varieties tend to do best when planted at the start of the planting season, and consequently should be the first varieties a producer plants. Early and medium-early varieties tend to produce the highest yields when planted later in the fall.

Barley is the earliest of the small grain species to head, so it is at greatest risk of suffering spring freeze damage and yield loss. In NC, the variety Boone had been a long-time standard for barley producers and rarely suffered late-spring freeze damage. Current varieties such as Thoroughbred and Dan have similar heading dates as compared to

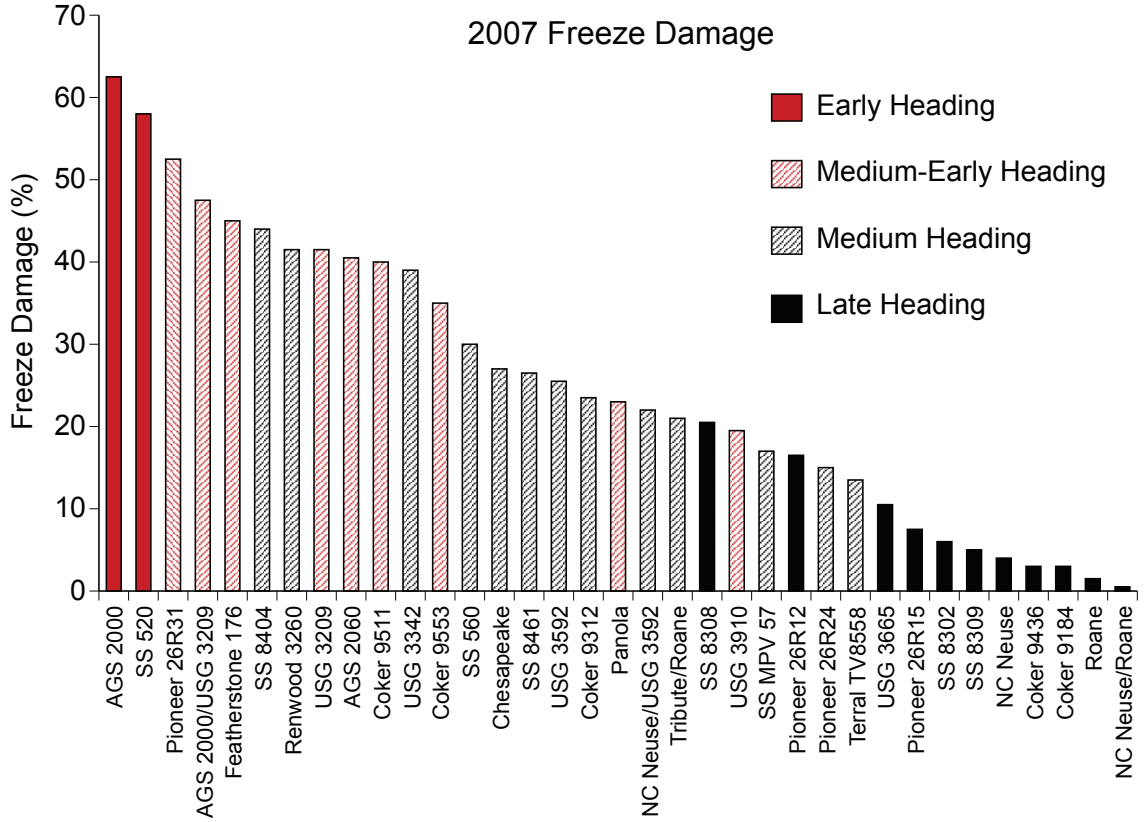


Figure 3-1. Damage caused by the April 2007 freeze for different wheat varieties. Early heading varieties (shown in solid red) were severely damaged. Medium-early heading varieties (striped red) also tended to be more severely damaged. But, late heading varieties (shown in black) were barely damaged at all.

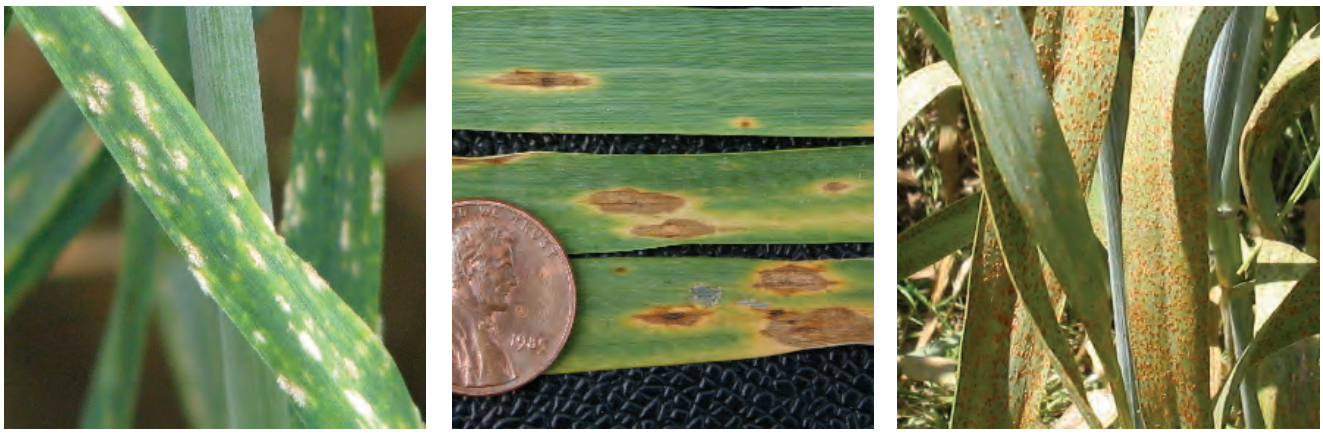


Photo 3-1. The three most common foliar fungal small grain diseases are powdery mildew (left), *Stagonosprora nodorum* blotch (center), and leaf rust (right). Wheat varieties that are resistant (or moderately resistant) to these diseases rarely require a fungicide application.

Boone. So barley varieties that head earlier than Thoroughbred or Dan should be viewed as having a greater risk of yield reduction from freeze damage.

Tailor Variety Selection to Match the Most Frequent Local Yield Robbing Factors

Variety selection is the best defense against most pest problems encountered in NC. The three most common foliar fungal small grain diseases are powdery mildew, leaf rust, and *Stagonosprora nodorum* blotch (Photo 3-1). Wheat varieties that are resistant (or moderately resistant) to these diseases rarely require a fungicide application. Two soilborne viral diseases (soilborne wheat mosaic virus and wheat spindle streak virus) are common in some areas, and variety resistance is the only control method for these diseases (Photo 3-2). *Fusarium* sp. head blight or scab (Photo 3-2) can be problematic primarily in years with warm, moist weather at heading, and variety resistance is the best control method producers have. In recent years, numerous wheat fields have suffered losses due to Hessian fly (Photo 3-2). Wheat growers with a history of Hessian fly problems should select Hessian fly-resistant varieties.

Here are some fine-tuning guidelines:

- Central piedmont. The most common yield robbers in this area include spring freeze damage, barley yellow dwarf virus, and scab. Varieties that are high yielding, late heading (to avoid freeze damage), and resistant to these two diseases would be ideal for the NC piedmont.

- Coastal plain. Powdery mildew, leaf rust, and soilborne mosaic virus are common wheat pests in the NC coastal plain. Ideal wheat varieties for this region should be high yielding and have resistance to all three of these diseases.

- Tidewater. Hessian fly and soilborne mosaic virus have been frequent yield robbers in the NC tidewater. Ideal wheat varieties are high yielding and have resistance to soilborne diseases. Where Hessian fly has been a problem, varieties with resistance to it should also be selected.

High Test Weight Varieties

High test weight is usually associated with good quality. A low test weight will result in dockage at the elevator. Some varieties consistently have superior test weight. Even a high test weight variety, however, will produce a low test weight grain if drought, potassium or sulfur deficiencies, fungal diseases, lodging, or wet weather at harvest occur. Coastal plain producers with deep sandy soils who need high test weight grain should watch for potassium and sulfur deficiencies.

Photo 3-2. Variety resistance is the best protection against *Fusarium* head scab (left). The only control method for soilborne mosaic virus (center) is variety resistance. Producers with a history of Hessian fly (right) should grow resistant varieties.

Lodging

Lodging is generally a greater problem in barley and oats than in wheat. Under intensive management practices, however, lodging will occur at a greater frequency in all small grains. A lodged crop can reduce test weight and slow combine operation.

Milling and Baking Quality of Wheat

Millers and bakers in NC use wheat for many diverse products, and certain varieties are superior to others for production of specific products. Therefore, if you plan to grow wheat for sale directly to a mill, discuss variety choice with the mill quality-control staff. Just like test weight, even a high-baking-quality variety can produce a low-quality grain if nitrogen, potassium or sulfur deficiencies, fungal diseases, lodging, or wet weather at harvest occur.

Special Consideration for No-Till Variety Selection

No-till producers should keep several additional facts in mind when choosing varieties. Tillering and fall growth are often slower in no-till small grains. Consequently, no-till producers often achieve higher yields if they plant during, or slightly ahead, of the opening planting dates (see chapter 5, "*Small Grain Planting Dates*" in this production guide: www.smallgrains.ncsu.edu/_Pubs/PG/Pdates.pdf).

Planting early requires special care to select varieties that (1) are "late" heading to avoid freeze damage, (2) have "good" Hessian fly resistance to prevent fall infestations (especially important in the NC coastal plain and tidewater), (3) have at least moderate resistance to barley yellow dwarf virus (especially important in the NC piedmont), and (4) have at least moderate resistance to powdery mildew if planting in areas where powdery mildew is common.

4. To Plant or Drill: Does Row Spacing Matter?

Randy Weisz

Many growers have wondered if they could plant wheat with the same implement they use to plant narrow-row corn or soybeans. Does it make a difference if wheat is drilled in 6- or 7.5-inch rows compared to being planted in 15-inch rows? If it does not make a difference, then the cost of replacing a drill could be avoided.

We tested this idea in Salisbury in 2012, and Andrew Gardner tested it in Union Couny in 2010 and 2011. Our results were similar to those previously reported from other states. Figure 4-1 shows the results from winter wheat row-spacing tests conducted at 35 locations across six states (NC, VA, GA, PA, OH, and IN). As row spacing increases, wheat yield declines. The lowest yields were with 20-inch rows. Fifteen-inch rows had an average yield (BLUE line, Figure 4-1) of 60.8 bushels per acre, 7.5-inch rows averaged 68.7 bushels per acre, and 4-inch rows averaged 76.1 bushels per acre. The difference between 7.5-inch and 15-inch rows was 7.9 bushels per acre. If the price of wheat is $7.50 per bushel, that comes to $59.25 lost per acre by planting instead of drilling wheat.

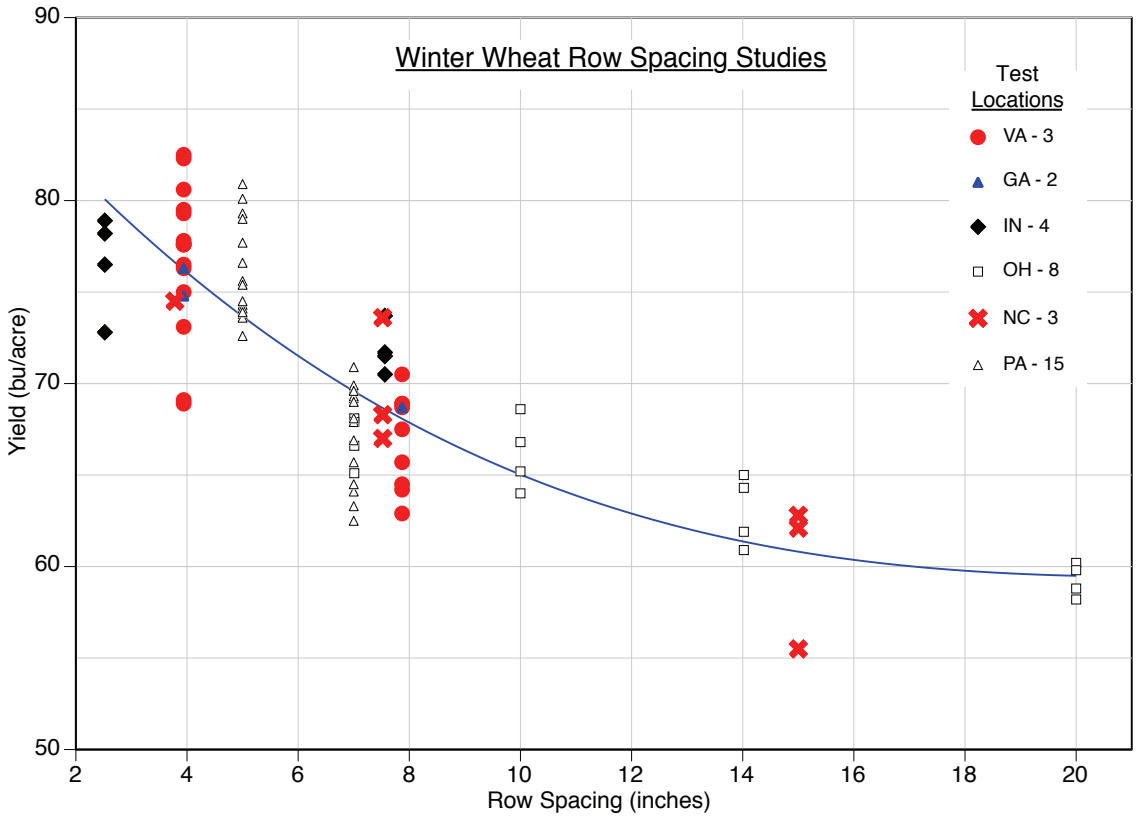


Figure 4-1. Wheat yields at different row-spacings from studies conducted in NC, VA, GA, PA, OH, and IN.

Some data from: Beuerlein, LaFever. Applied Agric. Res. 4:47-50, and 4:106-110; Gardner. www.smallgrains.ncsu.edu/_Pubs/OnFarm/Union2010.pdf, and www.smallgrains.ncsu.edu/_Pubs/OnFarm/Union2011.pdf; Joseph, Alley, Brann, Gravelle. Agron. J. 77:211-214; Johnson, Hargrove, Moss. Agron. J. 80:164-166; Marshall, Ohm. Agron. J. 79:1027-1030, and Roth, Marshall, Hatley, Hill. Agron. J. 76:379-383.

5. Small Grain Planting Dates

Randy Weisz and Ron Heiniger

For producers of small grains, the goal is to select a planting date that gives an opportunity to develop as many fall tillers as possible while avoiding potentially severe damage associated with fall insect and disease infestations or an early spring freeze. Small grain tillers produced in the fall are most likely to have large heads with kernels of high-test weight: the two components of a high-yielding crop. Fall tillers also tend to have stronger root systems and consequently may be more stress resistant. The key advantage to planting early in the fall is the opportunity to make the most of warmer temperatures. The warmer the weather, the more tillers are likely to be produced. Cold temperatures impede growth, so it is important to plant small grains while there is still enough time and mild weather for tillers to form before winter sets in. On the other hand, planting too early can result in increased risk of diseases such as barley yellow dwarf virus and powdery mildew, increased risk of Hessian fly infestations, and increased risk of spring freeze damage. The same warm temperatures that enhance wheat growth also promote the development of insects and diseases and shorten the period from emergence to flowering. At least one night below 32°F is required to reduce Hessian fly or aphid populations and to slow disease development. Therefore, the selection of a planting date for small grains is a balance between achieving good fall growth and avoiding severe damage.

Wheat

The traditional guideline for finding the right compromise between planting early enough to encourage tillering, but late enough to avoid insect and disease problems, has been to plant wheat within one week of the first frost. Figure 5-1 shows starting dates for wheat planting in NC. The dates shown in this map are one week earlier than the 30-year average local freeze dates for weather stations throughout NC. These dates mark the start of the wheat planting season. In most parts of the NC tidewater, coastal plain, and southern piedmont, planting on these dates will allow wheat plants to develop two to three additional large tillers by February 1. That puts the crop in an excellent position for high yield potential and reduces the likelihood of needing to apply two applications of N fertilizer in the spring. It also assures that some cold weather will occur shortly after the seedlings emerge to reduce disease and insect pest activity.

The dates shown in Figure 5-1, however, are often when soybean, cotton, and (in some parts of NC) peanut harvest is underway. This may force producers to plant later. Planting wheat later than the dates shown in Figure 5-1 can have a significant impact on a crop's yield potential. For example, based on average NC weather records, planting 14 days later than the dates shown in Figure 5-1 usually results in enough warm weather to produce only one additional large tiller per plant by February 1 in the NC tidewater and central to southern coastal plain. In the rest of the state, not enough warm weather may occur to get even a single additional large tiller to develop by February 1. This makes it very important to ensure that a late planted crop was drilled in at higher seeding rates (see chapter 7, "*Small Grain Seeding Rates*" in this production guide: www.smallgrains.ncsu.edu/_Pubs/PG/Srates.pdf) and to scout the wheat in late January to determine if an early N fertilizer application will be required in February to stimulate further tiller development in the spring (see chapter 8, "*Nitrogen Management for Small Grains*" in this production guide: www.smallgrains.ncsu.edu/_Pubs/PG/Nitrogen.pdf).

Barley, Oats, Rye, and Triticale

Barley and oats should be planted about 5 to 10 days earlier than the dates shown for wheat in

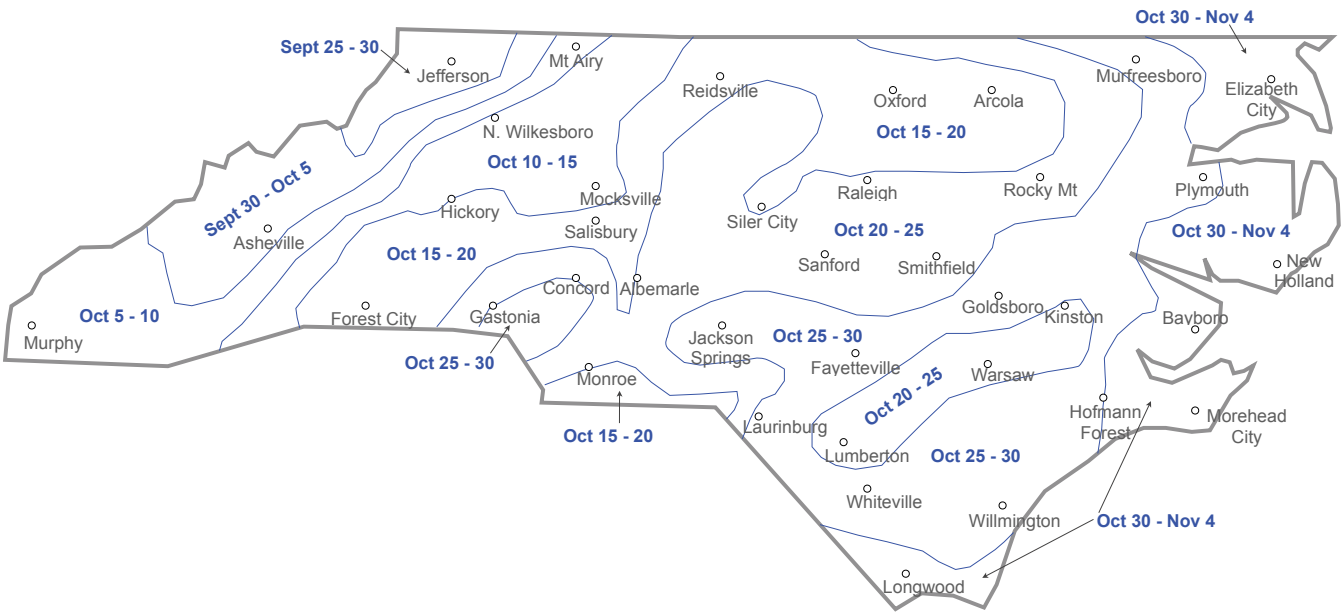


Figure 5-1. The start of wheat planting dates. The dates shown on this map are 7 days earlier than the date when there is a 50% chance of having a freeze.

Figure 5-1. Rye planting dates are similar to those for wheat. Triticale varieties that have been developed for NC, like Arcia, can be planted on the same dates as wheat. Trical triticale varieties that have been tested in NC and shown to head at the same time as wheat can also be planted on the same dates shown in Figure 5-1. However, some triticale varieties (such as Trical 498) are early heading, and need to be planted late to avoid spring freeze damage. It is important to know the maturity rating for the triticale variety before selecting a planting date.

Special Considerations for No-Till

Heavy residue left on the soil surface can reduce soil temperatures. This results in slower germination and tiller growth. Because fall growth can be reduced in no-till, planting small grains early becomes even more important. Establishing a healthy, uniform stand by planting close to the dates shown in Figure 5-1 may be a key to achieving high yields in no-till. Some successful no-till producers say they need to plant on or even a little earlier than these dates (see chapter 6 "*Beating Soybean Harvest: A Very-Early-Wheat-Planting System*" in this production guide: www.smallgrains.ncsu.edu/_Pubs/PG/VeryEarly.pdf).

Special Considerations for Hessian Fly

Hessian fly has become a serious wheat pest in NC. Because Hessian fly adults are killed by freezing temperatures, a traditional method for preventing Hessian fly infestation is to delay planting until after the first freeze (often called the *fly-free date*). The fly-free date concept has not worked well in NC (see chapter 11, "*Insect Pest Management,*" in this guide: www.smallgrains.ncsu.edu/_Pubs/PG/Insects.pdf). Often a "killing freeze" does not occur until December in many areas of NC, after most growers need to have wheat planted if they want to have enough fall growth to produce high yields. Delayed planting will only prevent Hessian fly infestations if a freeze has occurred.

6. Beating Soybean Harvest: A Very Early Wheat-Planting System

Randy Weisz

Why Plant Before Soybean Harvest

In NC, the ideal dates for planting wheat (see Figure 5-1: www.smallgrains.ncsu.edu/_Pubs/PG/Pdates.pdf) herald the beginning of soybean and cotton harvest. Consequently, wheat planting is often delayed until cold wet weather has set in, and wheat development suffers. Research in Virginia and NC has shown that up to 85 percent of the yield in a any given wheat field is made up by grain heads formed on tillers that developed in the warm fall weather. When planting is delayed, there is less time for fall tillers to develop and this results in reduced yield potential. This is especially true for no-till. Wheat planted no-till (especially in NC coastal plain and tidewater soils) tends to grow and tiller more slowly than when planted in conventionally tilled seedbeds. Planting early is one way to help no-till seedlings make up for this slower growth and produce more fall tillers. It would be ideal if wheat could be planted before the start of soybean or cotton harvest to take full advantage of the warm tiller-inducing fall weather.

Challenges and Solutions

In chapter 5, "*Small Grain Planting Dates*" (www.smallgrains.ncsu.edu/_Pubs/PG/Pdates.pdf), we stated that the ideal time to plant wheat was within 7 to 10 days of the first freeze. Planting earlier than that puts the crop at risk of early season insect damage, including wireworm (especially in no-till production in the NC coastal plain), Hessian fly, and aphid feeding that can spread barley yellow dwarf virus. One way to avoid these problems is to use an insecticidal seed treatment (such as GauchoXT or Cruiser/Dividend). These seed treatments can give about 19 days of protection from these insects. A second potential problem is too much fall tiller production resulting in very thick stands that may lodge before the end of winter. A good way to avoid this is to reduce seeding rates. Finally, many growers will say that they cannot plant too early because of the risk of spring freeze damage. The earlier wheat is planted, the earlier it heads out in the spring. Once wheat has headed, it becomes freeze tender and can lose yield if a freeze occurs. In NC most "early-heading" wheat varieties head in the first week of April. "Late-heading" varieties may head out one to two weeks later. Consequently, if there is a freeze the end of the first week in April, early-heading varieties may be damaged while the late varieties may escape.

Making It Work

There are five essential parts to the very early wheat-planting system.

Planting 10 Days to Two Weeks Early

Plant 10 days to two weeks earlier than the dates shown in Figure 5-1: www.smallgrains.ncsu.edu/_Pubs/PG/Pdates.pdf. Because the seed treatments used in this system only give limited protection, planting should not be more than about 14 days early. In the NC central piedmont (at Salisbury), we have been planting between September 29 and October 3. In the NC central coastal plain (at Kinston), we have been planting from October 6 through October 8. In the NC tidewater at Plymouth and Terra Ceia, we've planted between October 8 and 11.

Plant Only Late-Heading Varieties

Late-heading varieties have the lowest risk of damage from a spring freeze. These are the only

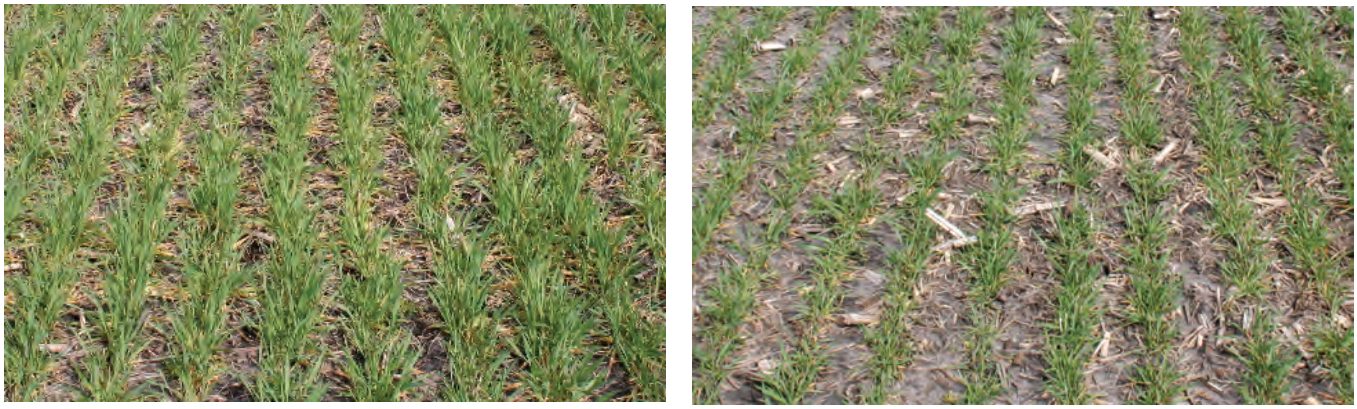


Photo 6-1. Even though the very-early-planting-system uses 30% less seed, it often results in denser stands due to greater tillering in the fall. *Left*: The very-early-planting system at Plymouth, NC, planted on October 8, 2009. *Right*: Normal wheat planting system also at Plymouth, planted on October 29, 2009. The photographs were taken on February 17, 2010.

varieties that should be used in the very early planting system. This system has been tested with NC-Neuse and Roane (two late-heading wheat varieties) for six years in Salisbury, and shown to work well.

Always Use an Insecticidal Seed Treatment

Treating all seed with an insecticidal seed treatment such as GauchoXT or Cruiser/Dividend is critically important. In our very early planting trials in the NC piedmont, using an insecticidal seed treatment usually resulted in a 10-bushel-per-acre yield advantage over untreated seed. In eastern NC, the seed treatment is critical to prevent Hessian fly, wireworm, and aphid infestations.

Plant at Reduced Seeding Rates

Early planting results in extra tiller development. To avoid excessive growth, wheat is planted with one-third less seed then normal (see chapter 7, "*Small Grain Seeding Rates For NC*" in this production guide: www.smallgrains.ncsu.edu/_Pubs/PG/Srates.pdf).

Restrict No-Tillage to the Piedmont

In the NC piedmont this system has worked well with no-till planting. In the NC coastal plain and tidewater, very early no-till planting is not recommended. This is due to the slower growth that young wheat plants exhibit when planted no-till in eastern NC. This slower growth combined with possible wireworm and Hessian fly damage can reduce no-till yields even with the insecticidal seed treatments. On the other hand, very early planting in eastern NC has worked well with conventional tillage.

Very-Early-Planted Variety Testing

Tests across NC have shown that when the five steps outlined above are followed, wheat yields are similar to those achieved when planting at the normal recommended times shown in Figure 5-1: (www.smallgrains.ncsu.edu/_Pubs/PG/Pdates.pdf) using normal seeding rates (Table 7-1: www.smallgrains.ncsu.edu/_Pubs/PG/Srates.pdf) and untreated seed. The very early planting even at the lower seeding rates allows the wheat time to tiller and often to produce a thicker stand than would normally be achieved (Photo 6-1). Yield results from trials conducted in Salisbury in 2009, 2010, 2011, and 2012 are shown in Table 6-1.

Table 6-1. Very-early-planting variety test results from Salisbury, NC. The tests were planted on Sept. 29 using reduced seeding rates, GauchoXT, and only late-heading varieties.

Late-Heading Wheat Varieties	Yield (bu/acre)			
	2012	2011	2010	2009
Pioneer 26R20	109.0			
DynaGro 9053	105.9			
Pioneer 26R12	101.3	131.5	99.7	106.1
DynaGro Shirley	101.2	133.2	102.8	
Branson	98.1	131.3		
Pioneer 25R32	93.6	127.2		
UniSouth Genetics 3665	91.2	133.5	92.2	102.4
AgriPro Coker 9436	91.1	130.3	86.9	85.5
VA Merl	90.6	133.2	92.9	
Pioneer 26R15	90.6		82.4	99.0
Southern States 8302	90.4	132.6	97.1	102.6
ARS Appalachian White	66.6			
DynaGro V9713		128.2	90.0	99.5
NC Yadkin		122.6		
NC Neuse		118.4	87.5	86.4
UniSouth Genetics 3725			91.1	
VA Roane			85.8	93.5

7. Small Grain Seeding Rates for North Carolina

Randy Weisz and Ron Heiniger

Wheat, Triticale, and Hulled Barley

The results from ten wheat seeding-rate studies (conducted in Virginia and North Carolina) are shown in Figure 7-1. In these studies certified seed with a high germination rate was planted on different sites at seeding rates ranging from about 0.6 million to over 2.0 million seeds per acre. All ten tests were planted using conventional tillage near the recommended dates shown in Figure 7-2 for North Carolina. In Figure 7-1 yield is shown relative to the highest yielding seeding rate in each test. So, for each of the ten tests, the yield at the highest seeding rate is set to 0.

As seeding rates range from 0.9 to 1.6 million seeds per acre, average yield (blue line in Figure 7-1) only varies by about 1 bushel per acre! The grey box in Figure 7-1 shows a broad range in seeding rates (1.1 to 1.5 million seeds per acre) that produced the highest average yields. As seeding rates drop below that, yield becomes highly variable. In some years when the fall weather was warm, these lower seeding rates yielded well. In other years when the weather did not favor rapid tillering, low seeding rates resulted in up to a 12 bushel loss. Seeding rates above 1.5 million seeds per acre generally resulted in lower yields probably due to higher disease levels and lodging.

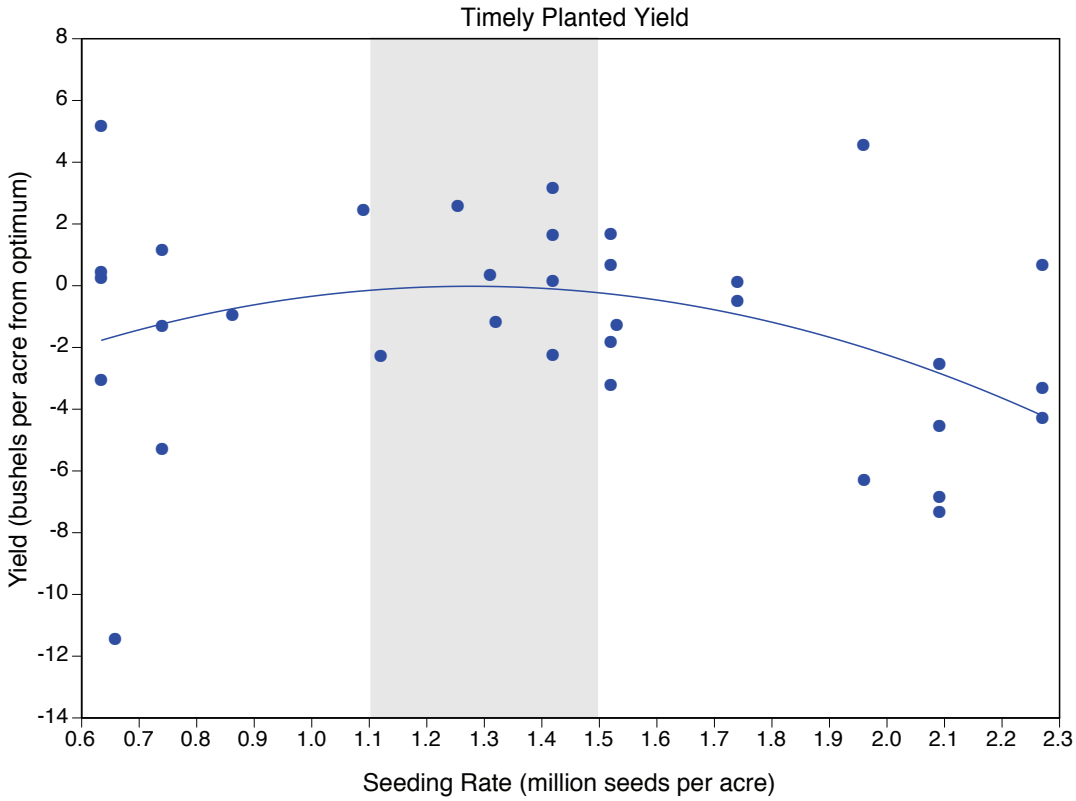


Figure 7-1. Ten wheat seeding-rate studies conducted using certified seed with high germination (at least 90 percent), planted into conventionally tilled seed beds and planted near the dates shown in Figure 7-2. Yield is shown as a percent of that at the highest seeding rate. Seeding rates ranged from 0.6 to 2.3 million seeds per acre. The grey box represents suggested seeding rates based on these tests.

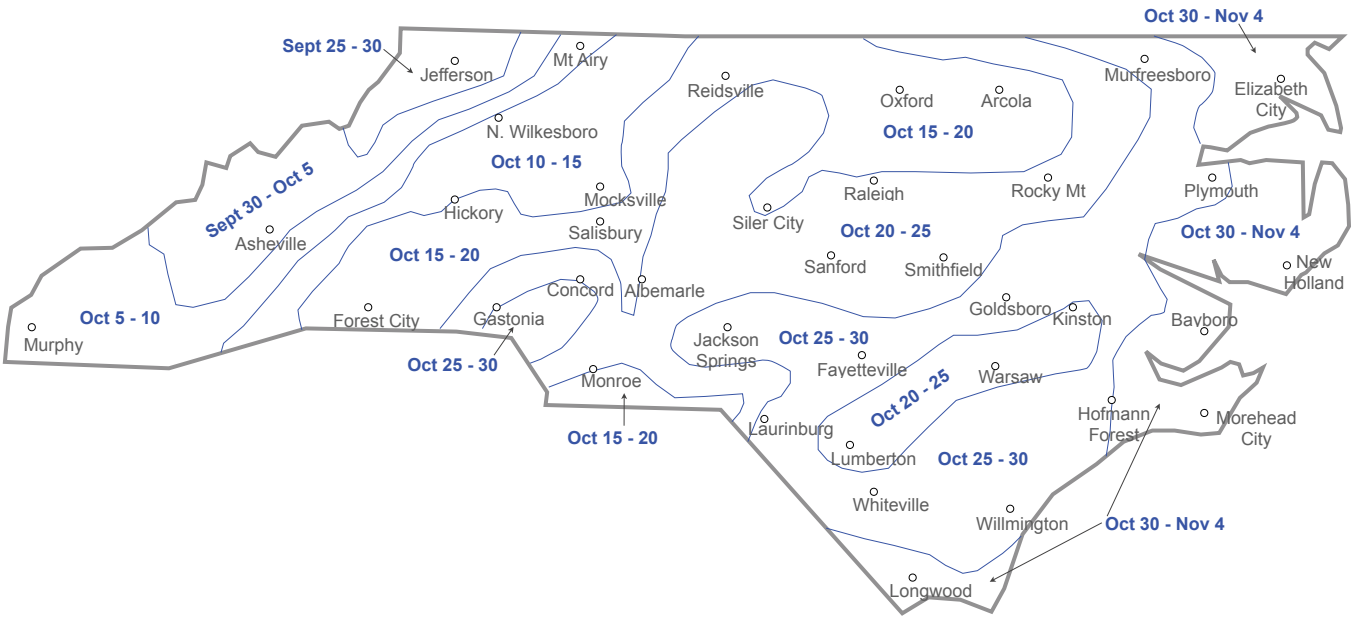


Figure 7-2. The start of wheat and triticale planting dates for NC. Timely planting for oats and barley is five to ten days earlier.

The grey area in Figure 7-1 shows an optimal range in seeding rates from 1.1 to 1.5 million seeds per acre. This range in seeding rates is similar to what other researchers have found. For example, Syngenta Seed has been doing wheat seeding-rate studies in the NC coastal plain. They report that optimum yields are frequently reached for most growers at around 1.1 million seeds per acre. They recommend 1.5 million seeds per acre for growers interested in intensive management. The intensive wheat management guide from the Virginia Polytechnic Institute recommends planting 1.31 to 1.52 million seeds per acre.

Many growers think about small grain seeding rates in terms of pounds of seed per acre. Table 7-1 shows how 1.31 and 1.52 million seeds per acre can be converted into more familiar units. The lower rate of 1.31 million seeds per acre is equal to 30 seeds per square foot. The higher rate (1.52 million seeds per acre) is the same as 35 seeds per square foot. But, the number of pounds of seed needed to reach these targets depends on seed size. A large seeded variety may only have 10,000 seeds per pound compared to a small seeded variety that could have up to 15,000 seeds in a pound. This makes planting a single number of pounds of seed per acre problematic. Table 7-1 shows that the ideal seeding rate of 1.31 to 1.52 million seeds per acre can range all the way from 87 to 152 pounds of seed per acre depending on seed size! It is important that growers consider seed size when selecting seeding rates based on pounds per acre!

Most drills have tables that indicate how to set the seed metering mechanism for a given seeding rate in pounds per acre. Ideally, if the seed size is known (for certified seed it is often printed on the tag attached to the bag), a grower could use Table 7-1 to determine the pounds of seed to plant per acre, and use the drill manufacturer's information to find the proper drill setting to plant that number of pounds per acre. However, experience has shown that using these factory settings can result in large over- or under-seeding. For example, in 2001 we calibrated a John Deere no-till drill to plant the correct seeding rate (based on Table 7-1) for 15 wheat varieties, each of which had half the seeds treated with GauchoXT seed treatment and half untreated. To produce the same seeding rate for each variety, we had to change the drill setting from 27 all the way to 45—depending on the variety and

Table 7-1. Wheat, triticale, and hulled barley seeding rates for conventionally tilled seed beds planted on time using a target of 1.31 to 1.52 million seeds per acre with 90 percent germination as a standard. These rates need to be increased by 20 percent for no-till.

Million seeds per acre:	1.31	1.52
Seeds per square foot:	30	35
Seed size (seeds per pound)	**Pounds of seed per acre**	
10,000	131	152
11,000	119	138
12,000	109	127
12,500	105	122
13,000	101	117
14,000	94	109
15,000	87	101
Drill row spacing (inches)	**Seed per drill-row foot**	
6	15	17
7	18	20
7.5	19	22
8	20	23

seed treatment! Our experiment revealed that the drill settings required to achieve the correct wheat-plant population varied widely among varieties and seed treatments and this variation was not reflected in the manufacturer's charts.

The best way to ensure a correct small grain seeding rate is to calibrate the drill for the specific seed being planted. The most accurate way to calibrate is to base seeding rates on the desired number of seed per drill-row foot. This number does not vary across seed sizes or change depending upon seed treatments. Table 7-1 gives target seeding rates in terms of seeds per drill-row foot across a range of drill-row widths. For example, Table 7-1 shows that if a grower has a drill with 7.5-inch row spacing, the correct seeding rate is between 19 and 22 seeds per drill-row foot (assuming planting is on time, the seed has at least 90 percent germination, and planting is into a conventionally tilled seed bed).

Hulless Barley

Hulless barley seed is more easily damaged then hulled seed. Consequently, hulless barley must be planted at higher seeding rates than traditional hulled varieties. Dr. Wade Thomason, the corn and small grain specialist at Virginia Tech, gives this guideline: When using high-quality hulless barley seed with at least 90 percent germination, the target seeding rate is 2.2 million seeds per acre or 50 seeds per square foot when using a conventionally tilled seedbed. Table 7-2 gives hulless barley seeding rates across a range of seed sizes and drill row widths.

Table 7-2. Hulless barley seeding rates for conventionally tilled seed beds using a target of 2.2 million seeds per acre or 50 seeds per square foot with 90 percent germination as a standard assuming planting is on time. These rates need to be increased by 20 percent for no-till.

Million seeds per acre:	2.2
Seeds per square foot:	50
Seed size (seeds per pound)	**Pounds of seed per acre**
10,000	218
11,000	198
12,000	182
12,500	174
13,000	168
14,000	156
15,000	145
Drill row spacing (inches)	**Seed per drill-row foot**
6	25
7	29
7.5	31
8	33

Oats and Rye

Oats should be planted at 2 bushels per acre. Rye should be planted at 1 to 1.5 bushels per acre.

Low Germ Seed

The seeding rates shown in Tables 7-1 and 7-2 are for seed with at least 90 percent germination. Some certified seed, and most bin-run seed, will not have germination rates this high. Consequently, the seeding rates in these tables need to be increased for seeds with a germination rate lower than 90 percent. Table 7-3 shows the increase required for different levels of germination.

Low Germ Seed Example

If a grower wants to plant wheat at the higher seeding rate of 1.52 million seeds per acre and has a variety with 12,500 seeds per pound, Table 7-1 indicates the recommended seeding rate would be 122 pounds of high germ seed per acre. A germ test indicates the seed has a germination rate of only 80 percent. Table 7-3 shows the seeding rate will have to be increased by 13 percent to compensate. Thirteen percent of 122 pounds is 16 pounds. So the grower would plant 122 + 16 = 138 pounds of this seed with lower germ.

Table 7-3. Increase in seeding rates required for lower germination seed.

Seed germination	Increase seeding rates in Tables 7-1 and 7-2 by:
85%	6%
80%	13%
75%	20%
70%	29%
65%	38%

What About Planting Late?

In NC, small grains frequently follow soybeans that are harvested in October or November. This results in small grains being planted after the optimal planting dates. When wheat, triticale, hulled or hulless barley is planted after the dates shown in Figure 7-2, seeding rates should be increased by 4 to 5 percent for each week planting is delayed.

Planting Depth

Wheat varieties have semidwarf genes that reduce overall plant height. These also reduce the chances of seedling emergence if the seeds are placed too deep. Conversely, a shallow planting can result in uneven germination due to dry soil. Small grain seeds should be planted 1 to 1.5 inches deep when soil moisture levels are adequate and slightly deeper if moisture is deficient.

Seeding Rates for No-Till

No-till planting causes special challenges related to uneven seed beds and surface residue. Although seeds should still be planted 1 to 1.5 inches below the soil surface, be aware that changes in the depth of any residue and undulations in the soil's surface may result in the drill missing the targeted seeding depth. When residue from the previous crop is unevenly distributed, achieving a uniform and correct planting depth can be difficult. Where the residue is uneven, the planting depth may be too shallow under high residue and too deep in areas of light residue. This can result in thin stands and excessive risk of winterkill. Preparation for no-till small grains begins with evenly distributing crop residues while harvesting the previous crop.

To obtain a uniform stand, start with a seeding rate that is 20 percent higher than what is recommended for conventional tillage (Tables 7-1 and 7-2). When no-till drilling, stop periodically and make sure that the planting depth is uniform and correct.

Drill Calibration

The manufacturer's seeding rate chart that comes with commercial drills is a rough estimate of how many pounds of seed will be planted at a given setting. Experience with wheat seed has shown that this estimate can be off by as much as 100%. The best way to be sure the correct seeding rate is being planted is to calibrate the drill for each seed lot being grown.

Three methods for calibrating a drill are demonstrated in an online video at www.smallgrains.ncsu.edu/drill-calibration.html. The simplest drill calibration method is outlined below:

1. Select the desired seeding rate. For example, if planting on-time, using conventional tillage, and high quality seed, a recommended wheat seeding rate would be 1.3 million seeds per acre.
2. Use Table 7-1 to convert seeds per acre to seeds per drill row foot. For example, if planting at 1.3 million seeds per acre with a drill that has 7.5-inch row spacing, Table 7-1 indicates that converts to 19 seeds per foot of row.
3. Hook a tractor to the drill, put at least several inches of seed in the hopper, and use the setting that is a "best guess" at what is needed to get the correct seeding rate.
4. Run the drill for 20 to 30 feet over firm ground (like a dirt road) with minimum down pressure on the openers and closing wheels so that the seed is exposed and easy to see.
5. Pick a drill row and count the number of seed in two feet.
6. If there are too many seed, lower the setting and try again. If there are too few seed, increase the setting and repeat. For example, if the target is 19 seed per drill row foot, but the drill dropped 24, the setting needs to be reduced.
7. Repeat step 6 until the number of seed being dropped is correct. Record the setting needed for this seed lot.

Online VIDEO:
How to Calibrate a Drill
www.smallgrains.ncsu.edu/drill-calibration.html

Special Considerations for Broadcast Seeding

Broadcast seeding often results in uneven seed placement in the soil, which results in uneven emergence and stands. Seeds may be placed as deep as 3 to 4 inches, where many seeds will germinate but will not emerge through the soil surface. Other seeds may be placed very shallow or on the soil surface. These seeds often do not survive due to dry soil or winter damage. The uneven stands from broadcasting often result in lower yields compared with drilling. One method of improving stand uniformity is to broadcast seed in two passes across the field using half the seeding rate for each pass. The second pass is made perpendicular to the first pass. Although this method should improve stand uniformity, it also increases the time required to seed the field. Because plant establishment potential is reduced and seed placement is not uniform, seeding rates should be increased for broadcast seeding. Increase broadcast seeding rates by 30 percent to 35 percent over drilled seeding rates.

Broadcasting wheat with fertilizer is a fast way to seed small grains. Take precautions to ensure that the seed is uniformly blended with the fertilizer and that the fertilizer-seed mixture is uniformly applied. Seed should be mixed with fertilizer as close to the time of application as possible and applied immediately after blending. Allowing the fertilizer-seed mixture to sit after blending (longer than 8 hours), particularly with triple super phosphate (0-46-0) or diammonium phosphate (18-46-0), results in seed damage (reduced germination) and, subsequently, a poor stand.

Considerations for Overseeding

Small grains may be planted by overseeding in standing, unharvested crops. To follow soybeans, seed as the first soybean leaves begin to drop. Following cotton, seed just before defoliation. The small grain can be injured or killed if it is growing when a desiccant is used. If no desiccant is used, seed when the leaves begin to drop. The leaves will form a mulch that conserves moisture and enhances germination.

The success or failure of overseeding depends on available moisture. Overseeding before a rainfall event improves the chances of success. Wheat and rye tend to emerge better when overseeded than do oats or barley.

Test the Results: Check the Stands

No matter how you plant the seed, be sure to check the stands shortly after emergence. Is the stand uniform? Determine the number of healthy seedlings present in a square foot. There should be 22 to 25 seedlings (or more, if planted late). If the stand is uniform and the plant density is correct, then the planting was successful.

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8. Nitrogen Management for Small Grains

Randy Weisz and Ron Heiniger

Nitrogen management is one of the most important keys to successful small grain production. It is also one of the easiest management strategies to misuse, resulting in yield reductions and environmental damage. To achieve optimum yields, follow the correct N guidelines for applications in the fall, winter, late January to early February, and at growth stage 30 (which usually occurs in March). Chapter 9, "*Nutrient Management for Small Grains*" (www.smallgrains.ncsu.edu/_Pubs/PG/Nutrient.pdf), discusses soil testing and management of all other nutrients. We discuss N management first and separately because there is no soil test useful for making N recommendations in NC, and because of its importance for small grain production.

Fall: Preplant Nitrogen

When Planting Near the Recommended Dates

When planting on time, 15 to 30 pounds preplant N per acre are generally sufficient to promote maximum growth and tillering. This application can be very important for high yields because N stress early in the season will prevent adequate tillering. When small grains follow soybeans or peanuts, enough carryover N may be present to meet small grain fall requirements. Unfortunately, the availability of carryover N is difficult to predict and there is no method for testing for available N in the fall. In many years and locations, the N released from a previous legume crop many not be available until the following spring or even summer, which is too late to support fall tillering. Consequently, unless experience with specific fields indicates otherwise, a small amount of preplant N is recommended even when following soybeans or peanuts.

When Planting Later Than Recommended

Research has shown that late-planted small grains may not respond to preplant N applications. When temperatures are too low to promote tillering, preplant N cannot be taken up by the plants and is easily leached out of the soil. Adding preplant N even at high rates cannot simulate tillering in cold soils. Consequently, when planting late, application of preplant N to small grains might be skipped.

Early Planting System

In chapter 6, "*Beating Soybean Harvest: A Very Early Wheat-Planting System*" (online at: www.smallgrains.ncsu.edu/_Pubs/PG/VeryEarly.pdf), we introduced a system for very early wheat planting. Small grains planted before the optimal planting dates risk freeze damage. So when planting very early, it is important to follow all the recommendations given in that chapter. Additionally, preplant N application to early planted small grains promotes increased tillering, but this can also increase the risk of freeze damage. While applying N to early planted small grains will often result in better looking stands, research has shown that it generally does not increase yields. Consequently, preplant N should be reduced or eliminated when planting earlier than the recommended dates (see chapter 5, "*Small Grain Planting Dates*, in this production guide: www.smallgrains.ncsu.edu/_Pubs/PG/Pdates.pdf).

No-Till

Preplant N management for no-till small grains is similar to conventional-till with a couple of minor differences. Many no-till growers find that their preplant N rates need to be on the high end of the recommended range. Therefore, when planting during the recommended planting dates, consider as much as 30 lbs of preplant N per acre. Growers using the early planting system may also want to

consider applying 15 to 30 lb N per acre preplant, particularly in conditions where corn or sorghum residue is heavy.

Winter: Rescue Applications

Nitrogen management during the winter consists of making sure the crop does not become N deficient. Small grains under N stress in the winter can lose tillers, which may reduce yield. Indications of a possible N deficiency are a pale green color, thin and poorly developing stands, and leaching rains after planting. An application of 15 to 30 pounds N per acre can help to green the crop back up if these symptoms occur. This rescue application needs to be made when daytime temperatures are expected to be above 50°F.

Late January and Early February: Last Chance to Grow More Tillers

Late January to early February is the time to determine if the crop has enough tillers to optimize yield. This is a very important decision. Apply N in January or February only if tiller densities are less than 50 tillers per square foot. If N is not needed, applying N in January or February results in increased risk of freeze damage, disease, lodging, and reduced yield. If tillering is low, however, an early application of N can help to stimulate further tiller development in the last few weeks before growth stage 30, resulting in higher yield and profit. The following guidelines will help you decide whether to apply N in late January or early February.

Guidelines for Wheat

If at the end of January or in the first week of February, wheat looks as thick as that shown in Photo 8-1, it is well on the way to being a potentially high yielding field. This wheat has about 100 well-developed tillers per square foot and should not have any N applied until growth stage 30. **A well-developed tiller is one with at least three leaves**.

The wheat in Photo 8-2 is a "medium" density stand with about 50 tillers per square foot. It also is well on the way to being a good yielding crop, and should not have any N applied until growth stage 30. The wheat in Photo 8-3, however, is poorly tillered and only has about 20 tillers per square foot. It has a low yield potential and needs more tillers to develop in February. It should have 50 to 70 pounds N fertilizer applied in late January or early February. A second N application should be made to finish this crop off at growth stage 30. Thin stands like those shown in Photo 8-3 need timely weed management, but should not have 2,4-D applied because 2,4-D may inhibit tiller development. Growers also need to scout for cereal leaf beetle in April, as these insect pests are often attracted to thin wheat stands.

Wheat stands that are thicker than the stand shown in Photo 8-3 but not as well developed as that shown in Photo 8-2 also need an early N application. Such a field will yield best with 40 to 50 pounds of N fertilizer applied in late January or early February and a second N application to finish the crop off at growth stage 30.

This approach to stand evaluation is shown in Figure 8-1. In late January and early February, a "tiller" is considered to be any stem that has three or more leaves. Rough estimates of tiller density can

Online VIDEO:
Counting Tillers to Optimize N Rates
www.smallgrains.ncsu.edu/tiller-counting.html

Photo 8-1. Well-tillered – about 100 tillers per square foot.

Photo 8-2. Medium-tillered – about 50 tillers per square foot.

Photo 8-3. Poorly-tillered – about 20 tillers per square foot.

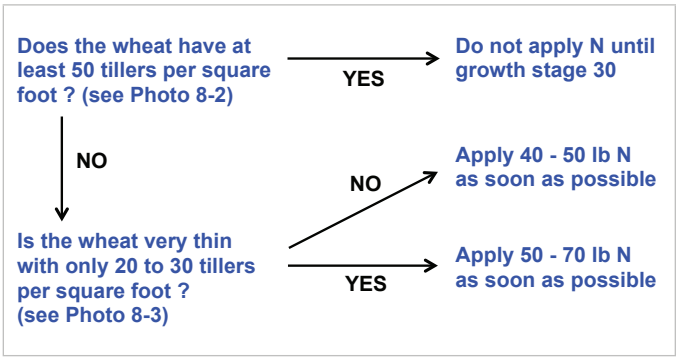

Figure 8-1. Late January to early February guidelines for wheat N fertilization.

be made by comparing a wheat field with Photos 8-1 through 8-3, or more exactly by counting tillers.

To determine tiller density, count well-developed tillers (those with at least three leaves). Ignore small tillers that have only one or two leaves. Do not be concerned with differences between the main plant and younger side tillers. Just count any stem with at least three leaves as a tiller. The final count will include main plants, tillers, and side tillers. Count all the tillers that have at least three leaves in a yard of row. Do this in several places and take an average. Tiller density is then computed as follows:

$$\text{Tillers per square foot} = \frac{(\text{tillers per yard of row}) \times 4}{(\text{row width in inches})}$$

Example: If in five counts of tillers in a yard of row the average was found to be 102 tillers per row and the row spacing is 7.5 inches, then tiller density is:

$102 \times 4 \div 7.5 = 54.4$ tillers per square foot.

An alternative is to mark out a square foot of ground and count all the tillers in that area that have at least three leaves. Do this in several places and calculate the average.

Guidelines for Oats, Barley, Triticale, and Rye

Research on counting tillers to time N applications for these crops has not been done. Growers will need to rely on past experience to judge when splitting N will benefit oat, barley, or triticale stands that are thin in late January to early February.

Growth Stage 30: The Most Important Time to Apply Nitrogen!

During growth stage 30, small grains switch from producing tillers, to starting reproductive growth. In the first phase of reproductive growth, the stem elongates, the plant gets taller, and the small grain crop begins to take up large amounts of N. The

future grain head is formed at this stage (although still underground), and N stress at this growth stage will affect head formation and result in smaller heads. Since N at this stage of development is critical and larger amounts of N are needed to satisfy N requirements, the bulk of spring N fertilizer needs to be applied at this stage. A typical fertilizer application rate at growth stage 30 for wheat is 80 to 120 pounds N per acre (minus any that was applied in late January or early February to stimulate tillering). However, optimal N rates can vary dramatically from field to field and year to year depending on the weather, the crop's yield potential, and the presence of carry-over N from previous crops. Tissue testing at growth stage 30 is one way to help fine-tune N rates to maximize economic return.

The Wheat Tissue Test

Tissue testing for wheat N rate recommendations was developed in VA and has been available for many years. It uses the N concentration detected in a tissue sample collected at growth stage 30. Research in NC, however, has shown that the VA recommendations can overestimate the required N for our growing conditions. Therefore, a new system has been developed that is helpful in optimizing wheat N fertilizer rates specifically for NC producers. This research indicates that N rates based on a tissue test are most reliable for wheat grown on well-drained soils. The test should not be used on poorly-drained organic soils. This new system and subsequent recommendations are especially helpful when N prices are high and growers need to minimize input costs without compromising yield. For assistance with growth stage 30 tissue testing, NC producers can contact an NC Department of Agriculture & Consumer Services (NCDA&CS) regional agronomist (www.ncagr.gov/agronomi/rahome.htm) or county Extension agent (www.ces.ncsu.edu). Here are the steps and information needed to determine the optimum N rate with a tissue test.

Step 1: Determine the Growth Stage

As temperatures warm in spring, tillering stops and the wheat crop's demand for N increases rapidly. This is the beginning of stem elongation, often referred to as growth stage 30. Because growth stage 30 is the best time to apply N fertilizer to winter wheat, it is important to know when the crop reaches this stage. The calendar date when wheat reaches growth stage 30 is influenced by variety, planting date, and environmental conditions. Early-heading varieties can reach it in February. Late-heading varieties may not reach growth stage 30 until mid-March. One clue that the wheat is at growth stage 30 is that the plants start to stand up and get taller. However, the best way to tell if wheat is at growth stage 30 is to pull up several plants and split the stems down their centers all the way to the base where the roots grow. Prior to growth stage 30, the growing point will be at the very bottom of the stem just above the first roots. At growth stage 30, the growing point will have moved ½-inch up the stem (Figure 8-2). After growth stage 30, it will move further up the stem and be above the soil surface. Tissue samples can be taken when the

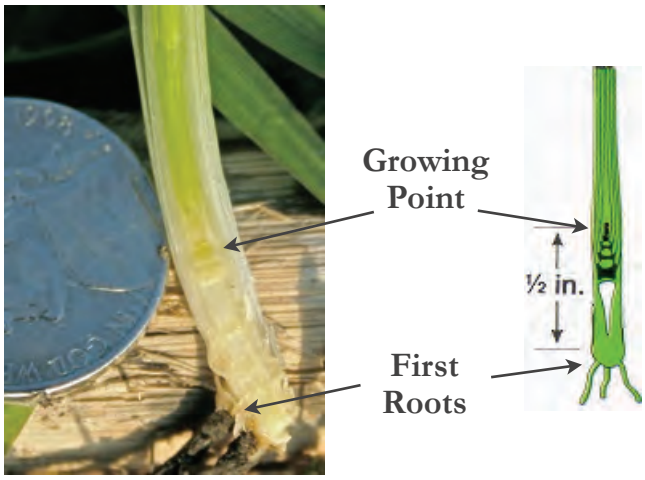

Figure 8-2. Wheat stem cross-section at growth stage 30. The growing point will be dark green, about 1/8-inch long, look like a tiny pine cone, and prior to growth stage 30 be at the very base of the stem next to the first roots. At growth stage 30 it will have moved 1/2-inch up the stem.

Sample Information	Laboratory Results						
Sample ID:	*N%*	*P%*	*K%*	*Ca%*	*Mg%*	*S%*	*Fe-ppm*
SHOP	3.50	0.62	3.26	0.40	0.19	0.29	107
Crop:	**Interpretation Indexes**						
Wheat	*N*	*P*	*K*	*Ca*	*Mg*	*S*	
Plant Appearance:	50	80	57	56	51	57	
Normal	**DRIS Interpretation:**			*Most limiting--*			

Recommendations:
Biomass: 36 grams
Nutritional status of your wheat sample looks good at this time; nutrient concentrations are with the desired rang

Figure 8-3: NCDA&CS Plant Analysis Report.

growing point is between ¼- and ¾-inch above the base of the stem.

Step 2: Collect Tissue and Biomass Samples

Two pieces of information are needed to determine the optimum N rate: percentage of tissue N and biomass. At growth stage 30, take a tissue sample by cutting wheat plants from 20 to 30 representative areas in the field. The plants should be cut ½-inch above the ground. Soil and dead leaf tissue must be removed and the cuttings placed in a paper bag labeled "tissue." The percentage of N is detected in this tissue sample. For the most accurate N rate recommendation, an estimate of above-ground biomass is also required. At one representative location in the field, cut all the wheat along a 36-inch section of row, remove any soil and weed tissue, and place the entire sample in a second paper bag labeled "biomass." The biomass or weight is detected in this sample. The two samples should be shipped to the NCDA&CS Agronomic Division immediately. If samples have to be stored for more than 24 hours after collection, they must be dried to prevent spoilage and loss of biomass.

Step 3: Use the Chart and Table with the Plant Report

An example of the NCDA&CS plant report is shown in Figure 8-3. In this example, the dry weight of the biomass cut from the 36-inch length of row was 36 grams and the tissue N percentage was 3.5. Using the biomass dry weight and the N percentage values, N fertilizer recommendations are determined using either the **BLUE**, **RED** or **GREEN** line in Figure 8-4. Low biomass wheat fields use the BLUE line. Medium biomass fields use the RED line. High biomass fields use the GREEN line. To determine which line to use, consult Table 8-1. Find the *biomass value* on the left side of Table 8-1. Look across the table to find the *drill row spacing* used in the field. The intersection of the correct drill-row column and the dry-weight row indicates which colored line to use. If the drill row spacing in the SHOP field (Figure 8-3) is 6 inches, then Table 8-1 indicates the GREEN line should be used to get a N fertilizer rate recommendation.

If the wheat was broadcast seeded, there will be no drill rows to sample and Table 8-1 cannot be used. In broadcast fields, the biomass dry weight in a square yard will need to be estimated. *Low* biomass fields are defined as those with less than 84 grams of dry biomass per square yard. *Medium* biomass

Table 8-1. Line color to use in Figure 8-4 for N rate recommendations.

Dry weight in 36 inches of row (g)	Row spacing in inches			
	5	6	7	8
≤ 10				
15				
20				
25				
30				
35				
≥ 40				

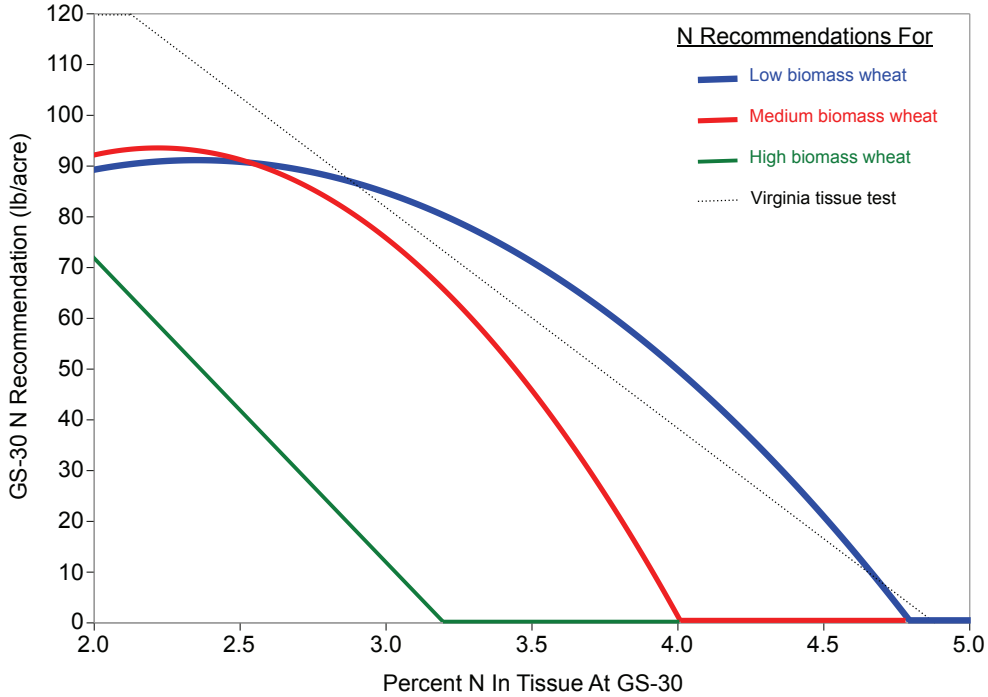

Figure 8-4. Growth stage 30 N rate recommendations based on the new NC wheat tissue test.

fields are defined as those with 84 to 157 grams dry weight per square yard. *High* biomass fields have more than 167 grams dry weight per square yard.

Step 4: Don't Let a Sulfur or Potassium Deficiency Rob Wheat Yield Potential

Sulfur-deficient wheat does not assimilate N fertilizer efficiently so it is important to make sure adequate sulfur (S) is available at growth stage 30. In addition to the percent N content, the NCDA&CS plant report also gives levels of other plant nutrients, including S. These levels can be checked against the critical values shown in Table 8-2. A tissue S content less than 0.25 percent, or an N-to-S ratio greater than 15, indicates that S is limiting and the wheat will likely benefit from an application of 20 to 30 lb S per acre at growth stage 30.

Table 8-2. GS-30 whole plant tissue sample nutrient sufficiency levels.

Nutrient	P	K	Mg	S	B	Zn	Mn	Cu
	------ % ------				------ ppm ------			
Sufficient level	0.25	2	0.1	0.25	3	12	20	3

North Carolina coastal plain wheat producers who have deep sandy soils can also use the growth stage 30 tissue test to optimize potassium (K) fertilizer inputs. This is especially important for producers who may have skipped or reduced preplant potash for their wheat and for the following double-cropped soybeans. Ideally, growers who have wheat on deep sandy soils should submit both a growth stage 30 tissue sample and a diagnostic soil sample from the same field. Tissue K levels of less than 2 percent indicate that the wheat crop is deficient. If the soil sample also shows low K-index levels, K will be needed as soon as possible for the wheat crop, and certainly before the subsequent soybean crop is planted.

Wheat Tissue Test Examples

Low Wheat Biomass Example

The plant report shows the biomass sample weighed 8 grams and the tissue sample had a N content of 3.5%. The wheat was planted in 6-inch rows. Table 8-1 indicates the BLUE line in Figure

8-4 is the correct one to use as this is a low biomass wheat field. Finding 3.5% on the horizontal axis of Figure 8-4 and using the BLUE line show the recommended N fertilizer rate is 71 lb per acre. Thin wheat fields could result from late planting or from fall temperatures that were too low to promote tillering and growth. In fields like this, the VA (dashed line) and NC system (BLUE line) make very similar N rate recommendations.

Medium Wheat Biomass Example

The plant report shows the biomass sample weighed 25 grams and the tissue sample had a N content of 3.5%. The wheat was planted in 7-inch rows. Table 8-1 indicates the RED line in Figure 8-4 is correct for N fertilizer rate recommendations as this is a medium biomass wheat field. Finding 3.5% on the horizontal axis of Figure 8-4 and using the RED line show the recommended N fertilizer rate is 46 lb per acre. In medium biomass fields, the VA system (dashed line) tends to overestimate the N fertilizer rate required to optimize yield and economic return, especially for wheat with N content greater than 3.5%.

High Wheat Biomass Example

The plant report shows the biomass sample weighed 36 grams and the tissue sample had a N content of 3.5%. The wheat was planted in 7-inch rows. Table 8-1 indicates the GREEN line in Figure 8-4 is correct for N fertilizer rate recommendations as this is a high biomass wheat field. Finding 3.5% on the horizontal axis of Figure 8-4 and using the GREEN line show the recommended N fertilizer rate to be 0 lb per acre. High biomass fields can result from high carry-over N from a previous crop, fall manure application, or unusually warm fall and winter weather that promoted excess tillering. In these fields, the VA system (dashed line) overestimates the growth stage 30 nitrogen fertilizer rate.

Oats, Barley, Triticale, and Rye

Research on using tissue samples to optimize N requirements for these crops has not been done. Use Table 8-3 to determine the crop's total spring N requirement.

Table 8-3. Spring N recommendations for oats, barley, triticale, and rye.

Region	Spring N Fertilizer (pounds per acre)			
	Oats	Barley	Triticale	Rye
Coastal Plains	100	100	120	80
Piedmont & Mountains	80-100	80	120	80
Tidewater	100	100	120	80

9. Nutrient Management for Small Grains

Carl Crozier, Ron Heiniger, and Randy Weisz

Routine Soil Testing to Prevent and Manage Nutrient Deficiencies

Soil testing before planting is an essential component of a small grain fertility management program. Different fields can vary so widely in pH and nutrient levels that it is impossible to predict optimum application rates without soil test results. It is much more economical to prevent yield losses associated with nutrient deficiencies than to try to correct them once visible symptoms appear. Producers should sample each field once every two to three years at the same time of the year, preferably in the early fall. Often this is done before a corn or cotton crop, which tends to be more sensitive to applied nutrients than small grains. However, if you suspect a nutrient problem, then sample more frequently before a small grain crop and use that information to adjust nutrient applications. Sample boxes, information sheets, test results, and recommendations are provided free of charge by the Agronomic Division of the NCDA&CS, and guidelines for soil testing procedures can be found in another Extension publication: *SoilFacts: Careful Soil Sampling – The Key To Reliable Soil Test Information* (www.soil.ncsu.edu/publications/Soilfacts/AG-439-30).

Diagnostic Soil Sampling and Plant Tissue Analysis

When abnormal growth or plant color is observed, it is often useful to obtain diagnostic samples to determine if there is a nutrient deficiency. If samples are collected to diagnose an observed problem rather than for routine purposes, then separate samples should be submitted to represent the surface soil (0 to 4 inches) and the subsoil (4 to 8 inches). Tissue analysis can determine whether an adequate amount of fertilizer has been applied or if a particular nutrient is limiting crop growth. Plant tissue analysis is particularly useful in determining a crop's need for mobile nutrients, such as nitrogen, sulfur, and boron; and for diagnosis of deficiency symptoms for manganese, copper, or zinc. To take a tissue test, clip a handful of plants above the ground with 8 to 10 samples collected from both the problem area and a corresponding area of normal growth. When taking diagnostic samples, both soil samples and plant tissues from the affected "bad" area and a nearby unaffected "good" area should be submitted for analysis to the NCDA&CS diagnostic laboratory.

Soil pH and Lime Recommendations

Proper pH is critical in obtaining good crop growth and yield. Small grains grow best when the pH is near the target level for each soil class. If pH is too low, soluble aluminum and acidity can limit root growth and nutrient uptake. If pH is too high, micronutrients such as manganese, iron, copper, and zinc can become unavailable. Stunted growth, nutrient deficiency symptoms, and low yield are the most common problems associated with soil pH levels that are not maintained in the proper range. Often nutrient deficiencies are the result of low or high pH rather than a lack of adequate amounts of the nutrient in the soil. Ideal soil pH levels vary based on soil type. Target levels are 6.0 for mineral soils, 5.5 for mineral organic soils, and 5.0 for organic soils. When the soil pH is below these targets, apply lime as early as possible in the production year to allow time for neutralizing soil acidity. Liming rates and the type of lime applied cannot be determined based on soil pH alone; they also depend on residual soil acidity, residual credit for recently applied lime, and measurement of available magnesium. For more information see *SoilFacts: Soil Acidity and Liming for Agricultural Soils* (www.soil.ncsu.edu/publications/Soilfacts/

AGW-439-50/SoilAcidity_12-3.pdf).

Phosphorus Recommendations

Phosphorus (P) plays a key role in germination and early plant growth, promotes winter hardiness, stimulates the growth of the wheat kernel, and has a role in determining when the plant reaches maturity.

Phosphorus Deficiency Symptoms

Purpling of the leaf margins and bottom leaf surfaces of the lower plant leaves and purpling of the leaf sheaths at the stem's base are symptoms of P deficiency. Slow growth or stunting is another sign of P deficiency. Phosphorus-deficient plants are slow to mature, and green heads are often found in spots in the field at harvest. Deficiency symptoms are often found on waterlogged, cool soils in late winter or early spring.

Phosphorus Fertilizer Rates

As noted previously, a good soil test is the best way to determine fertilizer requirements. The following P recommendations are made only as guidelines and should not replace soil testing as the primary means of determining crop nutrient needs.

A wheat crop yielding 40 bushels per acre typically requires 40 pounds of P_2O_5 (25 pounds in the seed and 15 pounds in the straw). Mineral soils, such as those found in the NC coastal plain and piedmont, bind P and prevent it from leaching. Heavy organic soils do not bind P, resulting in a movement of P to the lower soil horizons or to drainage waters. Soils high in clay content, such as those found in the piedmont, bind P very tightly, making it unavailable to the crop. Consequently, both heavy organic soils and soils high in clay content often test low in available P even though high amounts of P fertilizer are applied every year. Care must be taken on these soils to apply P in a way that limits the interaction between the P fertilizer and the soil. Because animal wastes are high in P, soils where heavy applications of animal waste have been applied will have high levels of available P. Table 9-1 shows the recommended rates for P fertilizer in the different regions and major soil types of the state.

Phosphorus Placement and Timing

Phosphorus should be broadcast on the soil just before planting. Growers farming heavy organic or clay soils should limit the amount of soil-fertilizer contact (and thus reduce nutrient binding), which means little to no tillage should occur after a P application.

Potassium Recommendations

Potassium (K) influences grain quality (including test-weight) and oil content, prevents lodging, and plays an important role in drought and disease tolerance.

Potassium Deficiency Symptoms

The most common deficiency symptom for K in small grains is stunted growth and early lodging. Plants with a K deficiency will have low vigor, poor drought or disease tolerance, and reduced kernel size. Under severe K deficiency, the leaf tip and margins on the lower leaves will bronze and eventually turn yellow and die. Deficiency symptoms are more likely on deep sandy soils or soils that are waterlogged and compacted.

Potassium Fertilizer Rate

A wheat crop yielding 40 bushels per acre typically requires 64 pounds of K_2O (16 pounds in the seed and 48 pounds in the straw). Because so much of the K in the plant is in the straw, most of it will be recycled in the soil. Most of the agricultural soils in NC have adequate to high levels of available K. In particular, soils where animal waste has been applied will be high in available K. The exception to this rule is that available K is low on sandy soils in the NC coastal plain and tidewater. Sandy soils do not bind K, so the K leaches below the root zone.

Table 9-1. Critical macronutrients for small grain production.

Element	Common deficiency symptoms	Common fertilizer forms [1]	Basis for fertilizer rate	Suggested rates per acre if soil test data are not available[2]	Notes
Phosphorus (P)	Stunting, purpling on margins of lower leaves or on leaf sheaths, delayed maturity	Granular monoammonium phosphate (MAP, 11-52-0) Granular diammonium phosphate (DAP, 18-46-0) Liquid ammonium phosphate (10-34-0)	Soil test	Coastal plain mineral soils: 0 to 30 lbs P_2O_5 Tidewater organic soils low P index: 30 to 50 lbs P_2O_5 Piedmont clay soils, shallow topsoil: 30 to 40 lbs P_2O_5	Limit the amount of soil-fertilizer contact on heavy organic or clay soils.
Potassium (K)	Lower leaf tip and margin burn, weak stalks, lodging at harvest, small ears, slow growth	Potassium [plus chloride (muriate 0-0-60), sulfate, nitrate, hydroxide, or magnesium sulfate]	Soil test	Sandy or very sandy soils: 50 to 60 lbs K_2O Organic soils (only if K is deficient): 50 to 60 lbs K_2O Mineral or clay soils: (only if K is deficient): 50 to 60 lbs K_2O	On deep sand, apply just before planting or split apply at planting and at growth stage 30.
Calcium (Ca)	Terminal and root tip damage, dark green, weakened stems, ear disorders	Lime, calcium sulfate (gypsum)	Soil test	Apply lime at recommended rate.	Generally OK if limed to target pH.
Magnesium (Mg)	Interveinal chlorosis in older leaves, leaf curling, margin yellowing	Dolomitic lime, magnesium sulfate (epsom salt), potassium magnesium sulfate, magnesium oxide	Soil test, tissue analysis	If needed: 20-30 lb Mg	Generally OK if dolomitic lime used.
Sulfur (S)	Yellowing of young leaves, small spindly plants, slower growth and maturation	Elemental sulfur; sulfate [plus ammonium, calcium (gypsum), magnesium (epsom salt), potassium, potassium magnesium]; Ammonium thiosulfate; Sulfur-coated urea	Tissue analysis or soil criteria	Sandy soils low in S: 15 to 25 lb S	Deficiency likely if sandy surface is 18+ inches deep.

[1] This table does not list all available chemical forms of fertilizers or recommend use of any specific form. Percent chemical analyses included are examples only, and may not reflect the composition of any specific commercial source.

[2] Soil samples should be taken to avoid underestimating or overestimating actual needs.

Potassium Placement and Timing

Potassium should be broadcast just prior to planting. On sandy or very sandy soils with a high leaching potential, K should be applied in two applications, half at planting and the other half just prior to growth stage 30 when N is applied. There is no benefit to applying K to a growing crop after growth stage 31.

Sulfur Recommendations

Sulfur (S) increases kernel weight, kernel size, grain protein, yield, and test-weight. Sulfur is required for the production of chlorophyll and many enzymes involved in the utilization of N. Consequently, a small grain crop must have adequate amounts of S to use N fertilizer property.

Sulfur Deficiency Symptoms

Symptoms of S deficiency include yellowing of young leaves, small spindly plants, slowed growth, and delayed maturation. Sulfur deficiency looks very much like N deficiency except that with S deficiency the young leaves at the top of the plant are the first to turn yellow. Sulfur deficiency symptoms usually occur in patchy spots across the field. Generally, S deficiencies are only found on deep sandy soils. However, in recent years, S deficiency symptoms have occurred in clay and organic soils during cool, wet weather when the plant is small. Periodic checks in the late winter and early spring can help identify fields with S deficiency.

Sulfur Fertilizer Rate

A wheat crop yielding 40 bushels per acre typically requires 10 pounds of elemental S (4 pounds in the seed and 6 pounds in the straw). While most of the agricultural soils in NC will have adequate to high levels of available S, sandy soils with low levels of organic matter usually are deficient in S because S is water soluble and easily leached. On sandy, S deficient soils, 15 to 25 pounds S per acre can be applied at planting or with the N sidedress. Sulfur should be applied before jointing to avoid crop damage and increase the likelihood of an economic response.

Calcium and Magnesium Recommendations

Calcium (Ca) deficiency symptoms include terminal and root tip damage, dark green stems, weakened stems, and poor ear formation. Magnesium (Mg) deficiency symptoms include interveinal chlorosis in older leaves, leaf curling, and yellowing of the leaf margins. Generally, Ca and Mg levels are maintained through dolomitic lime applications. If deficiencies occur and no pH change is desired, then sulfate forms such as gypsum (calcium sulfate) or epsom salts (magnesium sulfate) can be applied at the rates recommended in Table 9-1.

Micronutrient Management

Due to expense and the potential for toxicity, applications of micronutrients (including copper, manganese, and zinc) are generally not made to small grains unless they are specifically recommended by a soil test or if specific deficiencies are identified. Common problems often found in wheat in NC include manganese deficiencies on overlimed soils and copper deficiencies on organic soils.

Copper Recommendations

Proper levels of copper (Cu) in the plant enhance protein content of the kernel and grain yield.

Copper Deficiency Symptoms

Common Cu deficiency symptoms include stunting, leaf tip or shoot die-back, and poor upper leaf pigmentation. Perhaps the best way to diagnose a Cu deficiency is by observing the leaf tip. "Pigtailing" or "corkscrewing" of the leaf tip is a sign of Cu deficiency. Organic soils are naturally low in Cu, and often deficiency symptoms can be found in plants grown in these soils, particularly when the plant and root system are small. Wheat is very sensitive to Cu deficiency and will be one of the first crops to show symptoms.

Copper Fertilizer Rate

A wheat crop yielding 40 bushels per acre typically requires 0.04 pounds of elemental Cu per acre (0.03 pounds in the seed and 0.01 pounds in the straw). Table 9-2 shows the rate of Cu to use when a soil test detects a low level or when deficiency symptoms are noted. Growers should take care to avoid the over-application of Cu fertilizers since

Table 9-2. Critical micronutrients for small grain production.

Element	Common deficiency symptoms	Common fertilizer forms [1]	Basis for fertilizer rate	Suggested rates per acre if soil test data are not available[2]	Notes
Copper (Cu)	Stunting, leaf tip/shoot dieback, poor upper leaf pigmentation	Copper sulfate, copper oxide, copper chelates	Soil test, tissue analysis	If deficient: apply 0.25 lb Cu to foliage with 0.50 lb of hydrated lime, or 2-8 lb[3] Cu to soil.	
Boron (B)	Leaf thickening, curling, wilting; reduced flowering/ pollination	Boric acid, borax, solubor, borates	Tissue analysis		Avoid toxicity, apply only as needed.
Iron (Fe)	Interveinal chlorosis of young leaves	Ferrous sulfate, ferric sulfate, ferrous ammonium sulfate, iron chelates	Tissue analysis		
Manganese (Mn)	Upper leaves pale green or streaked	Manganese sulfate, manganese oxide, manganese chelate, manganese chloride	Soil test, tissue analysis	Coastal plain, sandy soil or any soil with Mn index less than 25: 10 lb Mn If deficient: apply 0.5 lb Mn to foliage, or 10 lb Mn to soil.	Overliming decreases availability.
Zinc (Zn)	Decreased stem length (rosetting), mottling-striping, interveinal chlorosis	Zinc sulfate, zinc oxide, zinc chelates, zinc chloride	Soil test, tissue analysis	If deficient: apply 0.5 lb Zn to foliage, or 6 lb Zn to soil.	

[1] This table does not list all available chemical forms of fertilizers or recommend use of any specific form. Percent chemical analyses included are examples only, and may not reflect the composition of any specific commercial source.

[2] Soil samples should be taken to avoid underestimating or overestimating actual needs.

[3] NCDA guidelines are 2 lb Cu/ac or 6 lb $CuSO_4$/ac for mineral soils, 4 lb Cu/ac or 12 lb $CuSO_4$/ac for mineral-organic soils, and 8 lb Cu/ac or 24 lb $CuSO_4$/ac for organic soils.

high concentrations of Cu can be toxic to the plant.

Timing a Copper Application

The recommended time to apply Cu is preplant. This avoids the high cost of Cu chelates, eliminates the chance of leaf burn, and allows a much longer residual effect. However, if deficiency symptoms occur, a foliar spray can be applied at much lower rates than are recommended for soil applications. Usually, Cu chelates or organic dusts are recommended for foliar application. Do not apply Cu after jointing.

Manganese Recommendations

Proper levels of manganese (Mn) in the plant enhance plant growth and the production of chlorophyll.

Manganese Deficiency Symptoms

Manganese deficiency symptoms include stunting, gray specks in the leaf, and pale to almost whitish upper leaves or streaked yellowing (interveinal chlorosis) of the upper leaves. Manganese deficiency can be distinguished from a Mg deficiency in that Mn affects the upper leaves while Mg affects the lower leaves. Manganese deficiencies commonly occur in overlimed soils (pH greater than 6.5 on mineral soils or greater than 6.1 on mineral-organic or organic soils) with low cation exchange capacity. A common situation where Mn deficiencies are noted is the over-limed areas at the ends of the field where the spreader truck turned or where lime was stockpiled.

Manganese Fertilizer Rate

A wheat crop yielding 40 bushels per acre typically requires 0.25 pounds of elemental Mn (0.09 pounds in the seed and 0.16 pounds in the straw). Sandy soils in the NC coastal plain are typically low in available Mn. Table 9-2 shows the rate of Mn to use when soil test levels are low or when deficiency symptoms are noted.

Timing of Manganese Fertilizer Application

The best time to apply Mn on soils with low test levels is preplant. However, to correct a deficiency if the soil pH is high, use a foliar application. Manganese is commonly supplied as manganese sulfate, manganese oxide, and manganese chelates or organic complexes. Manganese chelates and organic complexes are recommended only for foliar application due to soil reactions that tend to convert the Mn to unavailable forms. Application of foliar fertilizers may have to be repeated several times to correct severe deficiency symptoms on fields that have been overlimed. Once wheat is jointing, consider whether response to fertilizer is likely to outweigh crop damage due to traffic.

Zinc Recommendations

Zinc (Zn) deficiency symptoms include decreased stem length (rosetting), mottling, and interveinal chlorosis. Zinc deficiencies are most common if the soil pH is greater than 6.5 and the soil phosphorus index is greater than 75. As with other micronutrients, recommended rates (Table 9-2) are lower for foliar applications, but residual effects are greater with soil applications.

Special Consideration for No-Till Production

Before a field is placed in 100 percent no-till production, it should be soil tested and brought to target pH and optimum nutrient levels. Once adequate fertility levels are achieved throughout the root zone, no-till production can begin. Long-term no-till studies suggest that yields and soil fertility can be maintained even though lime and fertilizer are applied to the soil surface without incorporation. Routine soil samples in established no-till fields should be collected to a depth of 4 inches. Use of starter fertilizers containing N and P are more important in no-till production because plant development is delayed.

Special Consideration for Precision Agriculture

Currently, precision agriculture is being used for three primary reasons: (1) to identify areas in fields with different pH or soil test indexes, and vary lime and fertilizer rates accordingly; (2) to monitor and map crop yield and moisture content; and (3) to document material applications, including fertilizers and pesticides. The cost of collecting grid soil samples or using a yield monitor must be returned by decreasing the amounts of lime or fertilizer applied, increasing crop yield, reducing negative environmental impacts, or by some combination of these benefits. Growers are more likely to increase profits by using precision farming practices in situations where pH or fertility levels are limiting wheat yields. An examination of the variability in soil pH or fertility within a field should indicate the potential for increasing crop yield through variable-rate lime or fertilizer applications. If at least a fourth of the field area has soil nutrient indexes

below 25, or pH levels below the target value for that crop and soil class, then it is likely that precision farming practices will increase wheat yields and profits.

Special Consideration for Animal Wastes and Sewage Sludge

Animal waste and sewage sludge can be excellent sources of nutrients and organic matter for a wheat crop. Organic forms of P can move deeper in soils than do inorganic fertilizer sources. Consequently, they can be advantageous in no-till or conservation tillage systems. When applying animal waste as a fertilizer material for wheat, all amendments should be tested *before* application to determine optimum application rates. Soils that are being fertilized with waste materials should be tested to determine nutrient levels. The amount of waste material applied should be based on the need for desirable nutrients, such as P or K, and the requirement that levels of P, Zn, Cu, cadmium, lead, and mercury should not exceed prescribed limits. Producers should rotate applications as much as possible to obtain nutrient benefits while minimizing excess nutrient and toxic metal accumulation. If you use lime-stabilized sludge or poultry litter, monitor the soil pH carefully to prevent overliming and possible Mn deficiency.

Applications of animal waste are most effective when made prior to planting a small grain crop. However, topdress applications of poultry or swine manure can be done in January or early February with good results. Several good publications on application of animal waste and/or sludge can be found online: www.soil.ncsu.edu/publications/extension.htm#WasteManagement .

10. Insect Pest Management for Small Grains

Dominic Reisig, D. Ames Herbert Jr., Gaylon Ambrose, and Randy Weisz

Insect management can be critical to the economic success of a small grains enterprise, and growers should be aware of the various insects and management strategies and tactics. These techniques can help you prevent and detect some potentially serious insect problems before significant loss occurs.

Aphids

Aphids are small sucking insects that colonize small grains early in the season and may build up in the spring or fall. They injure the plants by sucking sap or by transmitting the barley yellow dwarf virus (BYDV). BYDV is a persistent virus that can be retained by the aphid for weeks and can be transmitted in minutes to a few hours of aphid feeding. Although the exact relationship between aphid numbers and direct yield loss is unknown, aphids must be very abundant before injury from sap-removal occurs. However, low aphid abundance early in the fall can result in high BYDV occurrence in winter cereals. Aphid flights in the fall from grasses surrounding cereals pose the most serious threat for this disease. Predicting aphid flights is difficult; flights are generally initiated from cues such as temperature, sunlight, and increasing daylength. Flights generally decrease as precipitation, relative humidity, and wind speed increase.

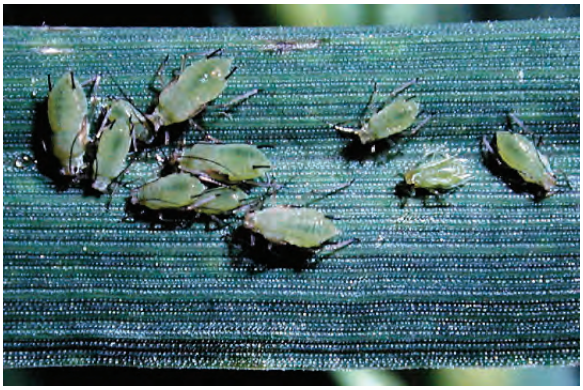

Photo 10-1. English grain aphid. Photo by M. Spellman.

Photo 10-2. Bird cherry oat aphid.

Photo 10-3. Corn leaf aphid. Photo by Jack Kelly Clark.

Life Cycle

Two species of aphids predominate in small grains: the English grain aphid (Photo 10-1) and the bird cherry-oat aphid (Photo 10-2). However, several others, such as the corn leaf aphid (Photo 10-3) and the greenbug (Photo 10-4), may be found occasionally. These aphids are described in *Insect and Related Pests of Field Crops*, AG-271 (http://ipm.ncsu.edu/AG271/small_grains/small_grains.html). Aphids' high reproductive rate enables their populations to quickly build up to levels that can cause economic loss. However, aphid populations are usually kept in check by weather

Photo 10-4. Greenbug. Photo by Alton N. Sparks, Jr., University of Georgia.

conditions and biological control agents, such as lady beetles, parasitic wasps, syrphid fly maggots, and fungal pathogens, which are often abundant in small grains.

Management

Aphids can occur throughout the growing season. In early-planted small grains, especially barley, low levels of aphids in the fall may transmit an infection of BYDV that can cause symptoms later in the season. Using a tolerant or resistant variety is an excellent management tactic. A list of the current wheat varieties that are resistant to BYDV (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf) is available on the NC Small Grain Production Website (www.smallgrains.ncsu.edu). Insecticides (either as seed treatments or as a foliar application) to control aphids in the fall are generally not recommended. There are several situations, however, in which the use of insecticides can be beneficial. In areas with a chronic BYDV history, early-planted small grains may benefit from preventive neonicotinoid insecticide seed treatments (such as Gaucho, Cruiser, or NipsIt INSIDE). This may be important in the NC piedmont, as a recent study demonstrated that BYDV incidence can increase when wheat is no-till planted into corn residue. An alternative to using an insecticidal seed treatment is to make a foliar application of a long-residual pyrethroid insecticide at or before three- to four-leaf stage wheat. BYDV symptoms are easier to recognize in the spring than the fall. When aphid populations are relatively low in the fall, an insecticide application is justified only if BYDV is anticipated and freezing weather is not expected for at least one week. As cold weather begins, populations quickly decline.

Scouting

Scouting for aphids requires searching plants or examining heads on 10 samples taken at locations scattered across each field. Each sample should consist of all plants in 1 foot of row or 10 heads, depending on plant stage. For foliage examination, counting aphids on each sample is not feasible; instead, use a simple estimation technique. Initially, the scout must "calibrate" by visually establishing a mental picture of aphids on 1 row foot and then counting aphids over the entire plant to determine the actual number. After several repetitions of this exercise, aphid counting is no longer needed because a calibrated mental image is available. This mental image is then used to visually estimate populations in field scouting. Head-infesting aphids are similarly estimated, except in this instance the calibration exercise is done by using heads rather than whole plants.

Threshold

Aphids may become much more abundant in the spring than the fall. However, because plants are actively growing in the spring, they can support many more aphids without injury. Also, spring-transmitted BYDV usually does not seriously affect small grains. Consequently, the thresholds for applying insecticides are much higher in the spring compared to those for the fall (see Table 10-1).

Armyworm

Armyworm infests small grains, usually wheat, from late April to mid-May. They can cause serious defoliation, injury to the flag leaf, and also cause

Table 10-1. Aphid thresholds for small grains in the fall and spring.

Fall	Spring			
	Plant Height (inches)			After heading
	3 - 6	4 - 8	9 - 16	
20 aphids per row foot, and BYDV has been a chronic problem or is expected, and cold weather is not forecast for at least one week.	aphids per row foot			25 aphids per head and 90% of heads infested, or 50 aphids per head and only 50% of the heads infested
	100	200	300	

head drop. Armyworm populations fluctuate greatly from year to year and across areas of NC. Typically, the northeastern and mid-coastal counties experience the most consistent armyworm problems

Life Cycle

Armyworm moths are one of the first moths to become active during the spring. Moths prefer to lay eggs on various grasses, and small grains are very attractive. Thick planting, narrow row spacing, and high N rates promote dense and lush growth, which is conducive to high armyworm infestation.

Young armyworm larvae are pale green, yellowish, or brown and have a habit of looping as they crawl. When they become larger (1 to 1½ inches), they are greenish-brown with pale white and orange stripes running down their bodies; the head is honeycombed with faint dark lines (Photo 10-5). The armyworm is described in *Insect and Related Pests of Field Crops*, AG-271 (http://ipm.ncsu.edu/AG271/small_grains/small_grains.html).

Armyworm is the only caterpillar found in large numbers in small grains. They are active at night, hiding under plant litter (such as old corn stalks) and at the base of wheat plants during daylight hours. After dark, they feed on foliage from the bottom of the plant upward. As they eat the lower foliage or as it is destroyed by leaf pathogens, the armyworm larvae feed higher, eventually reaching the flag leaf. If populations are high, large caterpillars may also feed on the stem just below the head.

Management

Management of armyworm is based on scouting, thresholds, and resulting application of insecticides when necessary. Infestations of armyworms are not easily detected by casual observation because caterpillars hide during the day. Fortunately, several signs of armyworm infestation occur, and caterpillars can also be monitored if the correct technique is used. Blackbirds (grackles and red-winged blackbirds) commonly search for armyworms in small grains. Any field with significant bird activity should be scouted. Signs of armyworm leaf feeding and caterpillar droppings can also be good indicators. Feeding is sometimes inconspicuous because small caterpillars do not eat much and feeding signs are often concentrated on

Photo 10-5. Armyworm. Photo by M. Spellman.

the lower part of the plant. When caterpillar populations are high, droppings may be seen easily but should not be confused with weed seed.

Scouting

Fields should be scouted for armyworms in May when caterpillars are normally small. Thorough scouting should not be done until the caterpillars are at least 3/8-inch long because populations of small worms are difficult to estimate accurately and often die out. Once caterpillars reach 3/8-inch or more in length, take at least 5 samples per field (10 samples in larger fields of 20 acres and more) by examining all the wheat in 3 feet of one row. Look for and count the caterpillars in litter around the base of plants and under old crop residue. Pay special attention to fields in which birds are active. Fields should be scouted weekly until a treatment or no-treatment decision is made. Re-infestation of caterpillars in May after a successful insecticide application does not occur.

Threshold

The economic threshold is 6 half-inch or longer caterpillars per square foot. The threshold changes to 12 caterpillars per square foot when grain is near maturity.

Cereal Leaf Beetle

Cereal leaf beetle, a native to Europe and Asia, was first detected in Michigan in 1962. Since then, it has spread throughout most of the Midwestern and Eastern United States and has become a significant pest of VA and NC small grains. This insect can become very numerous in small grain fields, and the larvae may reduce grain yield by eating the green leaf tissue. Preferred small grain hosts for the larvae are wheat, oats, and barley, although the adults will feed on corn, wild grasses and all other cereals.

Life Cycle

Adult beetles (Photo 10-6) are about 3/16-inch long and have metallic looking, bluish-black heads and wing covers. The legs and front segment of the thorax are rust-red. Adults overwinter in grasses, ground litter, or other debris, within wooded areas, or in other protected sites in the vicinity of last season's grain fields. In the spring, they emerge when the temperature is 48 to 50°F to feed, mate, and lay eggs in small grain fields.

Photo 10-6. Cereal leaf beetle adult.

Eggs (Photo 10-7) are elliptical, about 1/32 of an inch long, and yellow when newly laid, but later become darker to orange-brown and finally black before hatching. Most often the eggs are laid singly or end-to-end in short chains on the upper leaf surface between, and aligned with, the leaf veins. Egg laying occurs during March and into April with more larvae found in poorly tillered small grain fields. Females lay 100 to 400 eggs each. These eggs will hatch in about 5 days.

Larvae (Photo 10-8) are slug-like and have yellowish bodies with heads and legs that are brownish-black. However, body coloration is usually obscured by a black globule of mucus and fecal matter held on the

Photo 10-7. Cereal leaf beetle eggs.

body, giving the larvae a shiny black, wet appearance. Larvae develop in 10 to 12 days. Peak larval populations occur in mid-April to early May. Upon reaching full size, they dig ½ to 2 inches into the ground and pupate. Pupation usually lasts 15 to 20 days.

Injury to Small Grains

Although adults will feed on young small grain plants, their feeding does not affect the plant's performance. However, larvae eat long strips of green tissue from between leaf veins and may skeletonize entire leaves (Photo 10-9), leaving only the transparent lower leaf tissue. Severely defoliated fields can take on a white "frosted" cast (Photo 10-10) as green tissue is lost on the upper leaves.

Yield Reduction

Leaf feeding indirectly reduces the plant's ability to make its food and limits reproductive growth, particularly if the upper leaves are destroyed. Larger larvae are by far the most damaging. Yield reductions of 10 to 20 percent are typical in infested commercial fields. Yield reductions of 45 percent have been observed when defoliation was near 100 percent and the damage occurred early in the heading period. Damage late in the head-fill period does not have a great impact.

Scouting Method

- Take samples at a minimum of 10 random sites in the interior of the field (avoid the edges). At each site, examine 10 stems for eggs and larvae. This will result in 100 stems per field being examined.
- Eggs may be on the leaves near the ground. Record the number of eggs and larvae counted at each sample site and then calculate the total number of eggs and larvae found in the field.
- If there are more eggs than larvae, scout again in five to seven days. This is important because egg mortality can be very high. A large number of eggs does not necessarily mean there will be a

Photo 10-8. Cereal leaf beetle larva.

Photo 10-9. Wheat leaf damage caused by cereal leaf beetle larvae feeding.

Photo 10-10. A wheat field severely damaged by cereal leaf beetle feeding.

high larvae population.

- If there are more larvae than eggs, there is no need to scout again. A decision about applying an insecticide for control can now be made.

Threshold

When the scouting results show that there are more larvae than eggs, peak egg laying has passed and it is the correct time to use the spray threshold. If there are 25 or more eggs plus larvae on 100 stems, the threshold has been met.

Management Tips

Cereal leaf beetle adults are attracted to dense highly-tillered wheat fields, but more larvae per tiller are found in poorly-tillered fields. Management practices that lead to densely tillered stands by mid-February can help to reduce the risk of having a cereal leaf beetle infestation. These practices include planting on-time, using high quality seed planted at recommended seeding rates, making sure that preplant fertility is adequate for rapid fall growth, and applying a split nitrogen application in February and March if additional tillering is needed in the spring.

Cereal leaf beetle is easily controlled with low rates of many insecticides if they are applied when the threshold is met. Because only one generation hatches per year, if insecticides are applied based on the use of thresholds, one application will give adequate management. However, if insecticides are applied early before threshold levels are met (such as with top-dress nitrogen), reduced application rates may not be adequate. And even when full label rates are used, a second application may be required later in the season.

Insecticides labeled for cereal leaf beetle control in small grains are listed in Table 10-2. To be most effective, insecticides must be applied by early head-fill, before the larvae cause significant yield-reducing defoliation. In making a choice about insecticides, consider the presence of aphids or armyworms. Both carbamates and pyrethroids kill aphid parasites and predators. Carbamates can sometimes allow a serious aphid increase. Therefore, a carbamate should not be applied against cereal leaf beetle if aphids are a potential threat. Carbaryl, beta-cyfluthrin, lambda-cyhalothrin, and zeta-cypermethrin provide excellent management, with good residual effects at least 14 days after treatment. Spinosad provides adequate management under normal situations, with minimal residual effects. Under heavy pressure situations, using spinosad is equivalent to doing nothing.

Table 10-2. Insecticides labeled for cereal leaf beetle management (2013). Although they may be as effective as the chemicals listed here, generic formulations are not listed nor are pre-mixed products with multiple insecticide classes.

Insecticide Class	Active Ingredient	Trade Name	Formulation/A
Carbamates	methomyl	Lannate LV	1 to 2 pt
		Lannate SP	0.25 to 0.5 lb
	carbaryl	Sevin brand XLR PLUS	1 pt
Pyrethroids	beta-cyfluthrin	Baythroid XL	1.0 to 1.8 fl oz
	lambda-cyhalothrin	Karate Z or Warrior II	1.92 fl oz
		Karate or Warrior	2.6 fl oz
	zeta-cypermethrin	Mustang Max EC	1.6 to 4.0 fl oz

Hessian Fly

Why Has Hessian Fly Become a Problem?

In recent years, numerous NC fields have suffered extensive losses because of Hessian fly infestations. Historically a wheat pest in the Midwest, changes in field-crop production including early planted wheat, increased adoption of no-tillage double-cropped soybeans, and the use of wheat as a cover crop for strip-tillage cotton and peanut production have permitted the Hessian fly to reach major pest status in NC.

Hessian Fly Life Cycle

The adult Hessian fly is a small, long-legged, two-winged insect that resembles a small mosquito (Photo 10-11). It is one of many species of gnat-sized flies that may be found in wheat fields. The female Hessian fly adult is reddish-brown and black in color and about 1/8-inch long. The slightly smaller males are brown or black. The elliptical eggs are very small and orange. Eggs are deposited singly or end-to-end in "egg lines" between the veins on the upper surface of the young leaves (Photo 10-12). Newly hatched larvae (maggots) are also orange for 4 or 5 days before turning white (Photo 10-13). As larvae mature, a translucent green stripe appears down the middle of the back. The maggot is about ¼ inch long when full grown. The maggot transforms into an adult fly inside a dark-brown case, or *puparium*, that resembles a flaxseed in size and shape. Newly formed puparia will be a lighter-brown color that transforms to a mahogany-brown color with age. Puparia or "flaxseeds" (Photo 10-14) are located under leaf-sheaths and usually below ground on young tillers or below the joint in older plants.

Photo 10-11. An adult Hessian fly.

Photo 10-12. Hessian fly eggs.

Photo 10-13. Large Hessian fly larvae.

Hessian fly can be found in small numbers in most wheat fields at harvest. If the wheat stubble is destroyed after harvest, the fly dies and the life cycle is broken (Figure 10-1). If, however, the wheat stubble is left in the field, the fly can survive as "flaxseeds" in the stubble through the summer. In late August and September, adults emerge from the "flaxseeds" and lay eggs on volunteer wheat or on early planted cover-crop wheat. A first generation can be completed on these plants, and the next generation adults emerging from cover-crop or volunteer wheat plants can lay eggs on wheat planted for grain in October and November, before

Photo 10-14. Hessian fly puparia or "flaxseed".

the weather turns cold enough to kill the adult flies. Often Hessian flies begin depositing eggs very soon after seedling emergence.

Once Hessian flies are established on a new wheat crop, their eggs hatch within a few days and the tiny maggots migrate into the whorl of small wheat plants, ultimately locating below ground at the stem's base, where they enter the pupal stage. While feeding, the larvae injure the plants by rupturing leaf or stem cells. They cause the plant to form an area of nutritive tissue around the base to enhance their feeding, which can result in tiller stunting and dieback. A heavy infestation on early-stage plants may greatly reduce plant stand. A new generation of adults usually emerges in March depending on the weather, lays eggs, and produces new larvae that migrate to the stem joints where they feed and cause further injury. This spring injury may kill the wheat, but usually only results in weakened stems, small heads, and poorly filled grain heads with low-quality kernels. Often, wheat lodges in seriously infested fields.

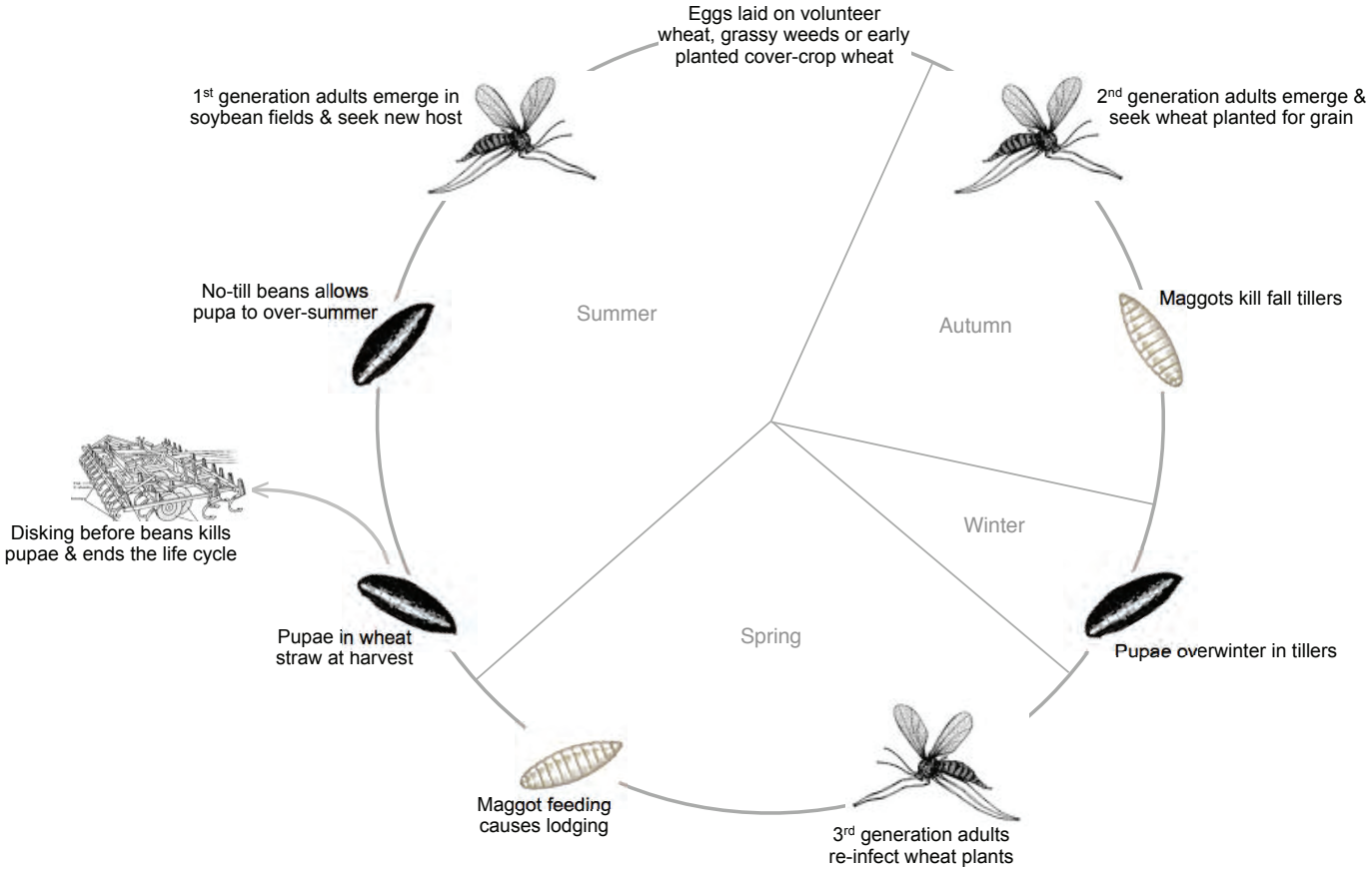

Figure 10-1. The Hessian fly life cycle.

Management

Rotation

Because the Hessian fly life cycle depends largely on the presence of wheat stubble, rotations that prevent new wheat from being planted into or near a previous wheat crop's stubble will be an effective way to prevent infestations. Avoid planting wheat into last season's wheat stubble! Continuous no-tillage wheat, double-cropped with soybeans, may result in severe problems and should be avoided in Hessian fly problem areas. Additionally, since the Hessian fly is a weak flier, putting distance between the location of new wheat plantings and the previous season's wheat fields can be a successful method of preventing new infestations. Although Hessian fly can become serious under other situations, most serious infestations occur when wheat is planted early into wheat stubble or into fields next to wheat stubble.

Tillage: Disking wheat stubble after harvest effectively kills the Hessian fly. Planting soybean no-till into wheat stubble enhances Hessian fly survival by preserving the site where puparia spend the summer. Burning wheat straw will reduce puparia, but many puparia are found below the soil surface. Therefore, burning is not as effective as disking and is not recommended as a management method.

Choosing Cover Crops

Serious Hessian fly infestations have occurred where wheat for grain was planted near early-planted wheat for cover or where early-planted wheat was present for dove hunting. In cropping systems where cover crops are used, such as in strip-till cotton or peanut production, the use of other small grains besides wheat will reduce Hessian fly populations. Although Hessian fly can develop on grasses in more than 17 genera, some are more favorable hosts for egg laying and development. Oats, rye, and triticale are not favorable for Hessian fly reproduction and do not serve as a nursery, making these grains preferable over wheat for cover cropping in areas where wheat for grain is also produced. If triticale is used for cover cropping, varieties that are adapted to NC should be planted.

Online VIDEO:
Identifying & Managing Hessian Fly
www.smallgrains.ncsu.edu/hessian-fly.html

Delayed Planting

Because freezing temperatures kill Hessian fly adults, a traditional method for preventing Hessian fly infestation is to delay planting until after the first freeze (often called the fly-free date). This concept has not worked well in NC because an early freeze is not a dependable event. Often a "killing freeze" does not occur until December in many areas of NC, after most growers need to have wheat planted for agronomic purposes. There is no reliable fly-free date in North Carolina.

Resistant and Tolerant Varieties

Correct varietal selection is probably the most inexpensive and effective method of Hessian fly management (Photo 10-15). Many wheat varieties are advertised as having Hessian fly resistance. Unfortunately, in most cases, resistance is based on a single gene present in the variety that must match a gene in the Hessian fly. This resistance often works by causing cell death and fortification of the cell wall around the nutritive tissue where the Hessian fly feeds. To be effective in NC, wheat varieties must be specifically resistant to the local Hessian fly genotype. A list of the current wheat varieties that are resistant to Hessian fly (ww.smallgrains.ncsu.edu/_Misc/

Photo 10-15. A wheat variety test demonstrating the effectiveness of variety resistance against Hessian fly. The plots with thin stands are susceptible varieties that have been damaged by Hessian fly larvae. The thick green plots are resistant varieties.

_VarietySelection.pdf) is available on the NC Small Grain Production website (www.smallgrains.ncsu.edu). In most cases, varieties rated as having "good" resistance should provide enough protection to avoid economic losses due to Hessian fly. In areas with severe Hessian fly problems, however, the use of resistant and tolerant varieties may not be sufficient to prevent infestations from occurring.

Systemic Seed Treatments

The use of systemic insecticidal seed treatments (neonicotinoid treatments) is not always effective to protect wheat seedlings from Hessian fly, especially at lower rates and when Hessian fly abundance is high. However, seed treatments can reduce fall populations when applied at the correct rate (1.33 oz/cwt Cruiser 5FS, 3.4 oz/cwt Gaucho XT, 1.2 oz/cwt Gaucho 600). Because these seed treatments are expensive, they should be used only after careful consideration of current production economics.

Foliar Insecticides

Long-residual foliar pyrethroid insecticides applied shortly after wheat emerges (at, or before, the two- to three-leaf stage) have been very effective in controlling Hessian fly. Local tests have shown that if applied at the right time, a pyrethroid will kill the adult flies, and may also kill freshly hatched larvae before they become embedded in the stems. Pyrethroids labeled for use against Hessian fly in 2013 include Baythroid XL, Karate Z, Mustang Max, and Warrior, although other pyrethroids are labeled for use on wheat for controlling other insects. At least three of the following conditions should be met before using a pyrethroid for early season Hessian fly control:

- Wheat has been planted in the same field, adjacent to, or close (within 400 yards) to the previous year's crop.
- A resistant wheat variety (rated as "good" on the NC Small Grain Production website (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf) has not been planted.
- The seeds were not treated with a neonicotinoid.
- Hessian fly has caused yield loses on this farm or nearby in previous years.
- Hessian fly eggs are present on the wheat leaves.

Fields that passed the winter with a significant Hessian fly infestation will also be attacked by the next generation of larvae re-cycling in the crop (Figure 10-1). Fields with low tiller counts should be examined in January or February for Hessian fly puparia. If a pyrethroid is applied as the flies emerge and lay eggs, usually in late March, a high level of control may be accomplished. This spring "rescue" treatment is not always effective and is generally most effective in high pressure situations. To judge the need for a pyrethroid treatment, examine the plants for puparia to identify fields that will have high fly numbers. Later scouting should focus on heavily infested fields for eggs on the top surface of new leaves. Eggs are very small, about half the size of a period, and magnification may be

needed. An experienced person with good eyesight can readily detect Hessian fly eggs, especially in direct sunlight, because the eggs will shine. Egg counts of four or more per leaf may justify a pyrethroid application.

Effective Management

For a management program to be most effective, growers must implement a combination of all the techniques mentioned above in coordination with neighboring producers. The efforts of a producer who rotates his wheat may be frustrated by a neighbor who plants wheat as a cover crop or who has a no-till double-crop soybean field adjacent to his farm. One or a combination of these management strategies will minimize Hessian fly damage: careful selection of oats, rye, or triticale for cover cropping; avoiding planting wheat into or near old wheat stubble; using resistant varieties, and planting after the first frost.

Insecticides for Small Grains

Insecticide suggestions for Hessian fly and cereal leaf beetle were discussed in the previous sections. Insecticides for the other wheat pests can be applied as broadcast spray by ground applicator or aircraft. Once plants become large, insect control, especially for armyworm, may be challenging in thick small grains if temperatures are low or if a short residual insecticide is used. In thick wheat, higher spray volumes may be necessary (5 gallons per acre by aircraft). Suitable insecticides are listed in *Insect Control in Small Grains* in the current edition of the *NC Agricultural Chemicals Manual* (http://ipm.ncsu.edu/agchem/5-toc.pdf).

Special Considerations for No-Till Small Grains

No-till planted small grains tend to grow more slowly in the fall. As a consequence, the developing seedlings and plants are more susceptible to several insect pests than those planted into conventionally tilled seedbeds. Many successful no-till planters have also found that to overcome this slower development they have to plant early while the weather is still warm. Tillage helps destroys crop residues, eliminating the host for some pests. In addition, increased surface residue may increase insect pest survival by raising temperatures near the soil, reducing insulation near the soil, and increasing soil moisture. These combined factors put no-till small grains at greater risk of damage by Hessian fly, wireworm, aphid feeding, and BYDV transmission.

No-Till in the Piedmont

In the NC piedmont, fall aphid feeding and BYDV infection are the most common problems associated with no-till. Many piedmont no-till producers have found insecticidal seed treatments to be cost-effective for this reason. Research has also shown that a foliar application of a long-residual pyrethroid insecticide when no-till wheat is at, or before, the three- to four-leaf stage can be highly effective in reducing BYDV infection. Selecting wheat varieties with good BYDV resistance is a very good way to reduce this problem in NC piedmont no-till wheat.

No-Till in the Coastal Plain

In sandy NC coastal plain soils, Hessian fly and wireworm are the most common insect problems associated with no-till. No-till seedlings in this region often emerge to produce a good-looking stand that slowly gets thinner over time. When this is due to Hessian fly, the tiller death that causes the thinning stand appears random, leaving living tillers throughout the infected area. Hessian fly adults seems to lay eggs and infest both no-till and conventional-till at the same rate. However, conventionally tilled wheat grows fast enough that it can usually produce new tillers faster than the fly maggots kill infected ones. Conversely, the slower growth in no-till plants cannot keep up with the maggot feeding, and the plants eventually die. Furthermore, tillage disrupts the life cycle of the Hessian fly by destroying the wheat stubble in which the pest can harbor.

When stand thinning is caused by wireworm, all the plants along individual rows are likely to disappear. This leaves large blank areas without any plants. Tillage apparently reduces wireworm populations enough that damage is rarely seen in conventionally tilled wheat.

Hessian fly and wireworm can be controlled for about 19 days after planting with the use of insecticidal seed treatments. In many years this provides adequate control of these two pests. In years with prolonged warm fall weather, however, seed treatment control will not be long enough and no-till stand thinning will only be delayed. Under these circumstances, foliar application of a long-residual pyrethroid insecticide when no-till wheat is at, or before, the three- to four-leaf stage is likely to give better Hessian fly control than seed treatments but will not control wireworm feeding. The most effective Hessian fly control tactic is selection of fly-resistant varieties (Photo 10-15). No-till NC coastal plain producers are encouraged to select varieties with Hessian fly resistance and to consider using an insecticidal seed treatment for wireworm control.

No-Till in the Tidewater

In organic and mineral-organic soils, wireworm problems are rarely seen and Hessian fly is the most common insect problem associated with no-till wheat. Hessian fly can be controlled for about 19 days after planting by using insecticidal seed treatments. In years with prolonged warm fall weather, this control will not be long enough. Under these circumstances, foliar application of a long-residual pyrethroid insecticide at, or before, no-till wheat is in the three- to four-leaf stage is likely to give better Hessian fly control than seed treatments. One of the most effective Hessian fly control strategies is selection of fly-resistant varieties (Photo 10-15). No-till NC tidewater producers are encouraged to select varieties with Hessian fly resistance.

11. Insect Pests of Stored Small Grains

Dominic Reisig and Steve Bambara

Many types of insects attack small grains in storage. Because small grains are usually harvested in late spring and early summer and stored when temperatures are high, insects can develop rapidly within the grain. Therefore, insect problems in storage are more severe in small grains than in other grains, such as corn, that are harvested and stored during cooler fall and winter months. If a problem occurs, the first step is to identify the insect pest. Producers not familiar with stored-grain pests should consult their county Extension agent for assistance.

Primary Feeders

Weevils

The rice weevil and maize weevil are common pests. These weevils look similar, although the maize weevil, usually found in corn, is somewhat larger and darker than the rice weevil, which is more often found in small grain (Photo 11-1). Both are small snout beetles, about 1/8-inch long, and are reddish-brown to almost black. The wing covers are usually marked with four reddish or yellow spots. Eggs are laid within individual kernels, and the grub-like larvae consume the grain from within. Pupation occurs in the kernel, and adults emerge through a small round hole, leaving behind a hollow kernel. During warm weather, an entire generation may be completed within 26 days; thus, stored grain may be severely damaged within a month of harvesting. Infestations may start near the top of a storage bin (because of insects that fly in from outside, entering underneath the eaves) or near the bottom (caused by insects that migrate up through the perforated floor). Weevils are very mobile and may be found anywhere within the grain mass.

Lesser Grain Borer

Adult and larval stages of this insect feed on and within kernels (Photo 11-2). Grain produced in NC is only occasionally infested by this insect. However, grain shipped in from the Midwest may be infested. The beetles have a slender, cylindrical form, with the head turned under the body. They are dark brown or black and are slightly less than 1/8-inch long. Eggs are laid in the grain. After they hatch, the young larvae feed upon debris or flour produced by the boring beetles. In a short period, larvae bore into the kernels and feed from within. Lesser grain borer populations can build up rapidly in warm weather and can cause significant losses. The beetles can develop throughout the grain mass and cause weevil-like damage.

Photo 11-1. Rice weevil (adult). Joseph Berger, Bugwood.org

Photo 11-2. Lesser grain borer (adult). Bugwood.org

Photo 11-3. Angoumois grain moth (adult). Clemson University – USDA Cooperative Extension Slide Series, Bugwood.org.

Photo 11-4. Indianmeal moth.

Grain Moths

Indianmeal moth and angoumois grain moth larvae (Photos 11-3 and 11-4) usually feed on the exposed surface of the stored grain mass. They rarely penetrate more than 1 foot below the surface. Therefore, their damage potential is somewhat limited. However, damage and contamination from these insects can cause an economic loss.

The angoumois grain moth is a small, buff-colored or yellowish brown moth with a wingspan of about ½-inch. Infestation may occur in the field or within bins. Under normal circumstances, eggs are laid on the outside of the grain and the larvae bore into and develop within the grain. The larvae are small, white caterpillars with yellowish heads and grow to 1/5-inch long. An important identification characteristic of this insect is the small round emergence hole produced in each infested kernel.

Indianmeal moth caterpillars feed from the outside of the kernel and primarily destroy the germ. They also feed on dust, chaff, and broken kernels. Thus, they are more of a threat to seed grain than grain intended for feeding purposes. The moths have a wingspan of about ¾-inch with reddish-brown to copper markings on the outer two-thirds of the front wings. Larvae are dirty-white, about ½-inch long, and may produce a great deal of webbing. They stay on the surface of the grain and do not develop deep within the grain mass. Severe infestations are covered with large amounts of surface webbing that may clog unloading and grain-handling equipment.

Secondary Feeders

Many insects are secondary feeders on grain, but in NC this group is usually limited to one or more bran beetles. Most likely to cause problems are the red flour beetle, the sawtoothed grain beetle (Photo 11-5), and the rusty grain beetle (small reddish beetle with head and antennae pointing forward). These insects do not attack whole kernels and are limited to feeding on grain fragments or damaged grain, so they are more likely to damage milled products than stored whole grain. However, these insects can be important sources of contamination in stored grain. Indian meal moth larvae, discussed in the primary insect section, may also become serious secondary feeders.

Management

Prestorage Procedure

Insect management for stored grain depends upon good sanitation and grain storage practices. Clean grain-handling equipment before harvest, and discard or feed to livestock the first few bushels that come through the combine and auger. Clean nearby feed storage areas, feed rooms, and similar areas to reduce the potential for insect migration into the new, noninfested grain.

Photo 11-5. Sawtoothed grain beetle (adult). USDA Cooperative Extension Slide Series, Bugwood.org.

Before harvest, thoroughly clean inside, around, and under the empty bin. Although it may be difficult and time-consuming to remove and clean under the perforated floor, most insect problems originate in carryover material from this area. The floor should be periodically taken up, if possible. Spray the bin walls, roof, and floor to the point of runoff with malathion, Tempo, Diacon II, or Storcide II according to label guidelines. Be sure to treat cracks, crevices around doors and behind false partitions, and similar voids.

Sprays will not successfully control insects hiding in grain debris below nonremovable perforated subfloors. However, chloropicrin fumigant (sold as Chloro-pic and by other names) will control insects below the perforated floor if used properly. Chloropicrin tear gas is a restricted-use pesticide, and the applicator must be properly certified in fumigation (F-phase). Special placarding and venting procedures are required.

Stored grain should contain minimal foreign material and have a moisture content of 13 percent or less. Do not mix new grain with old grain. Grain bins should not be overfilled. Once the bin is full, a load or two should be removed and fed to the livestock or stored in another location and used as soon as possible. This removes many of the hard-packed fines in the center of the bin and also makes leveling easier. The leveled grain surface should be at least 8 inches below the lip of the bin; this allows for a topdressing application of grain protectant and also makes effective examination and fumigation easier.

Once the grain is dried to 13 percent moisture or less, cool it as soon as possible by running aeration fans on cool nights. Reducing the grain temperature to less than 60ºF stops insect reproduction and lowering it to less than 50ºF stops insect feeding. While this may not be possible in June or July, the sooner the temperature can be lowered, the better. Aeration fans may be run whenever the air is cooler than the grain. Cooler air will not wet dry grain, but the grain must be dry (13 percent moisture or less) before it can safely be cooled.

Protecting Stored Grain

Apply liquid grain protectants to the grain as it is being augured into the bin to ensure adequate coverage. Do not apply these products prior to drying with heat, as the insecticidal activity will be destroyed. Malathion is no longer registered for direct application to grain going into storage and many stored grain pests have developed resistance to it. Centynal, Diacon II, diatomaceous earth, pyrethrums, or Storicide II can be used on small grains. Actellic can be used on corn or grain sorghum, but not on small grains. Storicide II gives the longest protection, up to one year, and is effective on all common grain-infesting pests except the lesser grain borer. Pyrethrum has very short residual protection and is not often used for long-term storage. It also is often in short supply and hard to obtain. No effective protectant for the lesser grain borer in stored small grains is available.

After applying the protectants, topdress with additional pesticide if allowed by label instructions. To keep the pesticide barrier intact, do not disturb the grain after treatment. If pyrethrum is used, an additional liquid or dust topdressing of *Bacillus thuringiensis* (Bt) should be applied to control indianmeal moths.

As stated earlier, cool the grain below 50°F as soon as possible. Stored-grain insects generally do not reproduce at temperatures below 60°F or feed below 50°F.

Inspect the grain at monthly intervals (weekly when the temperature is greater than 60°F). Use probes and appropriate equipment to monitor temperature, moisture, and insect presence at several sites and depths. Even when outdoor temperatures are low, moisture, insects and sunlight may produce areas within the grain mass that are warm enough to allow insect development. Therefore, be sure to inspect the grain frequently and thoroughly.

Handling Infested Grain

If grain becomes infested, the best option would be to cool it to less than 50° F, if possible, and feed it to livestock, or if seriously damaged it may be discarded. If only secondary (surface-feeding) insects are involved, it may be possible to treat the grain with grain protectant as it is moved to a clean bin. This, of course, will not control insects feeding within individual kernels, such as weevils or angoumois grain moth larvae. Contrary to popular belief, it is a waste of time to try to apply such grain protectants by using an aeration fan; they simply will not penetrate far enough to do any good.

Fumigation

Infested grain that cannot be handled as suggested above should be fumigated.

Aluminum phosphide (such as Phostoxin and Fumitoxin) or magnesium phosphide are best in most circumstances. Five days in a very tightly sealed storage are normally required for phosphide fumigation (at least 200 ppm), depending on temperature. Sealing the bin is very important as adding more than the recommended amount will not make up for a leaky bin. Other fumigation options include ProFume, which requires training and certification from Dow AgroSciences to apply, and ECO_2FUME, which can only be used by certified applicators. A protectant, such as Storcide II, can be applied after fumigation for residual control.

For more information on grain protectants and fumigation, see Table 11-1 or refer to the latest edition of the *NC Agricultural Chemicals Manual* (http://ipm.ncsu.edu/agchem/5-toc.pdf). Follow all label directions. A properly managed grain storage operation rarely needs fumigation.

Warning

Fumigation is tricky and potentially dangerous. It should be done professionally unless the producer knows how to do it right, has the equipment to do it properly, and is properly certified. Careless (or uninformed) fumigators die young!

Entering a filled grain bin can be very dangerous. Never enter a bin alone when there is still grain present, especially if any emptying has taken place. Secure yourself with a safety harness. It takes 400 lbs vertical force to pull free a person buried in grain waist deep, and only minutes to suffocate when buried in grain chest deep.

Table 11-1. Insecticides recommended for stored grain pest management.

Active Ingredient	Trade Name	Application
Empty Bin Treatments		
chlorpyrifos + deltamethrin	Storcide II	See application warnings. Apply from above or from outside bin.
beta-cyfluthrin	Tempo SC Ultra	Commercial use only.
deltamethrin	Centynal, Suspend SC	
methoprene	Diacon II, D	IGR insect growth regulator.
pyrethrins	Pyrenone Crop Spray	
Direct Grain Protectants		
chlorpyrifos + deltamethrin	Storcide II	
deltamethrin	Centynal	
diatomaceous earth	Dryacide, Insecto, Protect-It, etc.	Apply when moisture and humidity levels are low.
methoprene	Diacon II	See label for commodity.
pyrethrins	Pyrenone Crop Spray	
primiphos-methyl	Actellic 5E	**For sorghum and corn only.**
Top Dresses		
methoprene	Diacon D	IGR. Top dress dust 12 inches.
Bacillus thuringiensis (Bt)	Dipel, Biobit HP	Top dress top 4 inches. Moth larvae only.
Vapona, DDVP	PROZAP, HotShot NoPest	Hang strips in bin head space only.
Grain Fumigants		
aluminum phosphide	Phostoxin, Fumitoxin, Detia	**Licensed professional fumigator is strongly advised.**
magnesium phosphide	Degesch Magtoxin Prepac Spot Fumigant	
phosphine gas	ECO_2FUME	
sulfuryl fluoride	ProFume	Requires training and certification by Dow Agrosciences

When using any agricultural chemical, be sure that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before applying any chemical. For assistance, contact your county extension agent.

12. Small Grain Disease Management

Christina Cowger and Randy Weisz

Small grain diseases are serious threats to high yields and grain quality in many parts of NC. While some small grain diseases can be treated after they appear, others are difficult to treat once they are established. Additionally, when commodity prices are low, the costs associated with controlling diseases once they have started can cut deeply into already thin profits. The best way to minimize disease management costs and to maximize yield potential is to include disease control in every stage of small grain management. This includes variety selection, choice of seed source, seed treatment, planting date, seeding rate, fertility, and all aspects of spring pest control. A comprehensive disease management plan starts with an understanding of the major diseases common to small grains in NC and where they are likely to be a problem.

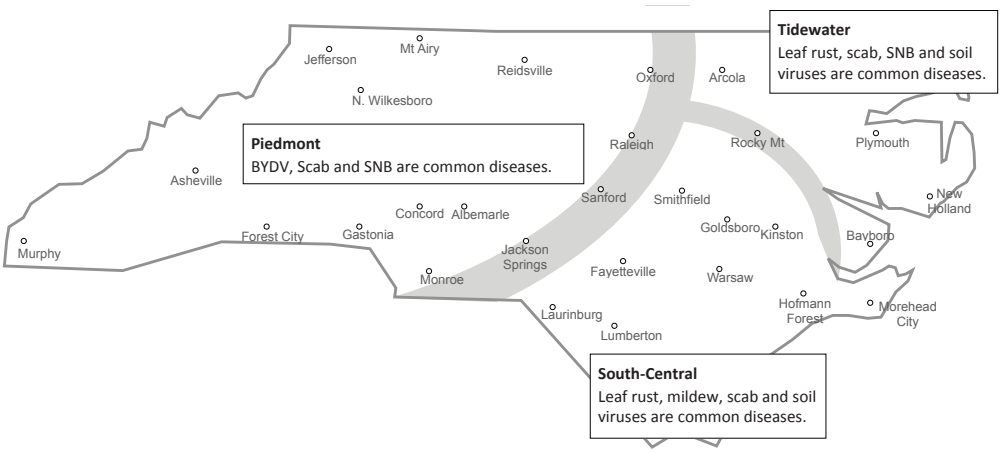

Figure 12-1. The most common small grain diseases found by region of the state.

Small Grain Disease Trends Across the State

Any of the diseases discussed here can occur in any part of the state, but some geographical trends occur. As a rule, NC's piedmont growers do not see much powdery mildew or leaf rust on their small grains. By the same token, barley yellow dwarf virus does occur in the NC coastal plain, but it's usually not as widespread or as damaging there as in the NC piedmont. Fusarium head blight (scab) has become an increasing problem in NC since about 2003, and it appears more frequently and wreaks more havoc in the NC piedmont and tidewater. The most common diseases in the three regions of NC are shown in Figure 12-1.

Barley Yellow Dwarf Virus

Description

Barley yellow dwarf virus (BYDV) is one of the most important viral diseases of wheat, oats, barley, and rye in this state. Symptoms of BYDV are often overlooked and can be easily confused with nutritional problems. Infected plants are normally found in small patches, usually a few feet in diameter. Leaves are discolored in shades of yellow, red, or purple, especially from the tip to the base and from the margin to the midrib (Photo 12-1). Plants may also be stunted. When infected early in the fall, discoloration and stunting can be severe. Infections that occur in the spring generally result in foliar discoloration but less stunting. BYDV in oats

Photo 12-1. Barley yellow dwarf virus causes leaves to be discolored in shades of yellow, red, or purple, especially from the tip to the base and from the margin to the midrib.

Photo 12-2. Barley yellow dwarf virus in oats produces striking red-purple discoloration.

produces a striking red-purple discoloration (Photo 12-2).

The virus is transmitted by aphids that summered over on nearby corn crops or host grasses, such as orchard grass, tall fescue, or ryegrass. The English grain aphid is the most important transmitter of BYDV in the fall (see Photo 10-1 in chapter 10 of this production guide or online: http://www.smallgrains.ncsu.edu/_Pubs/PG/Insects.pdf). The bird cherry-oat aphid is the most important transmitter in the spring (Photo 10-2 in chapter 10 or online: www.smallgrains.ncsu.edu/_Pubs/PG/Insects.pdf).

Environment

BYDV is most likely to occur after a warm fall and mild winter, which foster the growth and development of both host grasses and aphid populations. BYDV also can be more severe in no-till wheat planted into heavy corn debris than in wheat planted into soil free of surface corn debris. This may be because the pale corn debris attracts and shelters the aphids that transmit BYDV.

Control Measures

Cultural Practices

The standard preventive measure is to plant small grains after a frost has reduced the aphid population. This, however, can make early planting impossible, especially in years when the first frost is delayed.

Variety Selection

Some varieties of wheat have moderate resistance to BYDV. The best source for information on variety resistance is the *Wheat Variety Performance and Recommendations SmartGrains Newsletter* publication, which is available online (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf) or from local county Extension centers. Also, the oat varieties SS76-40, Rodgers, and Caballo are moderately resistant to BYDV.

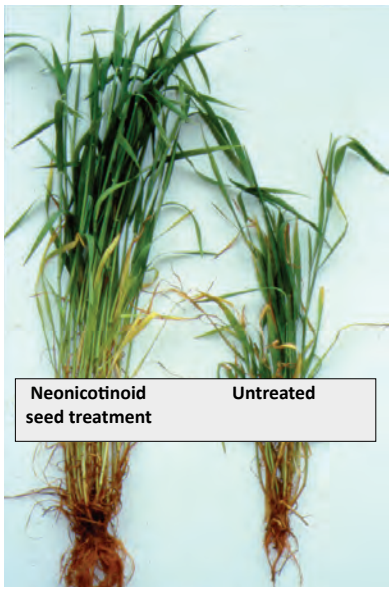

Photo 12-3. Insecticidal seed treatments can prevent aphids feeding in the fall and may reduce BYDV. These plants were from a no-till field planted after corn. The plant on the left was treated with an insecticidal seed treatment and has few BYDV symptoms. The plant on the right was untreated, and BYDV has severely stunted it.

Insecticides and Seed Treatments

There are several situations in which the use of insecticides can be beneficial for BYDV. In areas with chronic BYDV, early-planted small grains may benefit from preventive neonicotinoid insecticide seed treatments (such as Gaucho or Cruiser, Photo 12-3). This may be especially important in the NC piedmont, as a recent study demonstrated that BYDV incidence in this area can increase when wheat is no-till planted into corn residue. An alternative to using an insecticidal seed treatment is to make a foliar application of a long-residual pyrethroid insecticide when wheat is in the three- to four-leaf stage. This won't prevent BYDV development in the spring but should greatly reduce fall BYDV transmission that causes the most yield loss because of stunting.

Leaf Rust

Description

Leaf rust attacks wheat, rye, triticale, and barley. Lesions are small, circular, and vivid orange (Photo 12-4). They may occur on stems but are most common on the leaves' upper surface. When heavily infected, the whole leaf will die. Leaf rust can develop rapidly on a susceptible variety.

Weather

Winds can carry rust spores great distances. Dew promotes rust infection, and rapid disease build-up occurs between 60 and 80°F when moisture is not limiting.

Control Measures

Variety Selection

Many resistant varieties are available, and host resistance is the most economical control measure. Leaf rust resistance breaks down over a period of several years; see the *Wheat Variety Performance and Recommendations SmartGrains Newsletter* publication for the latest variety ratings (www.smallgrains.ncsu.edu/_SmartGrains/_VarietySelection.pdf). For barley variety ratings, see the latest Virginia Tech small grains publication (http://pubs.ext.vt.edu/category/grains.html).

Seed Treatments

Seed treatments are not effective against leaf rust.

Foliar Fungicides

Leaf rust usually develops late in the season when the weather is warm. This is often around the time small grains head in late April or early May. Begin scouting for leaf rust in April. It develops quickly. If the variety is rated moderately susceptible or susceptible and 1 to 3 percent of the leaf area is

Online VIDEO:
Managing Leaf Rust in Wheat
www.smallgrains.ncsu.edu/leaf-rust.html

Photo 12-4. Leaf rust attacks wheat, rye, triticale, and barley. Lesions are small, circular, and vivid orange in color.

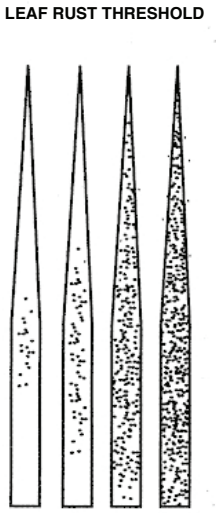

Figure 12-5. A fungicide is recommended if leaf rust covers 1 to 3% of the leaf area.

Photo 12-6. Loose smut: (A) at first, diseased heads are blackened and clearly visible among newly emerged green, healthy heads; (B) once the spores are dispersed by wind, all that remains is the stem or rachis.

covered with lesions (see Figure 12-5), a fungicide should be applied as soon as possible. However, if the variety is rated moderately resistant, it likely has adult-plant resistance, meaning that although a few leaf rust lesions will appear, it will never be profitable to apply a fungicide. Triazole fungicides (such as Folicur, Tilt, and Propimax) can be used against leaf rust, but the strobilurin fungicides (such as Headline and Quadris) or mixtures of strobilurins plus triazoles (such as Twinline, Stratego, and Quilt) are the most effective (see the latest *NC Agricultural Chemicals Manual* for fungicide recommendations and rates: http://ipm.ncsu.edu/agchem/6-toc.pdf). However, if the small grain variety that has leaf rust is also susceptible to head scab (see below) and the weather at heading is conducive to the development of scab (warm, humid, and rainy), do not apply strobilurin fungicides.

Fungicidal control of leaf rust is most effective when application is made close to the time the infection begins. For this reason, applying fungicides with top-dress nitrogen in March is usually not an effective leaf-rust management strategy.

Loose Smut

Description

Loose smut symptoms occur between heading and maturity. At first, diseased heads are blackened and clearly visible among newly emerged green, healthy heads (Photo 12-6A). Infected heads emerge slightly earlier than normal and their spikelets, except for a delicate membrane, are entirely transformed into a dry olive-black spore mass. The membrane tears easily as heads emerge, and once the spores are dispersed by wind, all that remains is the stem or rachis (stem of the head: Photo 12-6B). Seed infected with loose smut appear normal, but the fungus is inside the embryo of these seeds. When infected seed are planted, the fungus grows within the seedling and after the heads emerge, smutted grain is produced. Therefore, symptoms from infection that takes place in one year are not seen until plants from the infected seed mature in another year.

Weather

Infections occur only during flowering and are favored by wet weather and cool to moderate temperatures (61 to 72°F).

Control Measures

Because loose smut is seedborne, control measures focus on the seed to be planted.

Certified Seed

Certified seed fields are inspected for loose smut, and strict standards are enforced. Seed fields with loose smut are rejected. Using certified seed is a highly effective way to avoid loose smut.

Seed Treatments

Most fungicidal seed treatments (such as Dividend Extreme, RaxilXT, Proceed, Charter F2) are effective against loose smut (see the latest *NC Agricultural Chemicals Manual* for specific seed treatment recommendations: http://ipm.ncsu.edu/agchem/6-toc.pdf). When small grains are grown from farmer-saved seed, treating the seed with one of these fungicidal seed treatments to control loose smut (and other seedborne diseases) is recommended.

Powdery Mildew

Description

Powdery mildew can be a serious disease of wheat, barley, or oats. Lesions are first noticeable as white, powdery spots on the lower leaves (Photo 12-7A) and stems (Photo 12-7B). As the lesions mature, they become darker and sometimes turn grey or salmon with black spots or fruiting bodies (Photo 12-7D). If there is a severe epidemic, clouds of white spores can be seen when walking through the infected grain. Powdery mildew can also infect grain heads (Photo 12-7C). Mildew lesions on the leaves of stressed wheat plants can appear in "green islands" (Photo 12-7E).

Weather

Spores are dispersed by wind. High humidity (with or without rain) and cool temperatures (59 to 72°F) favor disease development. The disease is markedly slowed when temperatures rise above 77°F. Since late spring temperatures typically are above 77°F, waiting for warmer weather can be an effective control if threshold levels have not been reached.

Control Measures

Seed Treatments

Several seed treatments are labeled for early season powdery mildew control; however, studies at Virginia Tech and at NC State University have found that seed treatments are not effective enough to be a reliable control method.

Variety Selection

Many resistant varieties of wheat and barley are available. In most years, resistant wheat varieties will not require a fungicide for mildew control and consequently resistance is the most economical control measure. Mildew resistance breaks down over a period of several years, so it is important to keep up-to-date with variety performance. The best sources for this information for wheat are the *Wheat Variety Performance and Recommendations SmartGrains Newsletter* publication (www.smallgrains.ncsu.edu/

Online VIDEO:
Managing Powdery Mildew in Wheat
www.smallgrains.ncsu.edu/powdery-mildew.html

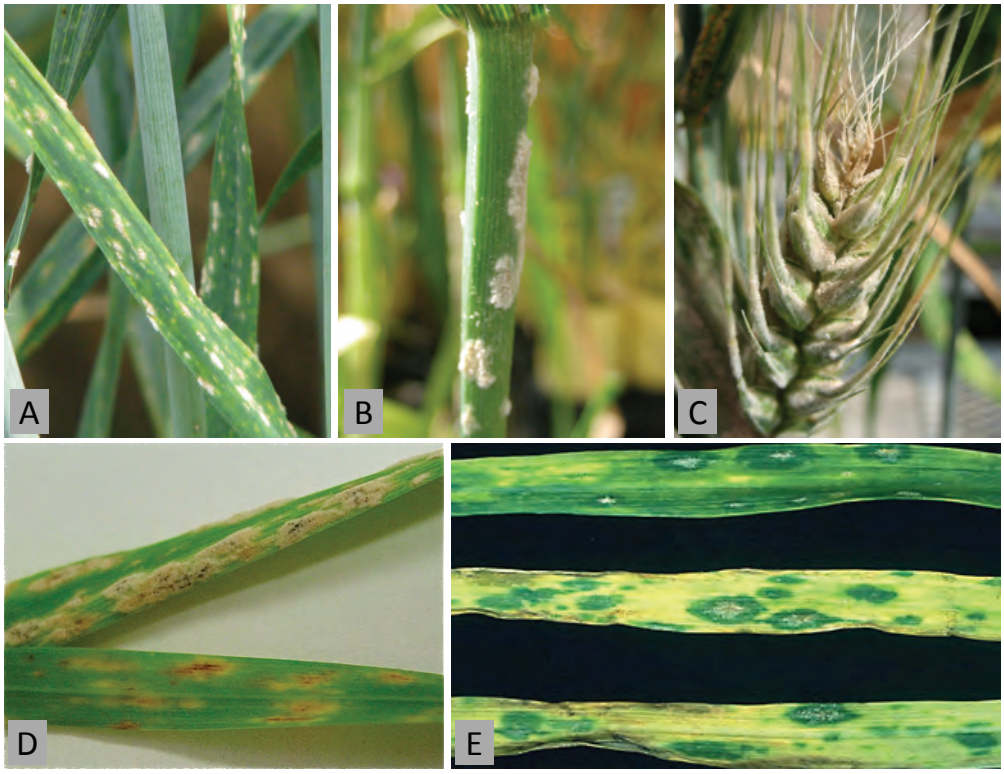

Photo 12-7. Powdery mildew: (A) lesions are first noticeable as white, powdery spots on the lower leaves and (B) stems; (C) lesions may also be on the heads; (D) older lesions become darker, sometimes grey or salmon-colored with black spots; (E) mildew lesions on the leaves of stressed wheat plants can appear in "green islands".

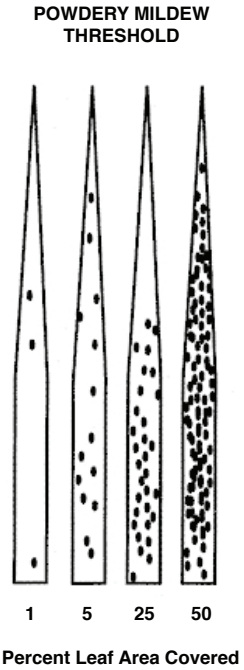

Figure 12-8. A fungicide is recommended if powdery mildew covers 5 to 10% of the upper leaves.

_Misc/_VarietySelection.pdf) and for barley, the Virginia Tech Small Grains publication (http://pubs.ext.vt.edu/category/grains.html).

Foliar Fungicides

Powdery mildew is a cool-season disease that is most likely to reach high levels of infection in late March or April. Scouting for mildew should begin in mid-March and continue until hot and dry weather has arrived, usually by late April. A fungicide is recommended if the upper leaves have powdery mildew covering 5 to 10 percent of their area (Figure 12-8). Propiconazole and strobilurin fungicides are labeled for powdery mildew, but products with propiconazole (such as Tilt and Propimax) are generally the most cost-effective (see the latest *NC Agricultural Chemicals Manual* for fungicide recommendations and rates: http://ipm.ncsu.edu/agchem/6-toc.pdf).

Stagonospora Nodorum Blotch

Description

Stagonospora nodorum blotch is caused by the fungus *Stagonospora nodorum* and is abbreviated SNB. It used to be called Septoria leaf and glume blotch and can be a serious disease of wheat. Symptoms may occur at any time during the plant's growth and on any portion of the plant. Lesions are round to lens-shaped and are found on the oldest leaves first. The youngest lesions will appear as dark-chocolate dots (Photo 12-9A) and then expand. Tissue death eventually extends beyond the lesion, and sometimes the entire leaf is killed. A diagnostic feature in older lesions are the small, dark, pimple-like spots known as *pycnidia* in the center of the lesion (Photo 12-9B). If rain splash reaches heads, lesions can appear on the heads as well (Photo 12-9C).

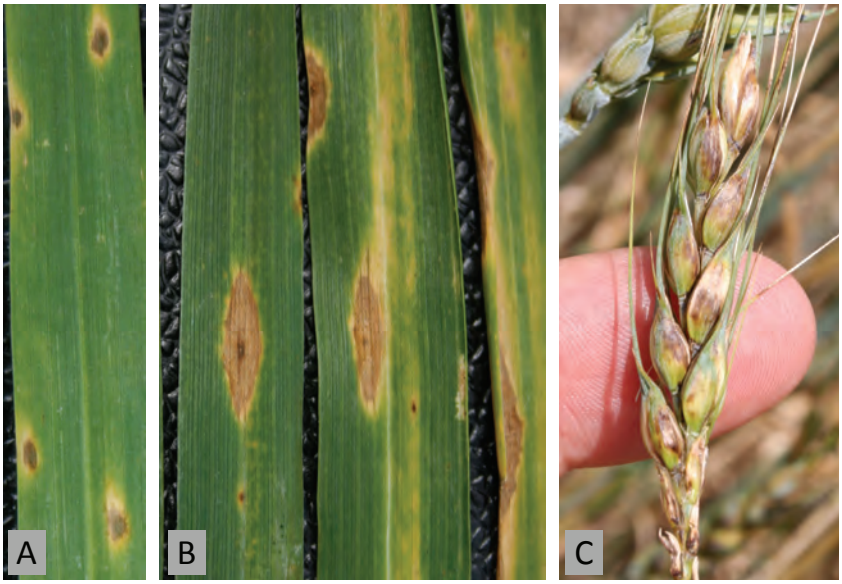

Photo 12-9. Stagonospora nodorum blotch: (A) the youngest lesions as dark-chocolate dots; (B) as lesions age they expand and in older le are often small, dark, pimple-like spots known as pycnidia; (C) if reaches heads, lesions can appear on them as well.

Environment

Wheat residues harbor the fungus, and its spores are dispersed by splashy rain. Wet, windy weather favors spore dispersal and increases the severity of SNB, while dry periods slow disease development.

Control Measures

Cultural Practices

Because wheat residues harbor the fungus, unincorporated residues can produce a severe SNB epidemic if fungal spores are splashed up onto the new crop. This puts no-till planted wheat that follows directly behind double-cropped soybeans at high risk of an SNB epidemic. Conversely, plowing under wheat stubble will eliminate residue as a source of infection.

Certified Seed

When SNB gets onto the developing grain head, it also infects the grain. If this grain is planted, the seedlings may be infected with SNB. Consequently, SNB can be seedborne. Certified seed fields are inspected for SNB, and those with significant SNB are rejected. Thus, using certified seed is an effective way to avoid SNB.

Seed Treatments

Most fungicidal seed treatments will reduce the incidence of seedborne SNB, but will not prevent a crop from being infected by rain- or wind-transmitted spores. (See the *NC Agricultural Chemicals Manual* for specific seed treatment recommendations: http://ipm.ncsu.edu/agchem/6-toc.pdf). When small grains are grown from farmer-saved seed, treat the seed with a fungicidal seed treatment to control seedborne SNB.

Variety Selection

No wheat variety is completely immune to this disease, but there are varieties with good levels of partial resistance (Photo 12-10). Moderately resistant varieties like the one on the right side of Photo 12-10 are unlikely to need a fungicide for SNB control, even in a wet spring. The best source for wheat variety resistance to SNB is the *Wheat Variety Performance and Recommendations SmartGrains*

Online VIDEO:
Managing SNB in Wheat
www.smallgrains.ncsu.edu/snb.html

Photo 12-10. The wheat variety on the left is susceptible to *Stagonospora nodorum* blotch (SNB), and most of the leaf area has been killed by the disease. The variety on the right is moderately resistant to SNB. Wheat varieties with moderate resistance are unlikely to need a fungicide for SNB control even in a wet spring.

Newsletter publication (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf).

Foliar Fungicides

Begin scouting for SNB in April. There are no reliable thresholds to help growers with fungicide decisions for SNB control. However, if a variety with moderate resistance is being produced, it will rarely require a fungicide application. The goal of SNB management is to keep this disease off the upper leaves and developing heads. All of the strobilurin fungicides, combinations of strobilurins and triazoles, and mancozeb are effective for SNB control. Headline is often the most effective (see the latest *NC Agricultural Chemicals Manual* for fungicide recommendations and rates: http://ipm.ncsu.edu/agchem/6-toc.pdf).

Scab (Fusarium Head Blight)

Description

Head scab of small grains is caused by the fungus *Fusarium graminearum*, which also infects corn. Scab can occur in all small grains. Wheat and barley are the most susceptible to the disease, oats are a little less susceptible, and rye and triticale are the most resistant.

Infection occurs at or soon after flowering, when fungal spores reach small-grain heads by wind or rain-splash. Once it's established in a spikelet, the fungus can spread along the rachis (stem inside the head) to other spikelets, resulting in heads that are partly green and partly bleached (Photo 12-11A). Superficial pink or orange spore masses can be seen on infected spikelets (Photo 12-11B). Early infections can cause kernel abortions, and later infections can cause shriveled kernels (called "tombstones") that have low test weight (Photo 12-12). Scab produces toxins in the harvested grain, the most common being DON (deoxynivalenol, or vomitoxin). When DON reaches 2 parts per million (ppm), the grain is no longer fit for human consumption and cannot be sold to a flour mill. When DON reaches 5 ppm, the grain is no longer fit even for swine feed.

Environment

Wet weather before, during, and after small-grain flowering is the main factor determining whether

Online VIDEO:
Managing Fusarium Head Scab
www.smallgrains.ncsu.edu/head-scab.html

Photo 12-11. Head scab: (A) When the fungus is established in a spikelet, it can spread along the rachis (stem inside the head) to other spikelets, resulting in heads that are partly green and partly bleached; (B) later superficial pink or orange fungal growth (mycelium and spores) can be seen on infected spikelets.

there is a severe head scab epidemic. Fungal spores come from debris of corn or small grains and reach small-grain heads via rain-splash or air currents. Warm temperatures (59 to 86°F) before and during flowering also favor scab.

Control Measures

For the most up-to-date and detailed information about scab management, see *ScabSmart*, the national website (www.ag.ndsu.edu/scabsmart). Sadly, no single management practice will defeat scab. However, wheat producers who take the following measures will greatly reduce the likelihood of a major scab outbreak.

Plant Moderately Resistant Varieties

No wheat varieties are completely resistant to scab, but many commercial wheat varieties have good levels of moderate scab resistance. The best source for wheat variety resistance to scab is the *Wheat Variety Performance and Recommendations SmartGrains Newsletter* publication (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf). There are also a few barley varieties with some scab resistance (such as Thoroughbred from Virginia Tech).

Spread Out Flowering

Spring weather is often not warm and moist for more than a week or two. So scab risk can be reduced by planting at least three wheat varieties from different heading-date classes (for example, one medium-early variety, one medium variety, and one late variety). In that way, head emergence and flowering will be staggered through the spring, reducing the chance that environmental conditions will be conducive to scab in all wheat fields. A second way to force wheat to flower at different times in the spring is to stagger planting dates.

Tillage and Rotation

The primary sources of scab spores are corn or wheat residues left on the soil surface from previous crops. Conventional tillage practices that bury these residues can reduce scab severity somewhat, while planting no-till wheat into corn stubble carries a higher scab risk. If planting no-till wheat after corn, chopping or shredding the corn stalks may help reduce scab risk if it hastens corn decomposition.

Fungicide Decision-Making

Whether there is rain in April and early May is the main factor determining risk of a severe head scab epidemic in NC. Starting in mid-April, check the

Photo 12-12. Head scab can cause shriveled kernels (called "tombstones") that have low test weight and which may contain toxins. Several healthy kernels are in the upper left corner. The most severely infected kernels are on the bottom and right side of this photo.

scab risk forecasting website created and supported by the U.S. Wheat and Barley Scab Initiative (www.wheatscab.psu.edu). This interactive site allows you to enter an estimated flowering date for your wheat crop and see the level of risk of a severe scab epidemic in your county. If the risk of developing head scab is high and the variety being grown does not have moderate resistance, it may be wise to apply a fungicide for scab control. The most effective fungicides for head scab control are Caramba, Prosaro, and Proline. Application of these fungicides for scab control is only effective if it occurs at flowering. For the most up-to-date and detailed information on fungicides for scab control, refer to the *ScabSmart* website (www.scabsmart.org).

Scouting and Combine Adjustment

Scout for scab before grain heads turn golden, when the contrast between the bleached and green parts of heads is still apparent (see Photo 12-9A). If scab is severe (more than 10 percent of heads have scab), adjust the combine so that the lightweight diseased grain is blown out the back along with the chaff. This will not remove all the infected grain but can help reduce mycotoxin levels in grain heading to market.

Seed Treatments

Because wind and rain spread scab spores to small grain heads in the spring, seed treatments will not protect the crop from new infections. If scab-infected grain is planted to produce a new crop, however, many seedlings will likely be attacked by *Fusarium* seedling blight, resulting in a poor small-grain stand. Planting scab-infected seed is not recommended. Farmer-saved seed from a field with a scab infection should be thoroughly cleaned to remove any small, light, scab-infected seed. Germination should be tested. If the germination rate is low, a seed treatment will somewhat improve stand establishment but will not completely solve the problem. Planting certified seed is the best approach to preventing seedborne scab-related problems.

Take-All

Description

Take-all is a root rot caused by a soilborne fungus, *Gaeumannomyces graminis*. Symptoms are most obvious near heading, when patches of plants appear uneven in height, begin to die prematurely, and have white, bleached-out heads. Earlier in the season, plants with take-all are stunted, mildly chlorotic, and have fewer tillers. Heads of tillers killed by take-all are distinctly bleached and sterile, have shriveled grain, and are subject to darkening by "sooty" molds. Diseased plants typically pull up easily. On close examination their roots appear sparse, blackened, and brittle. Peel back the lowest leaf sheaths—if the stems just above the root crown are blackened and shiny, that indicates take-all (Photo 12-13).

Environment

Abnormally wet fall and winter weather favors take-all, especially if soils are poorly drained. A high soil pH (above 6.3) can increase a take-all infection. Thus, liming shortly before planting wheat is likely to aggravate a take-all problem.

Photo 12-13. Plants with take-all pull up easily. Their roots appear sparse, blackened, and brittle. Peel back the lowest leaf sheaths; the stems just above the root crown will be blackened and shiny.

Control Measures

Short rotations, such as continuous wheat double-cropped with soybeans, are common causes of root rots such as take-all. No wheat varieties are available with significant resistance to take-all, and no pesticide other than soil fumigation is effective against this disease.

Cultural Practices

Maintain adequate levels of N, P, and K for good crop health, and apply spring nitrogen as ammonium instead of nitrate to reduce the soil pH. If a field has a severe take-all problem, try a rotation with two years between wheat crops. Rotating out of small grains for even one year can reduce take-all severity. Rotations with soybeans, other legumes, or corn are most satisfactory. Control grassy weeds and volunteer wheat.

Seed Treatments

Dividend may reduce take-all, but it is not an effective control measure and should not be used in place of rotation away from small grains.

Soilborne Viruses

Description

There are two main soilborne viruses of small grains in NC. The first is wheat soilborne mosaic virus (WSBMV, Photo 12-14). It is a major and often unrecognized cause of stunting and yield loss in NC wheat. Strains related to WSBMV can also infect oat, rye, barley, and triticale. The other soilborne virus is called wheat spindle-streak mosaic virus (WSSMV, Photo 12-15). Both viruses are transmitted to the roots of host plants in the late fall and winter by a fungus-like organism, *Polymyxa graminis*, that lives in the soil. *P. graminis* swims in free water, so water-logged soil and low, wet areas are conducive to infection of wheat roots (Photo 12-16). Wheat plants can be infected with WSBMV and WSSMV alone or in combination, but WSBMV generally causes greater yield loss due to more severe stunting.

Photo 12-14. Wheat soilborne mosaic virus.

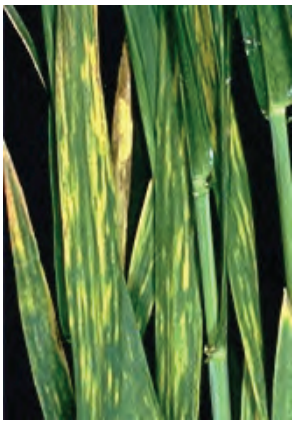

Photo 12-15. Wheat spindle-streak mosaic virus.

Photo 12-16. Water-logged soil and low, wet areas are conducive to infection by wheat soilborne mosaic virus and wheat spindle-streak mosaic virus. The variety on the left is susceptible to soilborne mosaic virus and shows typical symptoms of yellow leaves and stunting. The variety on the right is moderately resistant and is mostly disease free. However, even the resistant variety is showing symptoms in the lowest area of the field.

Besides stunting and reduced tillering, the chief symptoms are yellowing in young plants and yellow streaking and mottling on lower leaves in the early spring. These symptoms are often mistaken for nitrogen or sulfur deficiencies. Tillage spreads small-grain debris containing the vector and virus, so a problem in one part of the field is likely to spread around.

Control Measures

Short of soil fumigation, which is impractical, no chemical control measures are effective against the soilborne cereal viruses. The main line of defense is to know when a field has one or both of the viruses in the soil. From then on always choose resistant varieties.

Variety Selection

No wheat varieties are completely immune to WSBMV or WSSMV, but many commercial wheat varieties have good levels of moderate resistance to one or both of these viruses (Photo 12-16). See the *Wheat Variety Performance and Recommendations SmartGrains Newsletter* (www.smallgrains.ncsu.edu/_Misc/_VarietySelection.pdf) for an up-to-date list of wheat variety resistance to these diseases. A variety can be resistant to one of the viruses and susceptible to the other, however, so it is important to know whether you are contending with WSBMV or WSSMV. If you suspect a soil virus problem, send a whole-plant sample (including intact roots with moist soil around them) to the NC State Plant Disease & Insect Clinic (www.cals.ncsu.edu/plantpath/extension/clinic) for diagnosis. See the section on submitting a sample later in this chapter.

Crop Rotation

Crop rotation is not an effective control strategy because the vector, *Polymyxa graminis*, can survive in

dry soil without a host for at least 10 years and remain infectious.

Scouting, Disease Thresholds, Fungicide Timing, and Tank-Mixing

Small grain growers, and especially growers who are pushing their crop for high yield, should scout their small grains weekly in the spring. Ideally, begin scouting when the flag leaf emerges, and continue weekly through heading. If time is short, at least check the areas of a field with the thickest growth, as they are most at risk of disease. If a crop consultant is available, weekly scouting during this time frame is ideal. Apply fungicides only if and when thresholds are exceeded as described above for each disease.

Do Fungicides Increase Yield?

Some fungicide manufacturers recommend applying a fungicide to all small grains even if disease is not present. They claim that fungicides will improve the overall health of the plants and that this will result in increased yield. Research in NC has shown that applying fungicides routinely to wheat is rarely profitable. However, applying fungicides when a disease is present, and especially if the disease is over the recommended threshold, is profitable in most cases.

Tank-Mixing Fungicides with Top-Dress Nitrogen

Should a fungicide be tank-mixed with top-dress nitrogen in the spring? If a disease is present and over the recommended threshold, then tank-mixing a fungicide with top-dress nitrogen can be effective. However, this level of disease rarely occurs in the spring. Most wheat fields in NC will not have diseases at high enough levels at top-dress time for a fungicide to be profitable. Also, the ideal spray methods differ between fungicide and liquid nitrogen application. Fungicides need to be applied at high volume, high pressure, and with a small droplet size to get good coverage. Liquid nitrogen is best applied at low pressure and with large droplets (or even in streams) to minimize coverage and leaf burn.

Tank-Mixing Fungicides and Insecticides

The ideal time to scout for diseases (especially powdery mildew and SNB) and for cereal leaf beetle (www.smallgrains.ncsu.edu/_Pubs/PG/Insects.pdf) is in April around the time the flag leaf is emerging. Current fungicide labels allow fungal diseases and cereal leaf beetles to be treated with a single tank-mix application from flag leaf emergence until the grain heads have emerged. It makes sense to do this if thresholds for both pests have been reached.

Special Considerations for No-Till

Producers of small grains using no-till or minimum-till need to pay special attention to choosing varieties resistant to these diseases:

Head Scab

No-till production of small grains following corn increases the risk of severe head scab. Although spores of the scab fungus can blow in from other fields, having abundant corn debris on the soil surface provides a source of spores immediately beneath the wheat heads.

SNB

No-till wheat will probably have more severe SNB if wheat residues are left on the soil surface because spores of the *Stagonospora* fungus can splash from the wheat debris onto the new crop.

Barley Yellow Dwarf Virus

Corn and possibly other types of residue can increase the severity of barley yellow dwarf virus by attracting and harboring aphids.

See the specific diseases above for further control recommendations.

Diagnoses and Assistance from the Plant Disease and Insect Clinic

If you have a question about whether a small-grain problem is caused by a disease, an insect, or something else, send a sample to the NCSU Plant Disease & Insect Clinic (www.cals.ncsu.edu/plantpath/extension/clinic) for diagnosis. Send whole affected plants with intact roots surrounded by moist soil. Place a plastic bag around the roots to ensure they remain moist. If the plants are tall, it's fine to bend them double. For instructions and a submission form, contact the NCSU Plant Disease & Insect Clinic via the Web or by phone or mail:

Plant Disease and Insect Clinic
NC State University
Campus Box 7211
1227 Gardner Hall, 100 Derieux Place
Raleigh, NC 27695-7211

For disease problems: 919.515.3619
For insect problems: 919.515.9530
email: plantclinic@ces.ncsu.edu

13. Small Grain Weed Control

Wesley Everman and David Jordan

Weeds reduce yield and quality in small grains. An effective weed management program should include these strategies:

- Planting grain that is free of weed seed and wild garlic bulblets.
- Using good seedbed preparation and proper fertilization and liming.
- Seeding at the proper time and rate.
- Planting in narrow rows.
- Applying herbicides when needed.

Weeds that most often cause problems in small grains are winter annual broadleaf weeds, such as chickweed (Photos 13-1, 13-2) and henbit (Photo 13-3); perennials, such as wild garlic (Photo 13-4) and curly dock (Photo 13-5); and Italian ryegrass (Photo 13-6). One of the best tools for suppressing weeds in small grains is a healthy, vigorous crop. Good crop management practices that rapidly establish the wheat stand and develop the canopy will minimize the effects of weeds.

Managing Weeds with Herbicides

When applying herbicides, read and follow label recommendations. Information concerning weed response to herbicides and grazing restrictions for treated crops is provided in Tables 13-1 and 13-2. Additional information can be obtained from a current version of the *NC Agricultural Chemicals Manual* (http://ipm.ncsu.edu/agchem/8-toc.pdf). Refer to product labels for up-to-date suggestions and restrictions.

Generally, larger weeds are more difficult to control than smaller weeds; therefore, timely herbicide applications are critical. Many of the herbicides used in wheat affect growth processes within the target weed. In essence, the more actively the plant is growing, the better the control. Applications made to weeds stressed by drought, wet, or cold will often result in decreased control.

Many herbicides should be applied only during certain stages of wheat development to avoid crop injury. Although the stage of development provides a good indicator for application timing, factors such as environmental conditions, health of the crop, and variety (early vs. late maturity) also have an impact on crop tolerance.

Herbicides for Broadleaf Weeds in Small Grains

2,4-D

This phenoxy herbicide is available in several formulations under many trade names. The three basic formulations are amines, esters, and acid + ester mixtures. Ester or acid + ester formulations tend to be more effective under cooler conditions whereas amine formulations may be somewhat safer on the crop. Ester and acid + ester formulations also mix well with liquid nitrogen. Amine formulations can usually be mixed with liquid nitrogen, but the amine herbicide must first be premixed with water (one part herbicide to four parts water) and then the water-herbicide mixture added to the nitrogen with good agitation. Amines tend to give less burn on the small grain than esters when nitrogen is used as the carrier.

An amine formulation is safer to use when plants sensitive to 2,4-D are nearby. Ester and acid + ester

Photo 13-1. Mousear chickweed.

Photo 13-2. Common chickweed.

Photo 13-3. Henbit.

Photo 13-4. Wild garlic.

Photo 13-5. Curly dock.

Photo 13-6. Italian ryegrass.

formulations of 2,4-D can volatilize under warmer conditions and damage susceptible off-target species, such as tobacco seedlings in greenhouses.

2,4-D is registered for use on wheat, barley, oats, and rye. Oats are less tolerant than the other small grains and should not be treated under cold, wet conditions. Only amine formulations are suggested for use on oats.

2,4-D controls several common winter broadleaf weeds, such as buttercups, cornflower, cutleaf eveningprimrose, wild mustard, and wild radish (see Table 13-1). However, 2,4-D does not control chickweed (Photos 13-1, 13-2), henbit (Photo 13-3), and knawel.

Timing is critical to avoid injury to small grains. Small grains are most tolerant to 2,4-D after they are fully tillered but before jointing (growth stage 30). Application before this growth stage may cause a "rat-tail" effect, whereby the leaf does not form and unfurl properly. The crop may appear stunted and delayed in maturity, and tiller development may be adversely affected. 2,4-D should not be applied after jointing as malformed seed heads may result.

MCPA

MCPA is a phenoxy herbicide similar to 2,4-D. This herbicide has not been commonly used in NC, but it can be applied to wheat, barley, oats, and rye. Application timing is similar to the recommended timing for 2,4-D application, discussed above, but labels allow for reduced rates to be applied over a wider application window. MCPA is often somewhat safer on small grains than 2,4-D. The spectrum of weed control (Table 13-1) is similar to that with 2,4-D, but it is generally less effective than 2,4-D on larger weeds. MCPA can be tank mixed with Clarity, Harmony Extra SG, and Express for broader spectrum control.

Dicamba

Dicamba is a benzoic acid herbicide sold under several trade names, including Banvel and Clarity.

Table 13-1. Weed response to herbicides applied for broadleaf weed control.

Species	2,4-D	Dicamba	Express	Finesse[1]	Harmony Extra	MCPA
Buttercup	E	P			G	
Common chickweed	P	G	G	G	G	P
Cornflower	G	FG	P		P	
Curly dock	PF	F	GE		E	P
Cutleaf eveningprimrose	E	G			FG	E
Field pennycress	G	F	G		G	G
Henbit	P	F	F	G	G	P
Knawel	P	G			G	P
Shepherd's-purse	GE	FG	G		E	GE
Swinecress	G	G			E	G
Vetch	G	GE	P		P	FG
Virginia pepperweed	E	F			G	
Wild garlic	F	F	PF		GE	P
Wild mustard	E	F	G	G	G	GE
Wild radish	E	F	F	G	FG	GE

Key: *E = excellent control, 90% or better*

G = good control, 80-90%

F = fair control, 50-80%

P = poor control, less than 50%

[1]Can be applied preemergence or postemergence. For broadleaf control, better results generally received with postemergence applications. See comments under Ryegrass Control.

Generic brands are available. Banvel contains 4 pounds per gallon of acid equivalent formulated as the dimethylamine salt. Clarity contains 4 pounds per gallon of acid equivalent formulated as the diglycolamine salt.

Dicamba is more effective than 2,4-D on chickweed, henbit, and knawel but less effective on species such as buttercup, cornflower, Shepherd's-purse, Virginia pepperweed, wild mustard, and wild radish (see Table 13-1). Dicamba may be mixed with 2,4-D, MCPA, Harmony Extra SG, or Express for broader spectrum control.

Dicamba can be applied to wheat, barley, and oats. Labels allow dicamba application anytime prior to jointing. However, for best crop safety, apply dicamba after the small grain is fully tillered but prior to jointing.

Harmony Extra

Harmony Extra SG is a prepackaged mixture of the sulfonylurea herbicides thifensulfuron-methyl and tribenuron-methyl. Harmony Extra SG can be applied to wheat, barley, oats, and triticale. Generic brands are available.

Table 13-2. Forage, feed, and grazing restrictions for wheat herbicides.

Trade Name	Restrictions
Axial XL	Do not graze livestock or harvest forage for hay from treated areas for at least 30 days after application. Straw may be fed to livestock 60 days after application.
Axiom	Do not graze within 30 days of application.
Dicamba (Clarity, others)	Do not graze treated areas within 7 days of application or cut for hay within 37 days of application.
Express	Do not graze livestock or feed forage from treated areas for 7 days after application. Wheat may be cut for hay 30 days after application. Harvested straw may be used for bedding and/or feed.
Finesse	No grazing restrictions.
Harmony Extra	Do not graze livestock or feed forage from treated areas for 7 days after application. Wheat may be cut for hay 30 days after application. Harvested straw may be used for bedding and/or feed.
Hoelon	Do not allow livestock to graze treated fields for 28 days after treatment. Do not harvest forage, hay, or straw from treated fields prior to grain harvest.
MCPA	Do not forage or graze dairy animals or meat animals for slaughter within 7 days of slaughter.
Osprey	Do not apply within 30 days of harvesting wheat forage, and 60 days for hay and straw.
PowerFlex	Do not graze treated crop within 7 days following application. Do not cut the treated crop for hay within 28 days after application.
Prowl H20	Do not apply within 28 days of harvest of wheat hay, within 11 days of harvest of wheat forage, or within 60 days of harvest of straw.
Sharpen	Wheat can be grazed or used for hay 30 days or more after application.
Valor SX	No restrictions on grazing or use for hay.
2,4-D	Do not graze dairy cattle or meat animals within 14 days of application. Do not feed treated straw to livestock.

Harmony Extra SG has become the standard for broadleaf weed control in NC. It controls most of the common winter annual broadleaf weeds (see Table 13-1). Cornflower and vetch are major exceptions. Wild radish must be small (less than 6 inches in diameter) for adequate control by Harmony Extra SG. 2,4-D at 0.25 to 0.375 pound active ingredient per acre may be mixed with Harmony Extra SG for improved wild radish control and for control of cornflower. Harmony Extra SG is very effective on curly dock and wild garlic (see section on Wild Garlic Control below).

A nonionic surfactant at the rate of 1 quart per 100 gallons of spray solution is recommended when Harmony Extra SG is applied in water. Harmony Extra SG may be applied using liquid nitrogen as the carrier. In this case, premix the herbicide in water and add the mixture to the nitrogen with agitation. Because adding surfactant to nitrogen may increase burn on the small grain foliage, reduce the surfactant rate to 0.5 to 1.0 pint per 100 gallons of spray solution. For easy-to-control weeds, consider eliminating the surfactant when nitrogen is the carrier. However, do not eliminate surfactant when treating wild garlic. Do not use surfactant when mixtures of Harmony Extra and 2,4-D are applied in nitrogen.

An advantage of Harmony Extra SG compared with 2,4-D or dicamba is the wide window of application. Harmony Extra can be applied to wheat, barley, oats, or triticale after the two-leaf stage but before the flag leaf is visible. Application no later than the fully tillered stage is recommended for better spray coverage on weeds.

Express

Express contains tribenuron-methyl, one of the two active ingredients in Harmony Extra. It is registered for use on wheat, barley, and triticale. The spectrum of control is similar to that with Harmony Extra (Table 13-1), with notable exceptions being less effective control of henbit and wild garlic with Express. Express can be tank mixed with 2,4-D, MCPA, or dicamba on those crops for which these tank-mix partners are registered. Timing of application is the same as for Harmony Extra SG.

A nonionic surfactant at the rate of 1 quart per 100 gallons of spray solution is recommended when Express is applied in water. Express may be applied using liquid nitrogen as the carrier. In this case, see the label for adjuvant recommendations.

Finesse

Finesse contains chlorsulfuron and metsulfuron-methyl. It is registered for preemergence application to wheat or postemergence application to wheat, barley, and triticale. Finesse has been primarily used in NC to suppress ryegrass in wheat. For ryegrass suppression, Finesse must be applied preemergence; see the section in this chapter on "Italian Ryegrass Control." For control of broadleaf weeds, Finesse is best applied postemergence. It controls a number of broadleaf weeds (see Table 13-1), and it can be mixed with dicamba, 2,4-D, or MCPA for additional control.

Finesse has a long residual period. Only STS soybeans can be planted following wheat harvest. Because of the rotational restrictions, Finesse is generally not recommended for broadleaf weed control in NC. Products such as Harmony Extra SG or Express, which do not have long rotational restrictions, are preferred for broadleaf weed control.

Sharpen

Sharpen can be applied preplant, preplant incorporated, or preemergence to control broadleaf weeds in wheat. Sharpen does not control grasses. Sharpen can be applied as two sequential treatments prior to wheat emergence. Do not apply Sharpen if wheat has already germinated. See product label for application variables and tank mixtures with other herbicides.

Italian Ryegrass Control

Italian ryegrass (Photo 13-6) is a widespread problem in small grains in NC. Research has shown that wheat yields are reduced 0.4 percent for every ryegrass plant per square yard. Heavy infestations, if uncontrolled, can reduce yields by 75 percent or more. Management of this weed has become more complex with evolution of resistance to commonly used herbicides.

There are currently no control programs for Italian ryegrass in oats or rye. These crops should not be planted in ryegrass-infested fields unless significant yield reduction is acceptable. Axial and Hoelon can be used on barley.

Growers typically like to delay application until February or March in an effort to let all the ryegrass emerge before treatment. Delayed applications are usually problematic. First, larger ryegrass is more difficult to kill. Second, dense stands of ryegrass are very competitive with small grains. Even though larger ryegrass may be controlled adequately, dense stands can adversely affect small grains prior to herbicide application. Small grains will not recover from severe early season competition.

Temperature has a significant impact on herbicide activity on ryegrass. Better activity is obtained with

postemergence herbicides under warmer temperatures. Nighttime temperatures should be above 35°F for three days before and three days after application.

Axial XL

Axial XL, containing the active ingredient pinoxaden, is registered for postemergence application to wheat and barley from the two-leaf stage up to the preboot stage. The mode of action is inhibition of the ACCase enzyme, the same mode of action as Hoelon. It should be applied to ryegrass in the one- to five-leaf stage and prior to the third tiller emergence. An adjuvant is not necessary with Axial XL.

Axial XL controls ryegrass, but has no activity on annual bluegrass or broadleaf weeds. It can be tank mixed with Express, Finesse, Harmony Extra SG, or MCPA. When tank mixing, add the broadleaf herbicide to the tank first, agitate, then add the Axial.

Axial XL can be applied in liquid nitrogen, but the liquid nitrogen should constitute no more than 50 percent of the total spray volume. Add water to the tank first, add the Axial, then add the nitrogen. See label for specifics on carrier volume and other application variables.

Ryegrass that is resistant to Axial exists in NC. See the section in this chapter on "Herbicide-Resistant Ryegrass."

Axiom

Axiom is a mixture of flufenacet plus metribuzin. It can be applied to wheat from the spiking stage through the three-leaf stage. Application before wheat emergence can cause severe injury, especially on sandier soils. Axiom functions as a preemergence herbicide, hence best results are obtained when the herbicide is applied to spiking stage wheat before ryegrass emergence. Ryegrass control by Axiom can be inconsistent because timely rainfall is necessary to activate the herbicide. If activated timely (before ryegrass emergence), good control can be achieved. Control is decreased if ryegrass is in the one-leaf stage or larger before application and/or activation. Axiom controls certain broadleaf weeds such as chickweed, henbit, wild mustard, and wild radish. It also controls annual bluegrass if activated timely.

Finesse

Finesse must be applied preemergence for ryegrass control or suppression in wheat. It typically only suppresses ryegrass, with about 60 percent control at harvest.

Finesse is an ALS inhibitor. Ryegrass resistant to Finesse and other ALS inhibitors is becoming somewhat common in the NC piedmont. See the section on "Herbicide-Resistant Ryegrass" below.

If double-cropping soybeans after wheat treated with Finesse, plant only a soybean variety containing the STS trait. Non-STS soybeans can be severely injured.

Hoelon

Hoelon, containing the active ingredient diclofop-methyl, was widely used for several years to control ryegrass, until resistance to the herbicide became a problem. Hoelon, an ACCase inhibitor, is still an effective option for susceptible biotypes. See the discussion on "Herbicide-Resistant Ryegrass" below.

Hoelon can be applied postemergence to wheat and barley. NC research has shown that triticale tolerates Hoelon, but this herbicide is not registered for use on triticale. Hoelon does not control broadleaf weeds, wild garlic, or annual bluegrass.

Hoelon can be applied postemergence to any variety of wheat anytime before the first node, or joint, develops (up to growth stage 30). Hoelon can be applied postemergence to specific varieties of

barley after tiller initiation (growth stage 21) but prior to jointing. The Hoelon label specifies application only to the following varieties of barley: Anson, Boone, Callio, Henry, Milton, Molly Bloom, Mulligan, Nomini, Pennco, Starling, Sussex, and Wysor. Although wheat tolerance of Hoelon is typically very good, barley is less tolerant. Cold temperatures (less than 40°F) or prolonged wet conditions can increase barley sensitivity to Hoelon.

Recommended application rates of Hoelon vary by weed size; see the label. Best control is obtained when treating one- to three-leaf ryegrass (about 2 to 3 inches tall); this amount of growth often occurs before Christmas.

The Hoelon label allows for addition of crop oil concentrate. Crop oil is usually not necessary, and it may increase the risk of crop injury under stressful conditions. However, a crop oil can improve control under dry conditions or when treating large ryegrass. Do not add crop oil when treating barley.

Hoelon should not be applied postmergence in nitrogen nor tank mixed with other herbicides. Either of these situations can reduce ryegrass control. Additionally, to avoid reduced ryegrass control, do not apply 2,4-D, MCPA, or dicamba within five days of applying Hoelon.

Hoelon may be applied preemergence to wheat. Do not apply preemergence to barley. Applied preemergence, Hoelon can be very effective if adequate rainfall for activation is received prior to ryegrass emergence. However, Hoelon is consistently more effective when applied postemergence.

Osprey

Osprey, containing the active ingredient mesosulfuron-methyl, is registered for postemergence application only to wheat. It can be applied from wheat emergence to the jointing stage. Osprey is very effective on ryegrass if applied at the recommended growth stage. The ryegrass should be in the one-leaf to two-tiller stage. Osprey may control large ryegrass, but the level of control and the consistency of control decreases as the ryegrass exceeds the two-tiller stage.

Osprey may give adequate control of lighter infestations of chickweed, henbit, shepherd's-purse, and smaller wild mustard. It also controls small annual bluegrass. To extend the spectrum of broadleaf control, Osprey may be tank-mixed with Express, Finesse, or Harmony Extra SG. Do not mix with 2,4-D, MCPA, or dicamba. Separate applications of these broadleaf herbicides and Osprey by at least five days.

Osprey requires an adjuvant. The label allows for nonionic surfactant plus ammonium nitrogen, methylated seed oil (no nitrogen), or a "basic blend" adjuvant. See directions on the label. Good results have been obtained in NC with nonionic surfactant at 2 quarts per 100 gallons plus 1 to 2 quarts of liquid nitrogen per acre.

Osprey should not be applied with liquid nitrogen as the carrier due to the potential for crop injury. Topdress N applications and Osprey applications should be separated by 14 or more days.

Osprey is an ALS inhibitor. Ryegrass resistant to Osprey and other ALS inhibitors is becoming somewhat common in the NC piedmont. See the section on "Herbicide-Resistant Ryegrass" below.

Powerflex

Powerflex is registered for postemergence application to wheat from the three-leaf stage to jointing and ryegrass in the two-leaf to two-tiller stage. Ryegrass control is very similar to that with Osprey. Powerflex does not control annual bluegrass, but it is generally more effective than Osprey on broadleaf weeds. Powerflex will control chickweed, Carolina geranium, field pennycress, shepherd's-purse, Virginia pepperweed, wild mustard, and wild radish if treated when the weeds

are small. See details on the label. It will also suppress henbit.

Powerflex should not be tank mixed with dicamba, 2,4-D, or MCPA. It can be mixed with other herbicides registered for use in wheat.

Powerflex should be applied with a nonionic surfactant. Liquid nitrogen at 1 to 2 quarts per acre may enhance control. Powerflex can be applied with 50 percent UAN as the carrier, not to exceed 30 pounds of nitrogen per acre. Powerflex applications and topdress N applications in excess of this amount should be separated by seven or more days.

Powerflex is an ALS inhibitor. Ryegrass resistant to Powerflex and other ALS inhibitors is becoming somewhat common in the NC piedmont. See the section on "Herbicide-Resistant Ryegrass" below.

Prowl H2O

Prowl H20, active ingredient pendimethalin, can be applied postemergence to wheat from the first-leaf stage until just before the flag leaf is visible. Prowl does not control emerged weeds but can provide residual control of sensitive weed species if the herbicide is activated by rainfall in a timely manner. For ryegrass, Prowl can provide 70 to 80 percent control at 30 days after application, as long as the Prowl was activated prior to ryegrass germination. Prowl can be mixed with other registered herbicides to control emerged ryegrass.

In theory, a mixture of Prowl plus Axial, Hoelon, Osprey, or Powerflex would control emerged ryegrass plus provide residual control. However, most of the ryegrass seen at harvest is not ryegrass emerging after the postemergence herbicide application but rather is ryegrass that was not controlled with the postemergence herbicide. Prowl H2O will not help this situation. Research in NC has shown limited benefits from use of Prowl H2O in wheat.

Valor SX

Valor SX can be applied 30 or more days prior to planting wheat to provide residual control of ryegrass and several broadleaf weeds in no-till wheat. Application with paraquat (various formulations) will control emerged weeds and provide residual control of ryegrass. See label for specifics on adjuvant, spray volume, and other application variables.

Herbicide-Resistant Ryegrass

Herbicide-resistant ryegrass is becoming a very serious concern in NC, especially in the piedmont. Unfortunately, there is no practical way for a grower to determine if a resistant biotype is present. A grower can only consider past performance of a particular product. When a product has performed poorly in previous years, discontinue use of that product and other products with the same mode of action.

Resistance to Hoelon was confirmed in NC in 1990. Greater than half of the wheat fields in the NC piedmont now have Hoelon-resistant populations, and isolated populations can be found in the NC coastal plain.

Hoelon and Axial XL have the same mode of action; both are ACCase inhibitors. Cross-resistance to Hoelon and Axial would logically be expected, but that is not always the case. Axial will sometimes control Hoelon-resistant ryegrass. Of the Hoelon-resistant populations examined in NC, however, 80 percent were also resistant to Axial XL.

Osprey, Powerflex, and Finesse are ALS inhibitors. Resistance to Osprey was first noted in 2007 in NC's southern piedmont. Long-term use of Finesse probably contributed to resistance development. All Osprey-resistant populations examined in NC have also been resistant to Powerflex.

The key to avoiding or slowing resistance evolution is to reduce selection pressure on any given mode

of action. This can be accomplished by rotating herbicides with different modes of action.

In areas where neither ACCase-resistant nor ALS-resistant ryegrass is present, growers are encouraged to rotate Axial XL or Hoelon (ACCase inhibitors) with Osprey or Powerflex (ALS inhibitors).

Additionally, in springs when wheat is not planted, one should kill ryegrass prior to seed production. Ryegrass seed have a short life in the soil. Preventing seed production for one year can dramatically reduce populations the following year.

In the absence of a crop, ryegrass can be killed by early spring tillage, or it can be killed with paraquat (Gramoxone Inteon, and others) or glyphosate. Small plants are much easier to control than large plants, hence application in January or February is better than mid-March or later. Effective control with paraquat usually requires two applications about two to three weeks apart, especially on larger plants. Glyphosate is usually effective in one application. Be aware that glyphosate-resistant ryegrass has been documented in isolated areas in the NC piedmont. If glyphosate resistance is expected, use paraquat to avoid further selection for glyphosate resistance. Paraquat should be applied at 0.75 lb active ingredient per acre (3 pints Gramoxone Inteon) using flat-fan nozzles and at least 15 gallons of water per acre.

Wild Garlic

Wild garlic (Photo 13-4) does not compete with small grains, but aerial bulblets harvested with the grain impart a garlicky flavor to flour made from infested wheat. Off-flavor milk products result when dairy cows eat infested small grains. Growers receive a substantial discount for garlicky wheat.

A combination of adequate nitrogen fertilization and herbicide application is needed for wild garlic control. Application to wheat of 2 pints per acre of an ester formulation of 2,4-D will reduce aerial bulblet formation and bend over the tops of wild garlic plants so that a combine header can be set high enough to pass over most of the aerial bulblets. Control by 2,4-D, however, can be inconsistent. Additionally, 2,4-D at 2 pints per acre can injure wheat.

Harmony Extra SG at 0.75 to 0.9 ounce per acre is very effective on wild garlic. Wild garlic should be less than 12 inches tall and should have 2 to 4 inches of new growth (if treated in the spring) when Harmony Extra SG is applied. Temperatures of 50°F or higher will enhance control. Add nonionic surfactant according to the label.

No-Till Small Grains

Winter annual weeds, such as chickweed, henbit, annual bluegrass, and Italian ryegrass, have often emerged at the time of planting. Unless killed at time of planting, these weeds will have a head start on the crop and will be very competitive.

Emerged weeds can be killed at planting with glyphosate or paraquat. Application rates vary by weed size; see labels for directions.

A burndown herbicide is recommended in nearly every case. If few to no weeds are present at planting, one might consider eliminating the burn down and plan to apply Harmony Extra after the small grain reaches the two-leaf stage. Timing is critical as small winter annuals emerged at planting can quickly become too large for good control.

Acknowledgments

Alan York, William Neal Reynolds Professor Emeritus, contributed to the preparation of this chapter.

The photographs in this chapter were contributed by Bridget Lassiter and Alan York of NC State University.

Recommendations for the use of agricultural chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by the NC Cooperative Extension Service nor discrimination against similar products or services not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before applying any chemical. For assistance, contact your county Cooperative Extension Center.

A PRECAUTIONARY STATEMENT ON PESTICIDES

Pesticides must be used carefully to protect against human injury and harm to the environment. Diagnose your pest problem, and select the proper pesticide if one is needed. Follow label use directions, and obey all federal, state, and local pesticide laws and regulations.

Published by

North Carolina Cooperative Extension Service

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