North Carolina Small Grain Production Guide 2021

NC COOPERATIVE EXTENSION

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.

North Carolina Small Grain Growers Association Inc
1986

Small Grain Production Guide
Revised 2021

Prepared by

Angela Post, Small Grains Extension Specialist, NC State University

With additional contributions from

Matthew Bertone, Plant Disease & Insect Clinic Director, NC State University

Christina Cowger, USDA–ARS, Plant Pathologist, NC State University

Carl Crozier, Emeritus Soil Science Extension Specialist, NC State University

Wesley Everman, Weed Science Extension Specialist, NC State University

Luke Gatiboni, Soil Fertility Extension Specialist, NC State University

David Hardy, Section Chief, Soil Testing, NCDA & CS

Ron Heiniger, Cropping Systems Extension Specialist, NC State University

Ryan Heiniger, Official Variety Testing Director, NC State University

Kristin Hicks, Section Chief, Plant/Waste/Solution/Media Testing, NCDA & CS

Stephanie Kulesza, Nutrient & Animal Waste Management Extension Specialist, NC State University

Paul Murphy, Small Grains Breeder, NC State University

Dominic Reisig, Entomology Extension Specialist, NC State University

Derek Washburn, NC Farm School Associate, NC 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. Wheat Enterprise Budgets

By Derek Washburn, Wesley Everman, and Angela Post

In North Carolina, wheat is grown in rotation with corn, and also in a double-cropped soybean production system. The double-cropping system allows the risk of crop failure to be spread across two harvests and increases income potential. At current wheat and soybean prices (2021) the conventional wheat and double-cropped systems can both be 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 examples. Please note that these budgets are for planning purposes only.

Conventional-Till Wheat No-Till Beans

- Prices are based on futures contract prices for soybeans in November 21' and a wheat crop sold under contract as feed wheat with an assumed basis of corn futures + $0.30. Prices were pulled 7/30/2021.
- Fields are tilled using a 14' heavy disk in the fall prior to planting wheat.
- Wheat is planted with a 16-foot grain drill and soybeans are planted with a 16-foot no-till planter.
- Pre-plant fertilizer to provide 60 pounds P_2O_5, and 74 pounds K_2O per acre is applied by a commercial applicator as 130 pounds of triple super phosphate (0-46-0) and 123 pounds of potassium chloride (0-0-60) respectively. This is the assumed replacement rate for the nutrient removal of a wheat and soybean crop combined.
- Post-Planting fertilization using nitrogen is at a total rate to achieve 88lbs of N per acre. For this rate, we assume the use of soluble Urea (30-0-0) at a total of 293lbs per acre. This matches to an assumed nitrogen requirement of 1.6lbs of nitrogen for every bushel of wheat yield.
- Lime is applied once every three years and is cost prorated across three seasons.
- All herbicides, fungicides, insecticides, and top-dress N-fertilizer are applied using a Hi-Boy with a 90-foot boom.
- A broadleaf herbicide is applied in February.
- 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 24-foot wide header and hauled from the combine to a waiting truck with an 1100-grain cart.
- All soybeans are Roundup Ready planted no-till.
- An 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.

Conventional-Till Wheat

Below are the assumed differences as compared with the Soybean-Wheat Budget

- Wheat is planted at a higher rate of 2 Bushels to the acre.
- One aerial application is included at $13 an acre for cost considerations.
- Fields are tilled with an additional pass using a 20 foot light disc at a total cost of $11.11 per acre. This cost includes labor, fuel, lubrication, repairs, insurance, depreciation, and taxes.
- Pre-plant fertilizer of P_2O_5, and K_2O per is assumed at the removal rate for wheat only.

Soybean/Wheat-Conventional - 2021

NC STATE UNIVERSITY

ESTIMATED COSTS AND RETURNS PER ACRE, 2021
55 BUSHEL WHEAT YIELD AND 30 BUSHEL SOYBEANS YIELD

	UNIT	QUANTITY	PRICE OR COST/UNIT	TOTAL PER ACRE	YOUR FARM
1. GROSS RECEIPTS					
SOYBEANS	BU.	30.00	$13.23	$396.90	______
WHEAT	BU.	55.00	$7.90	$434.50	______
TOTAL RECEIPTS:				**$831.40**	______
2. VARIABLE COSTS					
SEED (WHEAT)	BU.	1.75	$22.50	$39.38	______
SEED (SOYBEANS)	THOU.	160.00	$0.40	$64.00	______
FERTILIZER					
NITROGEN (30%)	LBS	293.00	$0.14	$41.02	______
PHOSPHATE (0-46-0)	LBS	130.00	$0.26	$33.80	______
POTASH (0-0-60)	LBS	123.00	$0.21	$25.83	______
LIME (PRORATED)	TON	0.33	$54.50	$17.99	______
HERBICIDES	ACRE	1.00	$46.88	$46.88	______
INSTECTICIDES	ACRE	1.00	$10.19	$10.19	______
FUNGICIDES	ACRE	1.00	$7.06	$7.06	______
SURFACTANT	ACRE	1.00	$3.21	$3.21	______
AERIAL APPLICATION	APPL	0.00	$9.00	$0.00	______
HAULING	BU.	85.00	$0.26	$22.10	______
TRACTOR/MACHINERY	ACRE	1.00	$47.47	$47.47	______
LABOR	HRS	3.22	$12.67	$40.80	______
SCOUT	ACRE	1.00	$8.00	$8.00	______
INTEREST ON OP. CAP.	DOL.	$165.08	2.7%	$4.49	______
TOTAL VARIABLE COSTS:				**$412.22**	______
3. INCOME ABOVE VARIABLE COSTS:				**$419.18**	______
4. FIXED COSTS					
TRACTOR/MACHINERY	ACRE	1.00	$103.68	$103.68	______
TOTAL FIXED COSTS:				**$103.68**	______
5. OTHER COSTS					
GENERAL OVERHEAD	DOL.	$412.22	7.0%	$28.86	______
TOTAL OTHER COSTS:				**$28.86**	______
6. TOTAL COSTS:				**$544.76**	______
7. NET RETURNS TO LAND, RISK, AND MANAGEMENT:				**$286.64**	______

Wheat, Conventional-2021

NC STATE UNIVERSITY

ESTIMATED COSTS AND RETURNS PER ACRE, 2021
56 BUSHEL YIELD

	UNIT	QUANTITY	PRICE OR COST/UNIT	TOTAL PER ACRE	YOUR FARM
1. GROSS RECEIPTS					
WHEAT	BU.	56.00	$7.90	$442.40	________
TOTAL RECEIPTS:				**$442.40**	________
2. VARIABLE COSTS					
SEED (CERTIFIED)	BU.	2.00	$22.50	$45.00	________
FERTILIZER					
NITROGEN (30%)	LBS	293	$0.14	$41.02	________
PHOSPHATE (0-46-0)	LBS	61	$0.26	$15.83	________
POTASH (0-0-60)	LBS	35	$0.21	$7.35	________
LIME (PRORATED)	TON	0.33	$54.50	$17.99	________
HERBICIDES	ACRE	1.00	$11.41	$11.41	________
FUNGICIDES	ACRE	1.00	$7.06	$7.06	________
INSECTICIDES	ACRE	1.00	$3.73	$3.73	________
AERIAL APPLICATION	APPL	1.00	$13.00	$13.00	________
HAULING	BU.	56.00	$0.26	$14.56	________
TRACTOR/MACHINERY	ACRE	1.00	$23.13	$23.13	________
LABOR	HRS	1.62	$12.67	$20.53	________
INTEREST ON OP. CAP.	DOL.	$92.76	2.7%	$2.52	________
TOTAL VARIABLE COSTS:				**$223.13**	________
3. INCOME ABOVE VARIABLE COSTS:				**$219.27**	________
4. FIXED COSTS					
TRACTOR/MACHINERY	ACRE	1.00	$42.11	$42.11	________
TOTAL FIXED COSTS:				**$42.11**	________
5. OTHER COSTS					
GENERAL OVERHEAD	DOL.	$223.13	5.0%	$11.16	________
TOTAL OTHER COSTS:				**$11.16**	________
6. TOTAL COSTS:				**$276.40**	________
7. NET RETURNS TO LAND, RISK, AND MANAGEMENT:				**$166.00**	________

2. Small Grains Variety Selection

By Ryan Heiniger, Angela Post, and Christina Cowger

Introduction

Selecting the correct small grain variety is one of the most critical decisions a producer will make. That variety decision will determine the maximum yield potential for the year, as well as the inputs needed to realize that yield potential. Complicating this decision are the number of available varieties each year, the high amount of variety turnover that occurs each year, decline in performance of older known varieties, and the number of data sources that a grower can use to make this decision. Therefore, it is critical that each producer closely analyzes the variety criteria needed for their operation and that they use the most complete and unbiased information available. In this chapter, we will cover important characteristics a grower should use in making a wheat variety selections and the best place to find variety performance information in North Carolina.

Wheat Variety Selection Criteria

Yield

Final yield potential is an important criterion to consider when making a wheat variety selection. However, it is important to note that nearly all wheat varieties available to purchase in North Carolina have yield potentials over 90 bushels per acre. Therefore, the majority of small grains genetics available in North Carolina have the yield potential growers need to make a profit. In order to realize those yield potentials, each variety needs to be supported nutritionally throughout the season (see Chapters 5 and 6), weeds need to be controlled (see Chapter 7), insect populations should be scouted for and controlled (see Chapter 8), and disease susceptibilities need to be addressed throughout the season as they occur (see Chapter 9).

Maturity

Maturity, also known as Heading Date, is an important indication of how susceptible a variety will be to late-spring freeze damage. Early heading varieties tend to be at the most susceptible growth stage during late spring freeze events in North Carolina, while later heading varieties remain protected in the boot and are more likely to avoid yield loss due to spring freezes. In 2008 and 2017, spring freeze damage was observed at some OVT locations and early and medium-early varieties were 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.

In 2017, the NC OVT started reporting wheat variety maturity in terms of Growing Degree Units (GDUs) to 50% heading. Using GDUs to define maturity provides a more specific timing of wheat heading as compared to the "Early", "Medium", and "Late" designations used in the past. Also, in-season applications of fertility can now be targeted based on the GDUs accumulated by the planted variety. The current range of GDUs for wheat varieties tested in the NC OVT is 2180 to 2480 GDUs, with the lower number indicating an "earlier" variety.

Test Weight

A high test weight above 58 pounds per bushel is usually associated with good quality, while a low test weight will result in dockage at the elevator. Some wheat varieties are better at producing higher test weights and maintaining those test weights when grown over multiple environments and over multiple years. However, even a high test weight variety 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.

Disease & Insects

Variety selection is the best defense against most pest problems encountered in North Carolina. The three most common foliar fungal small grain diseases are powdery mildew (Photo 9.7), leaf rust (Photo 9.4), and *Stagonosprora nodorum* blotch (Photo 9.9). 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 9.14 and Photo 9.15). *Fusarium* sp. head blight or scab (Photo 9.11) 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 10.11). Wheat growers with a history of Hessian fly problems should select Hessian fly-resistant varieties. Visit chapters 8 and 9 for more details on these pests.

Yield Optimizing Tip

Where possible plant resistant varieties. Control of disease and insects in season is key to high yields.

Here are some fine-tuning guidelines for selecting varieties with disease resistance:

- **PIEDMONT:** The most common yield losses in this area include spring freeze damage, barley yellow dwarf virus, and Fusarium head blight. Varieties that are high yielding, late heading (to avoid freeze damage), and resistant to these two diseases would be ideal for the North Carolina piedmont.
- **COASTAL PLAIN:** Powdery mildew, leaf rust, and soilborne mosaic virus are common wheat pests in the North Carolina coastal plain. Ideal wheat varieties for this region should be high yielding and have resistance to all three of these diseases. Resistance to Fusarium head blight should also be considered when making a wheat variety selection for this region.
- **TIDEWATER:** Hessian fly and soilborne mosaic virus cause frequent yield loss in the North Carolina tidewater. Ideal wheat varieties are high yielding and have resistance to soilborne diseases. Where Hessian

Photo 2.1. Variety resistance is the best protection against *Fusarium* head scab (left). The only control method for soilbc mosaic virus (center) is variety resistance. Producers with a history of Hessian fly (right) should grow resistant varieties.

fly has been a problem, varieties with Hessian fly resistance should also be selected. Resistance to Fusarium head blight should also be considered when making a wheat variety selection for this region.

Height & 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, grain quality, and will slow down harvest of the crop. Height of small grains varieties should be considered based on the marketing goals of the crop and the next crop being planted after small grains harvest. In wheat, taller varieties will have higher straw yield at harvest providing an additional avenue to generate income from the crop. However, taller varieties are more prone to lodging and, if the straw is not being baled after harvest, they can interfere with planting double crop soybeans into the same field.

Head Type

Small grains variety head types are typically awned with stiff bristles extending from the head, or awnless with no stiff bristles present. While the head type itself has no direct impact on final yield for wheat varieties, the presence or absence of these awns can prevent damage to mature small grains from wildlife. In particular, deer and bear preferentially feed on awnless wheat varieties compared to awned varieties.

Milling & Baking Quality

Millers and bakers in North Carolina use wheat for many diverse products, and certain varieties are superior to others for production of specific products. This industry uses test weight, falling number and percent protein as quality metrics for determining whether to buy wheat from a producer for milling. The higher these values are, the more likely the wheat can be sold at higher prices for milling and baking quality. Falling number is the number of seconds it takes for a magnet to fall through dough created from the wheat flour mixed with water, while percent protein is the amount of protein present in the seed itself. Each year the OVT presents data for these three quality metrics from grain harvested at two locations in North Carolina. Quality metrics are analyzed by the NCSU Grain Quality Analysis Lab and the resulting values by variety are reported in the Variety Selection Tool.

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 in this production guide).

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 North Carolina coastal plain and tidewater), (3) have at least moderate resistance to barley yellow dwarf virus (especially important in the North Carolina piedmont), and (4) have at least moderate resistance to powdery mildew if planting in areas where powdery mildew is common.

Variety Selection Tool

The best source of unbiased small grains variety information can be found from the NC OVT program using the Variety Selection Tool (VST). This database contains multiple years of data across multiple locations for all varieties tested each year in the NC OVT program. Producers can use this database to find information on specific known varieties, or use the criteria described above to search the database for a list of varieties that will fit their operation. When using the database, there are four options for searching the data. Each option is briefly described below with a link to a tutorial video for each option. Extension Agents have been trained in the use of this tool and can serve as a resource when searching the tool to find a list of varieties that will work for a producer's farm. When using the tool, always make sure your crop of interest is selected on the home page.

Yield Optimizing Tip

Click "Wheat" then "Analytics" in the variety selection tool to get to the yield data for the current year

Find Variety

The Find Variety option should be used when a producer has a specific variety in mind. They can use this option to search the Variety Selection Tool for data on just that variety. Once Find Variety is selected, the name of the variety can be typed into the new window. If any part of the variety name is typed in, a drop-down menu will appear showing all available options in the database that contain those characters. Once the variety name is entered, click on the appropriate option, and a new window will appear. This new window will contain a picture or video of the variety, a link to the company technical sheet for that variety (if applicable), the company name and availability, attributes for the variety, and menu options at the top to look at additional information for that variety. In particular, the "Trials" tab will display the NC OVT data for that variety separated out by region in the state (Tidewater, Coastal Plain, and Piedmont). For more information on how to use the Find Variety feature of the VST, please visit the YouTube video Variety Selection Tool - Introduction and Find Variety (https://youtu.be/TXxDdE4S-AA).

Compare Varieties

The Compare Varieties option should be used when a producer has a list of specific varieties in mind. They can use this option to search the VST for information on just those varieties. Once Compare Varieties is selected, type the name of each variety one by one in the "Add Variety" field on the left-hand side of the screen. Similar to Find Variety, as the names are typed in a list of available varieties with that name will appear. Click on the variety that matches. Repeat this process for each variety of interest. As varieties are entered the screen on the right-hand side will be populated with information on each variety. Variety data will be stacked side by side with data for a particular variety listed under the variety name. Once all varieties are entered, this comparison can be downloaded to Excel via the "Download Data" optioin at the top of the screen, it can be downloaded as a picture via the "Save Comparison as an Image" option at the top of the screen, or it can be forwarded as a link via the "Copy Link" option at the top of the screen. Additional information for each variety can be found by clicking the book icon next to the variety name. This will open the same view found in Find Variety. For more information on how to use the Compare Varieties feature of the VST, please visit the YouTube video [Variety Selection Tool - Compare Varieties](https://youtu.be/lXBHHwsOkq0) (https://youtu.be/lXBHHwsOkq0)

Query Variety

The Query Variety option should be used when a producer has a set of criteria in mind for the variety they want to grow, but they do NOT have a specific variety name in mind. Using this option the grower can search for each relevant variety criteria and filter down to a concise list of varieties that fit those criteria. Once the Query Variety option is selected a window will open up showing available fields for data entry. The "+" icon can be selected to add additional query fields. The "Select Data Field" can be clicked to open a drop down menu showing all available data fields such as Yield, Height, and Test Weight. Click the data field of interest from the drop down menu. Once selected a "?" or drop down menu option ("No Value Selected") will be displayed on the right hand side depending on the type of data being searched. Where the "?" is displayed a value can be typed in to search on. The available values in this situation are displayed in brackets to the right of the open data field. Where "No Value Selected" is displayed, that field can be clicked on to show a drop down menu with all available options. Once all query fields have been populated, click on "Search." A list of available varieties fitting that query will be displayed below. You may need to adjust your query if 0 or more than 30 varieties are displayed. The target should be anywhere from 8 to 15 varieties. Once the appropriate number of varieties are displayed, click on the "Compare" option. This will open the Compare Varieties window described in the previous section with the variety list pre-loaded from the query. For more information on how to use the Query Variety feature of the VST, please visit the YouTube video [Variety Selection Tool - Query Variety](https://youtu.be/wxeautLo6J8) (https://youtu.be/wxeautLo6J8).

Analytics

The Analytics option is a visual way of querying data from the VST based on a set of variety criteria instead of specific variety names. If you are used to looking at the old NC OVT variety performance tables, this will be the option best suited for you. Click on Analytics and a new window will open. If this is the first time visiting this option, the window will be blank. Click "Select Data Fields" at the top and use the drop down menu to select any data that you would like displayed. Once all of the selections are made, click outside of the drop down menu to close it and click on "Rebuild Analytics." Each option selected from the drop down menu will be displayed in a separate tab on the next screen. The data for each tab is initially sorted alphabetically by variety name. Click on any column header to sort the data in that column from highest to lowest. Highest values in each column are in teal, values above average are in dark to light blue, average values are clear, below average values are in light to dark yellow, and lowest values are in red. The data in each tab is separated into single year data for the year displayed at the top of the screen for each location and region on the left and each region and statewide in the middle. Multiple year data for the year range selected is displayed on the right for each region and statewide. This section defaults to 3 years of data, but this can be changed by clicking on the gear icon at the top of the screen. This gear icon will also allow you to export the data in the displayed tab to Excel.

Data displayed is for all available varieties for the year indicated at the top of the screen. To filter this view by additional criteria, click on the "Filter by Variety" icon at the top of the screen. To find the correct icon, hover over the icon until the description is displayed. Once the Filter by Variety is selected, a filter field will be displayed on the left hand side of the screen. In this field, you can add in specific criteria as you did when using the Query Variety feature. For instance, you can filter all lines based on their availability, Head Scab tolerance, and their Falling Number data. Once the needed criteria are entered, click the "Filter Analytics" button. The view will be filtered to only display varieties that meet the criteria entered. Click the "Filter by Variety" icon to close the filter view. Once varieties are filtered, they can be loaded into the Compare Varieties view by clicking on the name of each variety of interest. Clicking will highlight the row that contains that variety. Once all relevant varieties are selected, click on the "Compare Selected Varieties" icon at the top of the screen. This will load the selected varieties into the Compare Varieties feature described in a prior section where all associated data for each variety can be examined side-by-side and downloaded into Excel. For more information on how to use the Find Variety feature of the VST, please visit the YouTube video Variety Selection Tool - Analytics (https://youtu.be/74I1s6Z5Q9U).

General Guidelines for Variety Selection

Where possible prioritize multiple year data

The Variety Selection Tool draws on data for varieties that have been in the test for one or multiple years. The best predictor of variety performance is multi-year data from multiple locations. In wheat, growers should prioritize consistent wheat varieties with at least 2 years of data from at least 8 site locations. This is easy to identify in the Analytics feature by looking for the "Y" and "L" numbers under the Multiple Year Averages section of the table. Where possible chose varieties that have multiple years of data. However, due to the turnover rate of varieties, it is possible that the only options returned in your search will be varieties with a single year of data. Where limited data are available, plant those varieties on a limited number of acres for the first year to confirm performance.

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 for a given season. To manage risk, producers should plant three or more varieties with differing characteristics each year. Growing at least three varieties will reduce the risk of losing everything to freeze injury, pest and disease damage, or other forms of crop failure, and maximize the potential for a high-yielding crop. Where possible, choose varieties with differing maturities to spread risk from weather-related loss during the growing season and to account for any delays during planting time. Divide the acres being planted into thirds and assign each of these varieties into each section.

Yield Optimizing Tip

Select varieties with multiple years and locations of data. Pick at least 3 varieties to grow to mitigate risk.

3. Wheat Growth And Development

By Angela Post

It is important to understand how small grains grow and develop in the field so that scouting and management decisions are made at the right time. Throughout the season decisions have to be made for applications of pesticides, nitrogen and other inputs. Two growth scales are commonly used to stage small grains in the field. The first is the Feekes Scale depicted. The second is the Zadoks. Refer to Figures 3.1, 3.2 and 3.3 and Table 3.1 for a visual and descriptive guide to each of these scales. This guide refers to small grain stages using the Feekes scale, but growers should be aware of both scales because pesticide labels and application recommendations from different sources may refer to one or the other. Here we cover the growth and development of small grains looking first at vegetative growth, reproductive growth, and finally maturation.

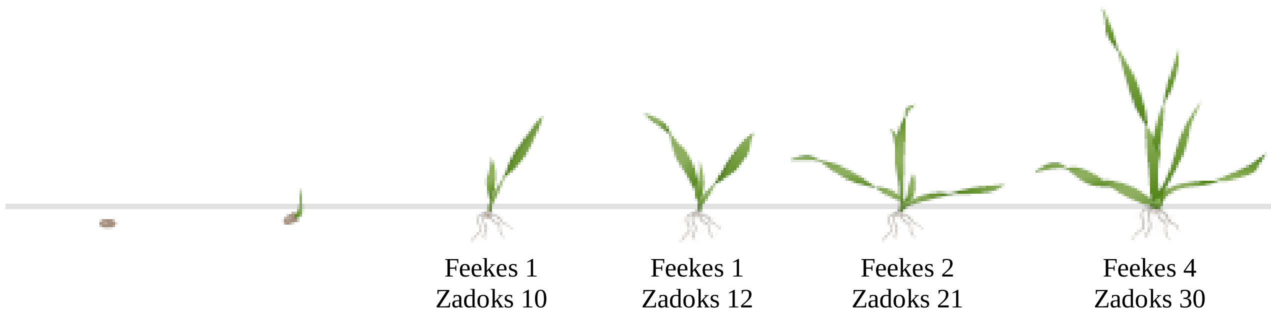


Figure 3.1 Wheat growth stage for Feekes and Zadoks scales from germination through tillering.

Vegetative Growth

Germination occurs approximately one week after planting when conditions such as soil temperature and moisture are good (Feekes 1 or Zadoks 11, see Figure 3.1). If conditions are sub-optimal, the germination process can take much longer and plants may emerge over a period of three weeks. The root emerges first and begins to grow downward in the soil and the shoot will emerge next and begin growing toward the soil surface. The initial shoot, called the coleoptile, will stop growing once emerges through the soil surface and the first true leaf emerges. After three leaves develop fully, the plant will begin to tiller (Feekes 2 or Zadoks 21).

Tillering continues throughout the fall while temperatures remain warm. Tiller development occurs most readily when developing plants are healthy, soil moisture is moderate and temperatures are above 50°F. Tillers production is important for final yield potential because each tiller develops one head. Once temperatures are consistently below 40°F, tillering slows down or stops and will resume when the temperatures rise again in late January or February. Tillers developed in the fall, before dormancy, have the most energy for grain production and produce larger heads with more grains per head than tillers developed in the spring after dormancy breaks. Spring tillers can contribute to yield, but spring tillers will only develop if proper fertility is available, particularly nitrogen. In North Carolina, tillering usually ends by early March.

Figure 3.2 Wheat growth stage for Feekes and Zadoks scales from stem elongation through flag leaf.

Reproductive Growth

Stem Elongation

At Feekes growth stage 4-5 (Zadoks 30), wheat stops producing viable tillers and begins stem elongation. The growing point, previously underground, emerges above the soil surface and forms the first visible node or joint at Feekes growth stage 6 (Zadoks 31) (see Figure 3.2). The joint is visible above the soil surface at the base of the plant and is a small swelling of the stem that somewhat resembles a joint on a human finger, hence the term. Additional nodes or joints form as the stem continues to elongate. Stem elongation is an important process in wheat development. The developing grain head is inside the stem just above the highest joint. For practical purposes, this means if damage occurs after stem elongation begins, the developing head may also be damaged. Freeze damage, drive traffic from applications of pesticide or fertility, and lodging due to wind can all damage the stem and developing head at this point in wheat growth.

At Feekes 8 (Zadoks 37) the last leaf, referred to as the flag leaf, develops on the wheat plant. As the flag leaf unfolds, the ligule or collar at the base of the leaf become visible at Feekes 9 (Zadoks 39). The developing grain head is now 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.

Figure 3.3 Wheat growth stage for Feekes and Zadoks scales from stem boot through ripening.

Heading and Flowering

Wheat is considered in the heading stage when the boot has split and the first spikelet is visibly emerged from the boot, Feekes 10.1 (Zadoks 50). Over the next few days the head will fully emerge from the boot at Feekes 10.5 (Zadoks 58) (see Figure 3.3). About 3-5 days later, the head will begin to shed pollen as flowering begins. Anthers will extend from the spikelets in the center of the head first during early flowering, Feekes 10.5.1 (Zadoks 60). Then anthers will extend from the upper florets during mid-flowering and finally along the entire head including lower portions of the head at Feekes 10.5.3 (Zadoks 70). Anthers will start out yellow in color and as the pollen sheds they will turn white and then to tan. Once they are tan and dried up, they will fall off the head.

Kernel Formation

After pollination, grain kernels begin to form almost immediately. Initial development sets the size of the kernel and it becomes watery ripe in about 10 days after pollination, Feekes 10.5.4 (Zadoks 71). If you squeeze the kernel a clear fluid will come out. About 15 days following pollination, dry matter starts accumulating in the kernels and the fluid in the kernel becomes milky, Feekes 11.1 (Zadoks 75). This is known as the *milk stage* of kernel formation. With continued growth and water loss, the kernel content changes from a milky fluid to a doughy or mealy consistency, called the soft dough stage at Feekes 11.2 (Zadoks 85). At soft dough, the green color of the head begins to fade (Photo 3.2). When the water content of the kernels drops to about 30 percent, the plant loses most of the green color and the kernels become difficult to split with the thumbnail. This is called the hard dough stage or Feekes 11.2 (Zadoks 91). This marks the end of all insect and disease pest management. When the kernels reach 13 to 14 percent moisture, the grain is ripe and ready for harvest (Photo 3.3).

Table 3.1. Feekes and Zadoks scales of small grain development.

Feekes	Zadoks	General Description
Vegetative Growth & Tillering		
1	10	1^{st} leaf through coleoptile
	12	2^{nd} leaf unfolded
	13	3^{rd} 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	1^{st} node detectable
7	32	2^{nd} node detectable
8	37	Flag leaf just visible
9	39	Flag leaf ligule visible
10	45	Boots swollen
Heading and Flowering		
10.1	50	1^{st} 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

Photo 3.1. Wheat at Feekes 2

Photo 3.2. Wheat at soft dough

Photo 3.3. Ripe wheat kernels

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.

Lollato, Romulo. 2018. Wheat growth and development. Kansas State University Agricultural Experiment Station and Extension Service. Accessed at: https://bookstore.ksre.ksu.edu/pubs/MF3300.pdf.

4. Small Grains Planting

By Angela Post and Ryan Heiniger

Row Spacing

The majority of growers plant wheat and other small grains on a 7 to 7.5" row spacing in North Carolina. A few growers use alternative row spacings above and below this width and many also choose to broadcast seed their wheat.

Some 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. From 2010-2012 Dr. Randy Weisz and Andrew Gardner tested row spacing in Rowan and Union counties. Results were similar to those previously reported from other states. They found yield decreases as row spacing increases. The highest yields occurred at row spacings of 7.5" or less and significantly lower yields as row spacing increased from 7.5" up to 15".

<u>Yield Optimizing Tip:</u>

We recommend planting on a 7.5 inch row spacing.

Seeding Rate

Seeding rate is a key consideration for wheat production. It is our recommendation that growers use a range of 1.3 to 1.8 million seeds per acre when planting wheat. Data generated from numerous seeding rate studies over the past decade in both North Carolina and Virginia have tested a range of seeding rates from 0.6 to over 2 million seeds per acre. Results suggest seeding rates from 1.3 to 1.8 million seeds per acre had the highest yield potentials with the least amount of variability. Having a wide range of available seeding rates allows a grower to adjust plans based on planting dates and expected conditions following planting. Seeding rate should first be determined based on planting date. The earlier you plant, the lower the seeding rate you can use because there will be more time and likely warmer temperatures for tillering. The later in the planting window your wheat is planted, the higher your seeding rate should be to produce enough tillers before plants go into dormancy. Later plantings will be subject to cooler and possibly wetter conditions in the fall, which limit tillering potential. Using a higher seeding rate will account for the limited tiller production per plant by increasing the plant population overall. The seeding rates

<u>Yield Optimizing Tip:</u>

When planting on-time plant 1.3 to 1.8 million seeds per acre. Stay low in the early part of the window and go high toward the later part of the window.

for wheat are discussed in depth here. Recommended seeding rates for other small grains are shown in table 4.1.

Crop	lb/bu	Seeds/acre (million)	Seed/ft²	Average seed/lb	Approx. Lb/ac	Approx Bu/ac
Oats	32	**1.05**	**24**	13,000	80	2.5
Hulled Barley	48	**1.13**	**26**	12,000	95	2
Hulless Barley	48	**1.75**	**40**	12,000	168	3.5
Rye	56	**1.75**	**40**	21,000	84	1.5
Triticale	48	**1.13**	**26**	12,000	95	2

Table 4.1. Recommended seeding rates for small grains other than wheat.

Many growers think of wheat seeding rates in terms of pounds of seeds per acre or bushels per acre, which is also how most drills are setup for calibration. However, this does not take into account the size of the seed being planted. 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 per pound. Relying solely on pounds or bushels per acre for a seeding rate, without considering the size of the seed, can result in much higher or lower seeding rates than intended. Use the table 4.2 and the known seed size of your chosen variety to determine the target pounds per acre. Seeds per pound information is printed on the bag or seed tag for certified seed. Use the formula below to calculate pounds per acre to plant when you know the seeds per pound and the target population

Pounds per acre = Target Population / Seeds per pound

Bushels per acre can be calculated from here using this formula:

Bushels per acre = Pounds per acre / 60

	Target Population (M)	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
	Seeds/ft²	23	25	28	30	32	34	37	39	41	44	46
Seeds/lb	10,000	115	127	138	150	161	173	184	196	207	219	230
	11,000	105	115	125	136	146	157	167	178	188	199	209
	12,000	96	105	115	125	134	144	153	163	173	182	192
	13,000	88	97	106	115	124	133	142	150	159	168	177
	14,000	82	90	99	107	115	123	131	140	148	156	164
	15,000	77	84	92	100	107	115	123	130	138	146	153

Table 4.2. Pounds per acre values calculated using target population (Seeds/acre or Seeds/ft²) and the seed size (Seeds/lb). The recommended seeding rate range for wheat is highlighted in green. The seeding rates shown above assume 85% germination.

Certified seed in North Carolina requires a minimum 85% germination. Table 4.2 assumes 85% germination rate in calculating a final pounds per acre seeding rate. If your seed has a germination rate lower than 85%, adjust your final seeding rate to compensate. Use the percentages in table 4.3 to increase the pounds per acre and account for lower germination rates. These recommended seeding rates are assuming conventional tillage ahead of the planter. See the No-Till considerations section for how to adjust seeding rates for no-till conditions.

We do not recommend using seed with germination rates lower than 65%. The volume of seed required to make up for germination rates below 65% can be prohibitive and costly. In addition, seed with low germination rates may have additional quality and vigor issues that will prevent optimum performance throughout the season.

Seed germination	Increase seeding rates in Table 4.2
80%	5%
75%	10%
70%	15%
65%	20%

Table 4.3. Increase in seeding rates required for lower germination seed.

Yield Optimizing Tip:
Use certified seed with ≥85% germination rates. Do not use seed with less than 65% germination

Drill Calibration

Accurate drill calibration is critical to ensuring the target seeding rate is applied. Most drills have tables that indicate how to set the seed metering mechanism for a given seeding rate in pounds per acre. However, seed size and seed treatment can affect the real-world flow of seed in any drill resulting in under- or over-seeding. To ensure an accurate seeding rate, you must calibrate the drill for each variety and seed treatment combination planted. The most accurate way to calibrate is to use your target number of seeds per row foot as calculated from your target seeding rate. Table 4.4 provides seeds per row foot calculations across different target populations and various row spacings. Take note of the reduced number of seeds per row foot when using row spacings less than 7.5 inches.

Target Population (M)		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
Seeds/ft^2		23.0	25.0	27.5	30.0	32.0	34.0	37.0	39.0	41.0	44.0	46.0
Row Spacing	6.0	11	12	14	15	16	17	18	19	20	22	23
	6.5	12	13	15	16	17	18	20	21	22	23	25
	7.0	14	15	17	18	19	20	22	23	25	26	28
	7.5	15	16	17	19	20	22	23	25	26	28	29

Table 4.4. Number of seeds per row foot calculated using target planting population (Seeds/acre or Seeds/ft^2) and row spacing. The recommended seeding rate range for wheat is highlighted in green.

A simple drill calibration method is outlined below:

1. Select the desired seeding rate. For example, if planting in the early part of the seeding window for your area, 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 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 reads 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 closest to your target population from the manufacturer's recommendations for your drill.

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.

8. Repeat for each variety and seed treatment combination you are using in a given season.

If broadcasting wheat instead of drilling, we recommend increasing seeding rates by 30 to 35 percent account for non-uniform seed placement.

Planting Date

Choosing a planting date for wheat is a balancing act between developing enough fall tillers ahead of dormancy and avoiding excessive fall growth. Planting date can also be used as a tool to avoid fall infestations of Hessian Fly and mitigate potential losses from spring freeze events. The optimum planting window for wheat planting in North Carolina is shown in Figure 4.1. These dates are one week prior to the 30-year average first freeze date for weather stations throughout North Carolina. These would be the earliest recommended planting dates that will allow for good fall tiller development while avoiding fall insect pressure and potential spring freeze damage. Planting on time for your area based on Figure 4.1 makes the most of remaining warm temperatures to develop fall tillers, which are the primary yield producing tillers. These dates also take into account the first freeze date for your area to reduce risk of infestation from Hessian Fly. If you plant earlier than the dates shown for your area you risk hessian fly infestation and increase the probability for wheat heads to be exposed during spring freeze events. In those cases where earlier planting may be necessary, choose a late maturing, Hessian Fly resistant variety.

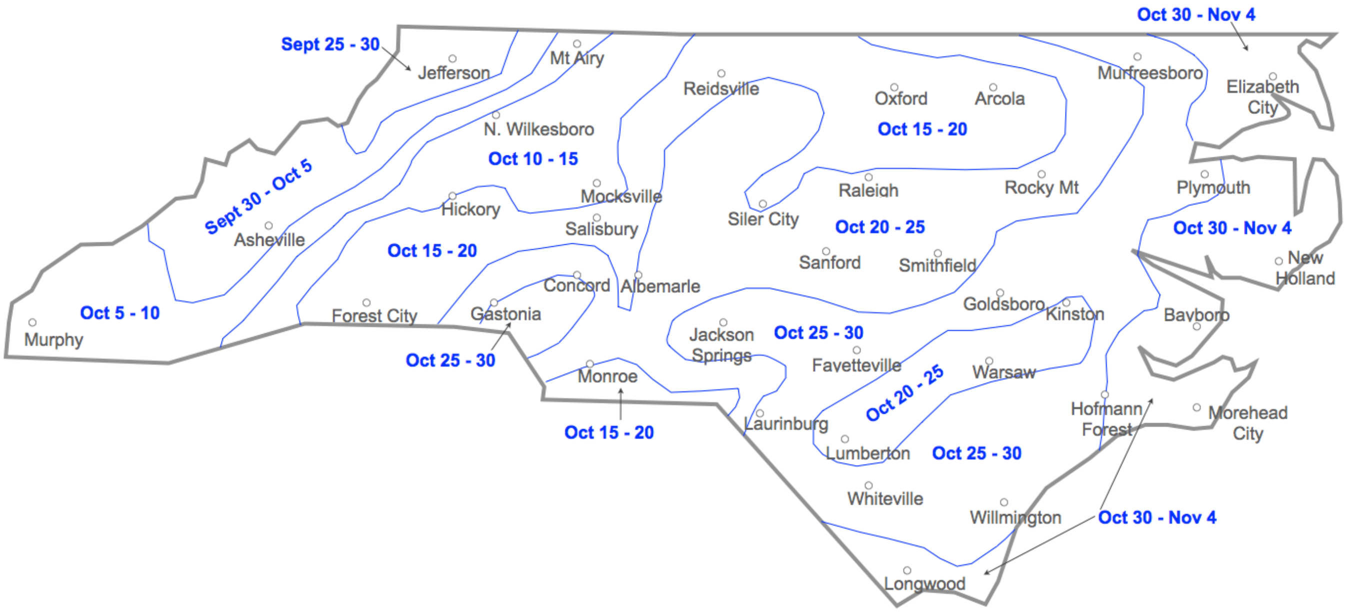


Figure 4.1. The start of wheat planting dates. The dates shown on this map are 7 days earlier than the date when there is a 50% chance of having a freeze.

Yield Optimizing Tip:

Use dates in Figure 4.1 as a starting point for wheat, triticale and rye planting in your location. Plant barley or oats one week earlier.

When choosing a planting date, it is also important to consider of the maturity of the wheat being planted. In general, later heading varieties should be planted first while the earlier heading varieties should be planted last. By planting in this order, the risk of head emergence ahead of spring freeze is significantly reduced.

Barley and oats should be planted one week ahead of the dates shown for wheat on Figure 4.1. Triticale and rye should be planted on dates similar to wheat.

Planting Depth

Most commercial wheat varieties have semi-dwarf genes that reduce overall plant height. These also reduce the chances of seedling emergence if the seeds are placed too deep. 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. Planting too shallow can result in uneven germination due to dry soil conditions nearer the surface. An adequate planting depth ensures good seed to soil contact and results in more uniform stands overall.

Yield Optimizing Tip:

Plant wheat seed from 1 to 1.5 inches below the soil surface.

No-Till Considerations

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 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 increased 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 10 to 15 percent higher than that recommended for conventional tillage (Tables 4.1 and 4.2). When no-till drilling, stop periodically and make sure that the planting depth is uniform and correct.

Heavy residue left on the soil surface can reduce soil temperatures, resulting in slower germination and tiller growth. Planting small grains early becomes even more important in no-till situations because fall growth can be reduced. Establishing a healthy, uniform stand by planting close to the dates shown in Figure 4.1 may be a key to achieving high yields in no-till.

5. Nutrient Management for Small Grains

By Luke Gatiboni, Stephanie Kulesza, Ron Heiniger, Kristin Hicks, and David Hardy

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, 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 NCDA&CS Agronomic Division, and guidelines for soil testing procedures can be found in the Extension publications: *SoilFacts: Careful Soil Sampling – The Key To Reliable Soil Test Information* (https://content.ces.ncsu.edu/careful-soil-sampling-the-key-to-reliable-soil-test-information) and Soil Facts: Soil Sampling Strategies for Site-specific Field Management (https://content.ces.ncsu.edu/soil-sampling-strategies-for-site-specific-field-management).

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, separate soil samples from "good" and "bad" areas should be submitted. This will permit a comparison between them. Details about diagnostic sampling procedures can be found at https://soilfertility.ces.ncsu.edu/diagnostic-samples/

Yield Optimizing Tip

Collect and submit "good" and "bad" soil and tissue samples when abnormal growth or plant color are observed

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. When taking diagnostic samples, both soil samples and plant tissue sample from the affected "bad" area and a nearby unaffected "good" area should be submitted for analysis to the NCDA&CS Agronomic Division laboratory. It is critically important to take the correct portion of the plant for tissue analysis depending on the growth stage. To take a tissue test from seedling to jointing (GS 1-31), clip all aboveground material in 8 to 10 locations from both the problem area and a corresponding area of normal growth. From second node jointing to pre-boot (GS 32-39), collect the top four leaves from 25-40 plants in each area. From boot to ripening (GS 45-100), sample the flag leaf from 30-40 plants in each area. These are the sampling procedures as described by the NCDA&CS Tissue Testing Lab (http://www.ncagr.gov/agronomi/tissue/wheat1p.htm). If you submit your samples to a different lab, check their website or call to verify their suggested protocols for sampling. For pictures of nutrient deficiency symptoms in wheat, the following guide published by the University of Nebraska-Lincoln is an excellent resource (https://cropwatch.unl.edu/soils/nutrient-deficiency-wheat)

Soil pH and Lime Recommendations

Yield Optimizing Tip

Optimal pH values in wheat:
Mineral soils = 6.0
Mineral Organic soils = 5.5
Organic soils = 5.0

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. Target levels are 6.0 for mineral soils, 5.5 for mineral organic soils, and 5.0 for organic soils. 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. 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 (dolomitic or calcitic) applied cannot be determined based on soil pH alone; they also depend on the soil exchangeable acidity (Ac), residual credit for recently applied lime, and measurement of available magnesium. For more information see *SoilFacts: Soil Acidity and Liming for Agricultural Soils* (https://content.ces.ncsu.edu/soil-acidity-and-liming-for-agricultural-soils).

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 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 when seen are often found on waterlogged, cool soils in late winter or early spring when P uptake is slowed. If soil P is not low, plants usually grow out of these symptoms when growing conditions improve.

In North Carolina, many soils test high or very high in P. For soil samples submitted for small grains, the 3-year average (FY 2017-2019) Mehlich 3 P index (P-I) is approximately 187. This indicates that P deficiency is mainly a concern during adverse growing conditions or when other factors affect root growth.

Phosphorus Fertilizer Rates

Phosphorus behavior in soils is complex and greatly depends on soil pH and clay content. If pH is low, P reacts with iron and aluminum associated with clay, greatly reducing plant availability; hence proper soil pH is important. Highly organic soils usually have low clay content and limited ability to hold or react with P, so the NCDA&CS soil testing lab uses a lower recommendation to safeguard excessive P application to lessen leaching potential.

In NC's mineral soils, P is usually held and accumulates depending on the amount and type of clay content. Sandy textured soils with lower clay content in the coastal plain require a higher soil test value to supply crops than the clay soils of the piedmont and mountains. However, this aspect of P behavior in soils has not been fully addressed in NCDA&CS's recommendation system, so one recommendation is currently used. At a P-I of 50, NCDA&CS recommendations for small grains are 0 and 30 pounds per acre for organic and mineral classed soils, respectively. Recommendations for mineral soils are a 0 at a P-I of 70. Consideration of potential mineralization of P should be given based on organic matter content and crop residue. 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). Because animal wastes are high in P, soils where heavy applications of animal waste have been used will have high levels of available P. Table 5.1 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 before planting. In most soils, it is usually best to incorporate P into the root zone (4 to 6 inches) since it is relatively immobile. Certainly if P is not recommended or if no-till is well established with no known issues of P deficiency, surface application should be satisfactory. In highly organic soils where P is more mobile, surface application should also give satisfactory results.

Phosphorus deficiency symptoms:

Purpling of leaf margins and lower plant leaves

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.

Potassium deficiency symptoms:

Stunted growth
Early lodging
Bronze to yellow leaf tips

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. In seasons with high rainfall during early growth stages, K can leach below the rooting zone and additional applications may be needed. 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 properly.

Sulfur Deficiency Symptoms

Sulfur deficiency is seen in small grains frequently, particularly on sandy soils where leaching occurs with excessive rainfall. 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 the young leaves at the top of the plant are the first to turn yellow when S is deficient. Sulfur deficiency symptoms usually occur in patchy spots across the field. Although more common on deep sandy soils, S deficiency symptoms can occur in clay and organic soils during cool, wet weather when the plant is small. S deficiency can also occur when the nitrogen to sulfur ratio (N:S) is high. An imbalance between N and S (>18:1) can lead to poor utilization of either or both nutrients. Small grains are more sensitive to the effects of high N:S ratios than most crops. Periodic plant tissue tests 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 easily leached. However, sometimes the S leached can be accumulated deeper in the clay horizons of the soil, if present. Response to S fertilizer is more likely if the depth to increased clay content is greater than 18 inches below the soil surface. More information can be found at *SoilFacts: Sulfur Fertilization of North Carolina Crops* (https://content.ces.ncsu.edu/sulfur-fertilization-of-north-carolina-crops). 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.

Sulfur deficiency symptoms:

Yellowing of new leaves
Small, stunted plants

Calcium and Magnesium Recommendations

Calcium (Ca) deficiency symptoms include terminal and root tip damage, dark green stems, weakened stems, and poor head 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

Table 5.1. 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 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 heads, 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, head 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.

lime applications. If deficiencies occur and no pH change is desired, sulfate forms such as gypsum (calcium sulfate) or epsom salts (magnesium sulfate) can be applied at the rates recommended in Table 5.1.

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 by a tissue test. Common problems often found in wheat in NC include manganese deficiencies on overlimed soils and copper deficiencies on organic soils. Soils that have received repeated applications of animal waste may have high soil test zinc and copper and should be monitored to avoid toxicity thresholds.

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 light green upper leaves. 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 complex copper, lowering plant availability. Often deficiency symptoms in organic soils can be found 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 5.2 shows the rate of Cu to use when a soil test detects a low level or when a tissue test indicates deficiency. Growers should take care to avoid the over-application of Cu fertilizers since 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

Table 5.2. 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/pollin ation	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.

Manganese Deficiency Symptoms

Manganese deficiency is a common concern in NC small grain production, often due to low inherent Mn levels in coastal plains soils, low availability at high pH, or a combination of the two. 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 5.2 shows the rate of Mn to use when soil test levels are low or when a tissue tests indicates deficiency.

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 deficiency is not common in NC small grain production. It is more likely when Zn soil test levels are low and soil pH is greater than 6.5. It may occur in fields with extremely high P levels (P-I > 200) due to physiological factors that affect plant metabolism. As with other micronutrients, recommended rates (Table 5.2) 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 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 receiving waste materials should also 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. Any source you suspect has a high liming potential, such as lime-stabilized biosolids, should be tested for calcium carbonate equivalence (CCE) when a waste analysis is submitted. A full nutrient analysis and CCE determination can be obtaining by submitting a sample of the waste material to the NCDA&CS Agronomic Division Waste Analysis laboratory http://www.ncagr.gov/agronomi/uyrwaste.htm.

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: https://nutrientmanagement.wordpress.ncsu.edu/nutrient-management-fact-sheets/.

6. Nitrogen Management for Small Grains

By Ron Heiniger, Kristin Hicks, Luke Gatiboni, and Angela Post

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 February-March). The next chapter of this Small Grains Production Guide discusses soil testing and management of all other nutrients. We discuss N management first and separately because nitrogen is a very dynamic nutrient in the soil; consequently, there is no soil test useful for making N recommendations in NC. Nitrogen is also a separate chapter of this Production Guide 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.

Yield Optimizing Tip:

Apply 15 to 30lbs per acre of nitrogen prior to planting

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 stimulate tillering in cold soils. Consequently, when planting late, application of preplant N to small grains might be skipped.

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 pre-plant 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 50ºF.

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 6.1, 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 6.2 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 6.3, 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 6.3 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 6.3 but not as well developed as that shown in Photo 6.2 also need an early N application. Such a field will yield best with 40 to 50 pounds of N fertilizer

Photo 6.1. Well-tillered – about 100 tillers per square foot.

Photo 6.2. Medium-tillered – about 50 tillers per square foot.

Photo 6.3. Poorly-tillered – about 20 tillers per square foot.

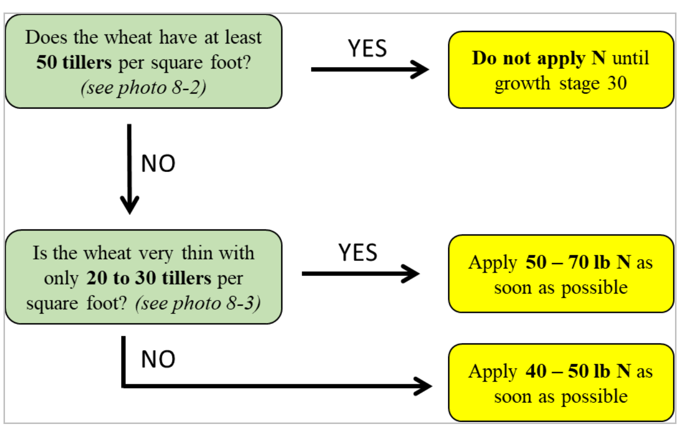


Figure 6.1. Late January to early February guidelines for wheat N fertilization.

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 6.1. 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 be made by comparing a wheat field with Photos 6.1 through 6.3, or more exactly by counting tillers.

Yield Optimizing Tip:

Apply 40 to 70lbs per acre of nitrogen if tiller counts are below 50 per square foot in late January or early February.

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, the soil type, and the presence

Yield Optimizing Tip:

Apply top dress nitrogen prior to jointing. Total nitrogen for the season should be between 100 and 150lbs per acre depending on yield potential of the field.

of carry-over N from previous crops. Nitrogen rates weighted by soil type and region can be found in this webpage https://realisticyields.ces.ncsu.edu/, where the table presents the Realistic Yield Expectation and the N rate recommended for each soil series. Besides this tool, 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.

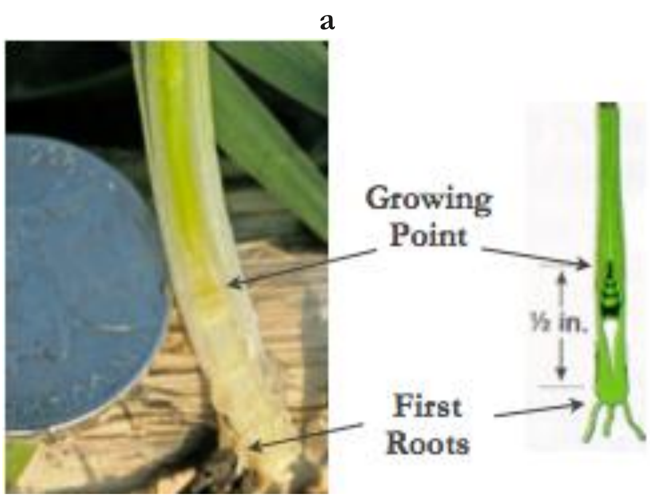


Figure 6.2. Wheat stem cross-section at growth stage 30. The growing point will be dark green, about 1/6.inch long, look like a tiny pine cone, and prior to growth stage 30 be at the very base of the stem next to the first roots. At growth stage 30 it will have moved 1/2-inch up the stem.

Nutrient Measurements are give

N (%)	P (%)	K (%)	Ca (%)	Mg (%)
2.21	0.24	2.57	0.25	0.14

Interpre

N	P	K	Ca	Mg
28-L	54-S	51-S	52-S	47-L

Other Results

Na (%)	Cl (%)	C (%)	DW (g)	Al
0.00	-	-	21.1	105

Figure 6.3: NCDA&CS Plant Analysis Report. The nitrogen % in the tissue and the dry weight (DW) of the corresponding biomass sample are used to determine the spring nitrogen application rate at GS 30.

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 6.2). After growth stage 30, it will move further up the stem and be above the soil surface. Tissue samples can be taken when the 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 N in the plant tissue and the dry weight (DW) of a corresponding biomass sample. 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 dry 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: Interpret and Use the Plant Report

Your plant report will come back with tissue nutrient concentrations for most nutrients. It will also report whether those nutrient levels are Low, Sufficient, or High. The report will also have a recommended application for one or more nutrients if they are indicated by your tissue test. You must use this information along with additional information available to you to determine the appropriate action. You may have disease clinic samples along with tissue samples or previous/recent soil samples which can indicate if the soil levels of the same nutrients are low.

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 6.2. A tissue S content less than 0.15 percent, or an N-to-S ratio greater than 18, 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.

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 2.5 percent indicate that the wheat crop does not have sufficient K to optimize yield. 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 6.1 indicates the BLUE line in Figure 6.4 is the correct one to use as this is a low biomass wheat field. Finding 3.5% on the horizontal axis of Figure 6.4 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 6.1 indicates the RED line in Figure 6.4 is correct for N fertilizer rate recommendations as this is a medium biomass wheat field. Finding 3.5% on the horizontal axis of Figure 6.4 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%.

Table 6.3. 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

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 6.1 indicates the GREEN line in Figure 6.4 is correct for N fertilizer rate recommendations as this is a high biomass wheat field. Finding 3.5% on the horizontal axis of Figure 6.4 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 6.3 to determine the crop's total spring N requirement.

7. Small Grain Weed Control

By Wesley Everman and Angela Post

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.
- Planting 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 7.1, 7.2), henbit (Photo 7.3), and wild radish (Photo 7.7); perennials, such as wild garlic (Photo 7.4) and curly dock (Photo 7.5); and annual grasses such as annual bluegrass and Italian ryegrass (Photo 7.6). 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.

Yield Optimizing Tip:

One of the best tools for suppressing weeds in small grains is a healthy, vigorous crop.

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 7.1 and 7.2. Additional information can be obtained from a current version of the *NC Agricultural Chemicals Manual* (https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual/chemical-weed-control). Refer to product labels for the most up-to-date information on a particular product. Timely herbicide applications are critical because larger weeds are more difficult to control than smaller weeds. Many of the herbicides used in wheat affect growth processes within the target weed. In essence, the more actively the plant is growing, the greater the control. Applications made to weeds stressed by drought, wet, or cold conditions will often result in decreased control compared to applications made when weeds are actively growing under optimal conditions.

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, crop health, and variety (crop maturity grouping) also have an impact on crop tolerance.

Table 7.1. Weed response to herbicides applied for broadleaf weed control.							
Species	**2,4-D**	**Dicamba**	**Express**	**Finesse[1]**	**Harmony Extra**	**MCPA**	**Quelex**
Buttercup	E	P			G		F
Common chickweed	P	G	G	G	G	P	G
Cornflower	G	FG	P		P		F
Curly dock	PF	F	GE		E	P	E
Cutleaf eveningprimrose	E	G			FG	E	E
Field pennycress	G	F	G		G	G	G
Henbit	P	F	F	G	G	P	G
Knawel	P	G			G	P	
Shepherd's-purse	GE	FG	G		E	GE	G
Swinecress	G	G			E	G	
Vetch	G	GE	P		P	FG	E
Virginia pepperweed	E	F			G		E
Wild garlic	F	F	PF		GE	P	
Wild mustard	E	F	G	G	G	GE	GE
Wild radish	E	F	F	G	FG	GE	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 Italian Ryegrass Control.


Photo 7.1. Mousear chickweed.


Photo 7.2. Common chickweed.


Photo 7.3. Henbit.


Photo 7.4. Wild garlic.


Photo 7.5. Curly dock.


Photo 7.6. Italian ryegrass.


Photo 7.7. Wild mustard.

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 result in less burn on the small grain leaves than esters when nitrogen is used as the carrier.

Table 7.2. Herbicides labeled by crop for small grains commonly grown in North Carolina

Herbicide		Wheat	Barley	Oats	Triticale	Rye
Preemergence or Spike Stage	Axiom	X			X	
	Zidua SC	X				
	Anthem Flex	X				
	Fierce	X				
	Sharpen	X	X	X	X	X
	Valor SX	X				
Postemergence	Axial BOLD	X	X			
	Osprey Xtra	X			X	
	PowerFlex HL	X			X	
	Harmony Extra	X	X	X	X	
	2,4-D	X	X	X		X
	Dicamba Clarity, others	X	X	X		
	Finesse	X	X		X	
	MCPA	X	X	X		X
	Quelex	X	X		X	
	Express	X	X	X	X	

An amine formulation is safer to use when plants sensitive to 2,4-D are nearby. Ester and acid + ester formulations of 2,4-D can volatilize under warmer conditions and damage susceptible off-target species, such as tobacco seedlings in nearby 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 7.1). However, 2,4-D does not control chickweed (Photos 7.1, 7.2), henbit (Photo 7.3), 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 7.1) 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. 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 7.1). 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 any time 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.

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 7.1). 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 non-ionic 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.

Quelex

Quelex is a prepackaged mixture of the growth regulator halauxifen and ALS-inhibitor florasulam. Quelex is labeled for use on wheat, barley, and triticale. Quelex may be applied in the spring or fall on wheat from the 2-leaf stage to flag leaf emergence. It controls most common winter annual broadleaf weeds (see Table 7.1). Buttercup, cornflower, and wild garlic are exceptions. Quelex may be applied in tank mix combination with Harmony Extra SG at 0.45 oz per acre for control of wild garlic.

A non-ionic surfactant at 1.6 to 4 pints per 100 gallons of spray solution is recommended when applied in water. Crop oil concentrate or methylated seed oil may be substituted at 4 to 8 pints per 100 gallons. Quelex may be applied in spray solutions containing liquid nitrogen fertilizer. 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 2 pint per 100 gallons of spray solution. Do not use surfactant when mixtures of Harmony Extra and 2,4-D are applied in nitrogen.

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 7.1), 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 non-ionic 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 7.1), 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 contains saflufenacil, a PPO-inhibiting herbicide. 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. Tank mix with a broad spectrum herbicide will be necessary to control emerged grass weeds at the time of application. See label for additional application variables and application instructions.

Italian Ryegrass Control

Italian ryegrass (Photo 7.6) 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 Italian 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 Italian ryegrass emerge before treatment. Delayed applications are usually problematic. First, larger Italian ryegrass is more difficult to control. Second, dense stands of ryegrass are very competitive with small grains. Even though larger Italian 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 35ºF for three days before and three days after application.

Axial XL and *Axial BOLD*

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 Italian 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 XL.

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 XL, then add the nitrogen. See label for specifics on carrier volume and other application variables.

Axial BOLD, containing the active ingredient pinoxaden plus fenoxaprop-p-ethyl, is also registered for postemergence applications from wheat emergence to preboot stage.

Italian ryegrass that is resistant to Axial XL exists in NC. See the section in this chapter on "Herbicide-Resistant Italian 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 Italian 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 Italian ryegrass, with about 60 percent control at harvest.

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

Osprey and Oxprey Xtra

Osprey, containing the active ingredient mesosulfuron-methyl, and Osprey Xtra, containing a mixture of mesosulfuron-methyl plus thiencarbazone-methyl, are registered for postemergence application to wheat or triticale. Both products can be applied from wheat emergence to the jointing stage. Osprey is very effective on Italian ryegrass if applied at the recommended growth stage. The Italian ryegrass should be in the one-leaf to two-tiller stage. Osprey may control large Italian 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 non-ionic 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 nitrogen applications and Osprey applications should be separated by 14 or more days.

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

Powerflex and Powerflex HL

Powerflex and Powerflex HL, both containing the active ingredient pyroxsulam, are registered for postemergence application to wheat from the three-leaf stage to jointing and ryegrass in the two-leaf to two-tiller stage. Italian 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 non-ionic 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. Italian ryegrass resistant to Powerflex and other ALS inhibitors is becoming somewhat common in the NC piedmont. See the section on "Herbicide-Resistant Italian Ryegrass" below.

Valor SX

Valor SX, containing the active ingredient flumioxazin, 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 Italian ryegrass. See label for specifics on adjuvant, spray volume, and other application variables.

Anthem Flex

Anthem Flex, containing the active ingredients pyroxasulfone plus carfentrazone-etyl, can be applied preemergence, delayed preemergence, or early postemergence to control grass and small seeded broadleaf weed species in wheat. DO NOT preplant incorporate to severe crop injury may occur. Anthem Flex provides residual weed control when applied at planting and may be tankmixed with postemergence herbicides to provide in-season residual control of Italian ryegrass and other weed species. Anthem Flex will not control emerged grass weed species, however may provide control of emerged broadleaf species if small.

Zidua and Zidua SC

Zidua and Zidua SC, containing the active ingredient pyroxasulfone, can be applied delayed preemergence, or early postemergence to control grass and small seeded broadleaf weed species in wheat. DO NOT preplant incorporate to severe crop injury may occur. Zidua SC provides residual weed control when applied delayed preemergence and may be tankmixed with postemergence herbicides to provide in-season residual control of Italian ryegrass and other weed species. Anthem Flex will not control emerged weeds.

Fierce

Fierce, containing the active ingredients pyroxasulfone plus flumioxazin, may be applied early postemergence when wheat is spike to 2-leaf stage of growth to control Italian ryegrass and wild radish up to 0.5 inch tall in wheat. DO NOT apply preemergence or severe crop injury may occur. Fierce provides residual grass and broadleaf weed control. Wheat seed must be planted between 1 and 1.5 inches deep or injury may occur.

Table 7.3. Herbicides labeled by crop for small grains

Herbicide		Wheat	Barley	Oats	Triticale	Rye
Preemergence or Spike Stage	Axiom	X			X	
	Zidua SC	X				
	Anthem Flex	X				
	Fierce	X				
	Sharpen	X	X	X	X	X
	Valor SX	X				
Postemergence	Axial BOLD	X	X			
	Osprey Xtra	X			X	
	PowerFlex HL	X			X	
	Harmony Extra	X	X	X	X	
	2,4-D	X	X	X		X
	Dicamba Clarity, others	X	X	X		
	Finesse	X	X		X	
	MCPA	X	X	X		X
	Quelex	X	X		X	
	Express	X	X	X	X	

Herbicide-Resistant Italian Ryegrass

Herbicide-resistant Italian 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. 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.

ACCase resistance was confirmed in NC in 1990 (to the herbicide Hoelon). Greater than half of the wheat fields in the NC piedmont now have ACCase-resistant populations, and isolated populations can be found in the NC coastal plain. Currently Axial XL and Axial BOLD are ACCase herbicides labeled for use in NC wheat. .

> **Yield Optimizing Tip**
> **Rotate herbicides with different modes of action to reduce selection pressure on any given mode of action.**

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.

In all areas, utilizing the residual herbicides Anthem Flex, Zidua, or Fierce, will provide control with at least one additional mode of action compared to postermergence applications alone. Residual herbicides should be used preemergence or postemergence and, in extreme cases with heavy infestations of resistant Italian ryegrass, at both preemergence followed by postemergence in an attempt to accomplish overlapping residual activity.

In areas where neither ACCase-resistant nor ALS-resistant Italian ryegrass is present, growers are encouraged to rotate Axial XL (ACCase inhibitor) with Osprey or Powerflex (ALS inhibitors) while also including the residual herbicides Anthem Flex, Zidua, or Fierce to slow the selection of herbicide resistant biotypes. Additionally, in springs when wheat is not planted, plan to control Italian ryegrass prior to seed production. Italian 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, control Italian ryegrass by early spring tillage, or 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 Italian 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 7.4) 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 garlic bulblets in 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 50ºF 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 controlled at time of planting, these weeds will have a head start on the crop and will be very competitive. Emerged weeds can be controlled 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.

Table 7.4. Forage, feed, and grazing restrictions for wheat herbicides.

Trade Name	Restrictions
2,4-D	Do not graze dairy cattle or meat animals within 14 days of application. Do not feed treated straw to livestock.
Anthem Flex	Do not harvest, feed, or graze within 7 days after application.
Axial XL & Axial BOLD	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.
Fierce	Do not harvest as green feed or permit livestock to graze fields within 42 days after application. Do not cut hay within 52 days after application.
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.
MCPA	Do not forage or graze dairy animals or meat animals for slaughter within 7 days of slaughter.
Osprey & Osprey Xtra	Do not apply within 30 days of harvesting wheat forage, and 60 days for hay and straw.
PowerFlex & PowerFlex HL	Do not graze treated crop within 7 days following application. Do not cut the treated crop for hay within 28 days after application.
Quelex	Do allow livestock to graze on treated crops for 7 days following application. Do not apply closer than 21 days before cutting of hay.
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.
Zidua SC	Wheat forage and hay can be fed or grazed 7 or more days after application.

Acknowledgments

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

8. Insect Pest Management for Small Grains

By Dominic Reisig

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.

Photo 8.1. English grain aphid. Photo by M. Spellman.

Photo 8.2. Bird cherry oat aphid. Photo Credit: Matthew Bertone

Photo 8.3. Corn leaf aphid. Photo Credit: Matthew Bertone

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.

Life Cycle

Two species of aphids predominate in small grains: the English grain aphid (Photo 8.1) and the bird cherry-oat aphid (Photo 8.2). However, several others, such as the corn leaf aphid (Photo 8.3) and the greenbug (Photo 8.4), may be found occasionally.

The high reproductive rate of aphids enables their populations to quickly build up to levels that can cause economic loss. However, aphid populations are usually kept in check by weather conditions and biological control agents, such as lady beetles, parasitic wasps, syrphid fly maggots, and fungal pathogens, which are often abundant in small grains.

Photo 8.4. Greenbug. Photo by Alton N. Sparks, Jr., University of Georgia.

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. 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, since 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.

Yield Optimizing Tip:

Controlling fall infestations of aphids can reduce BYDV disease incidence later in the growing season

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 8.1).

Table 8.1. Aphid thresholds for small grains in the fall and spring.

<table>
<tr><th rowspan="3">Fall</th><th colspan="4">Spring</th></tr>
<tr><th colspan="3">Plant Height (inches)</th><th rowspan="2">After heading</th></tr>
<tr><th>3 - 6</th><th>4 - 8</th><th>9 - 16</th></tr>
<tr><td rowspan="2">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.</td><td colspan="3">aphids per row foot</td><td rowspan="2">25 aphids per head and 90% of heads infested, or

50 aphids per head and only 50% of the heads infested</td></tr>
<tr><td>100</td><td>200</td><td>300</td></tr>
</table>

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 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 8.5).

Photo 8.5. Armyworm. Photo by M. Spellman.

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 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 Southeastern 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 8.6) 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 8.6. Cereal leaf beetle adult.

Eggs (Photo 8.7) 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 and these eggs will hatch in about 5 days.. While females prefer to lay eggs in thick wheat stands, the infestations are more evident in thin stands. Therefore, more larvae are generally observed in poorly tillered fields. Females lay 100 to 400 eggs each.

Photo 8.7. Cereal leaf beetle eggs.

Larvae (Photo 8.8) 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 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.

Photo 8.8. Cereal leaf beetle larva.

Injury to Small Grains

Although adults will feed on young small grain plants, their feeding does not affect plant performance. However, larvae eat long strips of green tissue from between leaf veins and may skeletonize entire leaves (Photo 8.9), leaving only the transparent lower leaf tissue. Severely defoliated fields can take on a white "frosted" cast (Photo 8.10) 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

Photo 8.9. Wheat leaf damage caused by cereal leaf beetle larvae feeding.

- 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 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.

Photo 8.10. A wheat field severely damaged by cereal leaf beetle feeding.

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

Table 8.2. Insecticides labeled for cereal leaf beetle management (2020). 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**	**16 to 32 fl oz**
		Lannate SP	**0.25 to 0.5 lb**
	carbaryl	**Sevin brand XLR PLUS**	**16 fl oz**
Pyrethroids	**beta-cyfluthrin**	**Baythroid XL**	**1.0 to 1.8 fl oz**
	gamma-cyhalothrin	**Declare EC**	**1.02 to 1.54 fl oz**
	lambda-cyhalothrin	**Warrior II**	**1.92 fl oz**
	zeta-cypermethrin	**Mustang Maxx EC**	**1.6 to 4.0 fl oz**

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 8.2. 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, gamma-cyhalothrin, 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, however, using spinosad is equivalent to doing nothing.

Yield Optimizing Tip

Scout for cereal leaf beetle after flag leaf emergence. Spray if there are 25 or more larvae plus eggs on 100 stems.

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 8.11). 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 8.12). Newly hatched larvae (maggots) are also orange for 4 or 5 days before turning white (Photo 8.13). 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 8.14) are located under leaf-sheaths and usually below ground on young tillers or below the joint in older plants.

Photo 8.11. An adult Hessian fly. Photo Credit: Matthew Bertone

Photo 8.12. Hessian fly eggs.

Photo 8.13. 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 8.1). 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 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

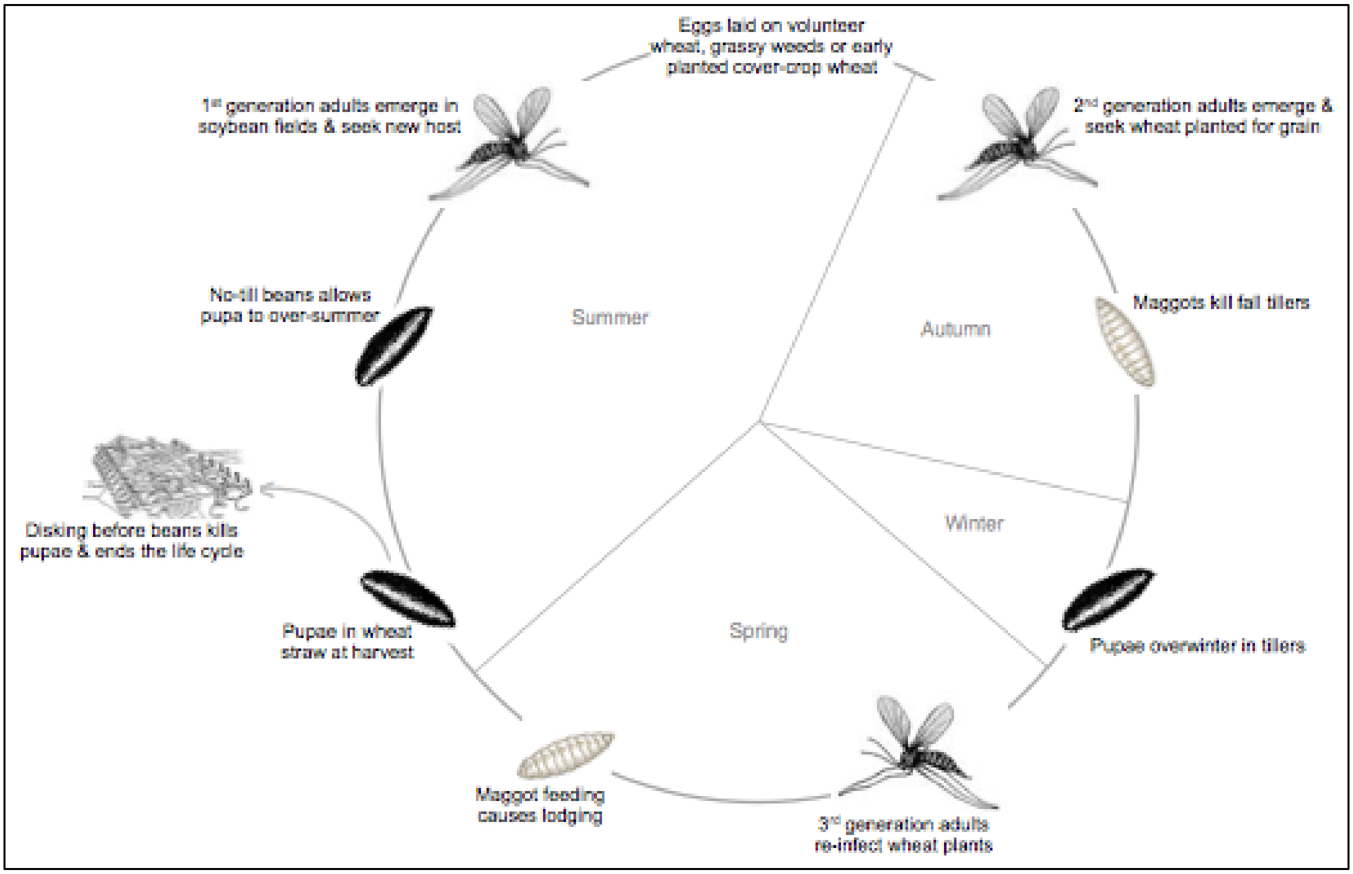


Figure 8.1. The Hessian fly life cycle.

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.

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.

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 8.15). 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. Current wheat varieties with Hessian fly resistance can be selected using the NC Official Variety Selection tool. 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.

Photo 8.15. 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.

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 only been moderately 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. At least three of the following conditions should be met before using a pyrethroid for early season Hessian fly control:

<u>Yield Optimizing Tip</u>

Mitigate Hessian fly damage on wheat crop through variety selection and other cultural practices

- 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 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 8.1). 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 the current edition of the NC Agricultural Chemicals Manual.

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 seem 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 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.

Additional Video Resources

Identifying and Managing Hessian Fly:
https://www.youtube.com/watch?v=aIideaTFhe0&feature=youtu.be

9. Small Grain Disease Management

By Christina Cowger

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.

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.

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 9.1). 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 produces a striking red-purple discoloration (Photo 9.2).

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 Chapter 8).

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.

Photo 9.1. 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 9.2. Barley yellow dwarf virus in oats produces striking red-purple discoloration.

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 9.3). 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.

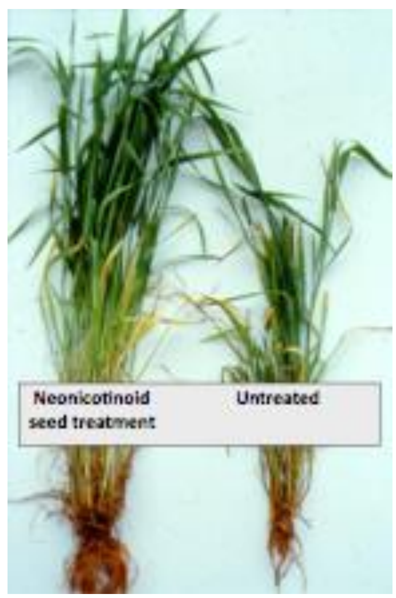


Photo 9.3. Insecticidal seed treatments can prevent aphids feeding in the fall and may reduce BYDV. These plants were from a no-till field planted after corn. The plant on the left was treated with an insecticidal seed treatment and has few BYDV symptoms. The plant on the right was untreated, and BYDV has severely stunted it.

Photo 9.4. Leaf rust attacks wheat, rye, triticale, and barley. Lesions are small, circular, and vivid orange in color.

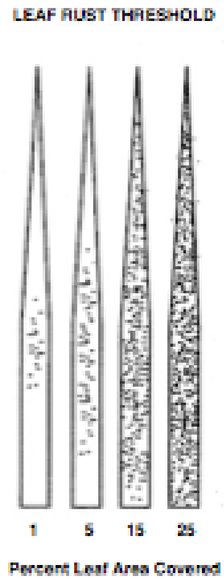


Figure 9.5. A fungicide is recommended if leaf rust covers 1 to 3% of the leaf area.

Leaf Rust

Description

Leaf rust attacks wheat, rye, triticale, and barley. Lesions are small, circular, and vivid orange (Photo 9.4). 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.

Environment

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.

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 covered with lesions (see Figure 9.5), 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: https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual/disease-control). 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 9.6A). 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 9.6B). 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.

Environment

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

Photo 9.6. 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.

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: : https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual/disease-control). 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 9.7A) and stems (Photo 9.7B). As the lesions mature, they become darker and sometimes turn grey or salmon with black spots or fruiting bodies (Photo 9.7D). 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 9.7C). Mildew lesions on the leaves of stressed wheat plants can appear in "green islands" (Photo 9.7E).

Environment

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.

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 9.8). 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: : https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual/disease-control).

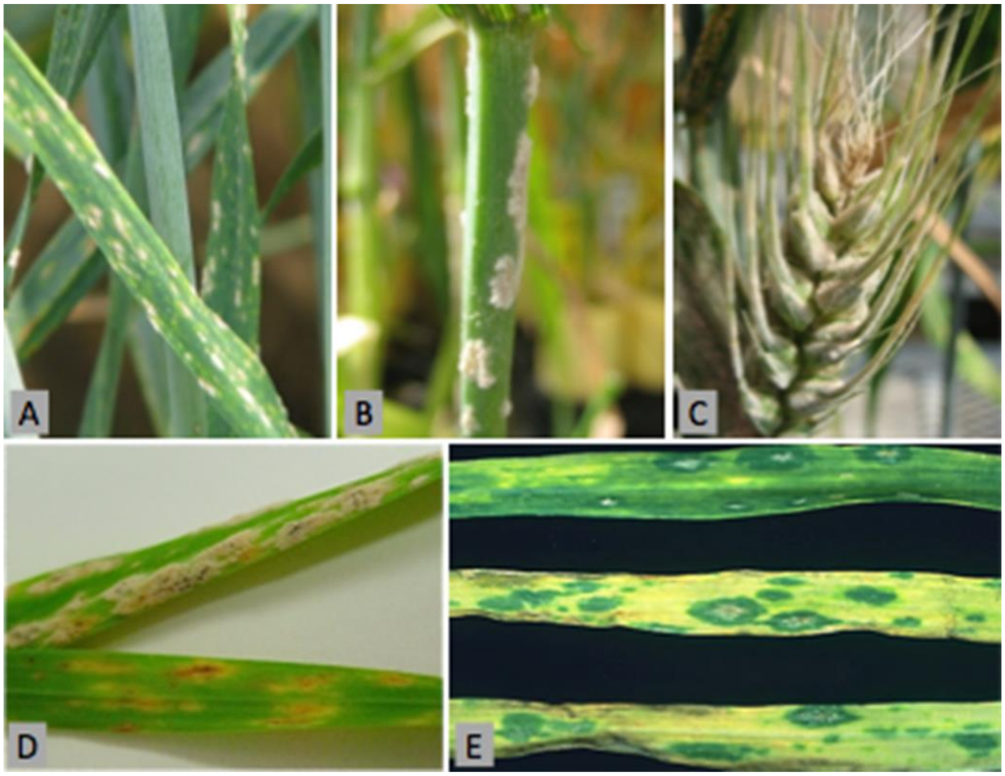


Photo 9.7. Powdery mildew: (A) lesions are first noticeable as white, powdery spots on the lower leaves and (B) stems; (C) lesions may also be on the heads; (D) older lesions become darker, sometimes grey or salmon-colored with black spots; (E) mildew lesions on the leaves of stressed wheat plants can appear in "green islands".

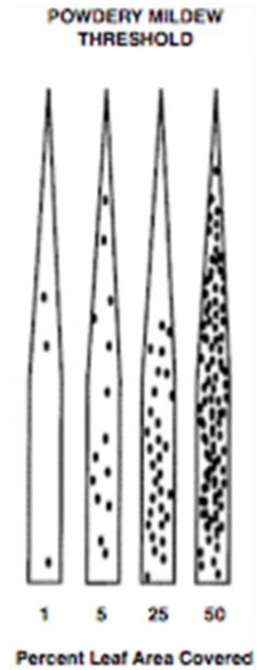


Figure 9.8. A fungicide is recommended if powdery mildew covers 5 to 10% of the upper leaves.

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 9.9A) 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 9.9B). If rain splash reaches heads, lesions can appear on the heads as well (Photo 9.9C).

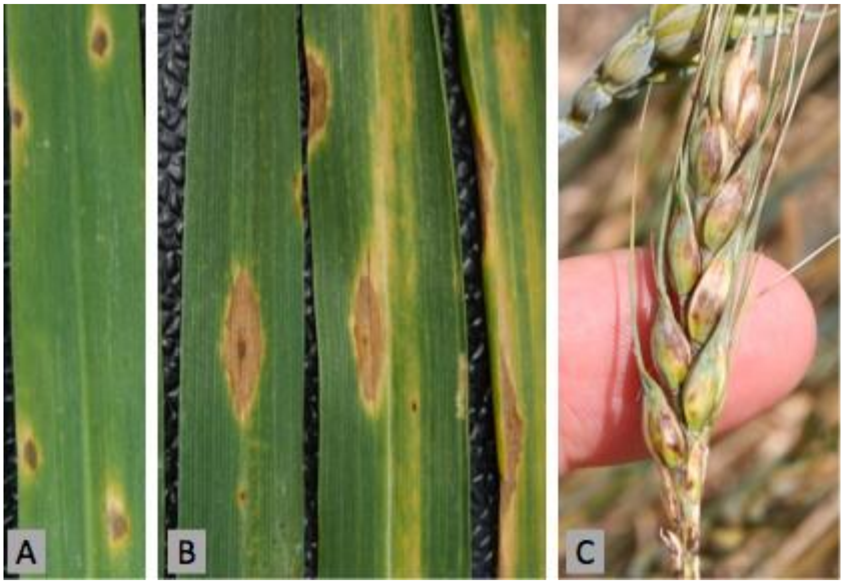


Photo 9.9. Stagonospora nodorum blotch: (A) the youngest lesions will appear as dark-chocolate dots; (B) as lesions age they expand and in older lesions there are often small, dark, pimple-like spots known as pycnidia; (C) if rain splash reaches heads, lesions can appear on them as well.

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: : https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual/disease-control). 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 9.10). Moderately resistant varieties like the one on the right side of Photo 9.10 are unlikely to need a fungicide for SNB control, even in a wet spring.

Photo 9.10. 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.

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: : https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual/disease-control).

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 9.11A). Superficial pink or orange spore masses can be seen on infected spikelets (Photo 9.11B). Early infections can cause kernel abortions, and later infections can cause shriveled kernels (called "tombstones") that have low test weight (Photo 9.12). 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.

Photo 9.11. 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.

Environment

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

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.

Photo 9.12. 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.

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 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 9.9A). 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.

Photo 9.13. 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.

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 9.13).

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.

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 9.14). 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 9.15). 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 9.16). 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 9.16. 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.

Photo 9.14. Wheat soilborne mosaic virus.

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 9.16). 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.

Photo 9.15. Wheat spindle-streak mosaic virus.

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 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.

Variety Selection Resources

For the most up to date information on wheat variety characteristics including disease resistance packages please see:

-NCOVT Wheat Variety Selection Tool (https://ncovt.medius.re/)

- Organic Commodities Wheat Variety Disease Packages Factsheet (https://organiccommodities.ces.ncsu.edu/organicgrains-production/wheat-variety-disease-packages/)

Video Resources

There are several videos available to assist with disease identification and scouting efforts:

Head Scab: https://smallgrains.ces.ncsu.edu/smallgrains-head-scab/

Leaf Rust: https://smallgrains.ces.ncsu.edu/smallgrains-leaf-rust/

Powdery Mildew: https://smallgrains.ces.ncsu.edu/smallgrains-powdery-mildew/

SNB: https://smallgrains.ces.ncsu.edu/smallgrains-snb/

Please visit the Disease Identification and Management section of the Small Grains portal for comprehensive information regarding small grain diseases:

https://smallgrains.ces.ncsu.edu/smallgrains-disease-identification-management/

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 (https://pdic.ces.ncsu.edu/how-to-submit/) 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

10. Plant Growth Regulators

By Angela Post

Photo 10.1. Wheat treated with growth regulator (left) versus untreated (right)

The decision to use a plant growth regulator should not be automatic. There are several factors that might affect the decision to use a plant growth regulator. The purpose of plant growth regulators is to reduce plant height and increase stem thickness to increase the stand-ability of the crop and prevent lodging. This management input is not necessarily needed every year.

Generally, a plant growth regulator is utilized to prevent lodging. Lodged wheat decreases the speed of harvest because more straw has to be processed through the combine when wheat is laying down in the field. Lodging also decreases yield because not all grain present in lodged heads is recovered. Finally, lodging may create more difficult planting conditions for double-crop soybean following wheat. Heavy wheat residues laying on the soil surface following harvest can impede the soybean planter.

Deciding to use a PGR

1) Wheat planted early planted with lots of growth
2) Taller wheat varieties more prone to lodging
3) Wheat with high nutrient inputs planned for the season and high potential yield
4) Wheat grown on ground with history of animal waste applications (hog waste, poultry manure)

Plant growth regulators will have less value as an added input in situations where one of the above scenarios is not true. We will go through them one-by-one here.

Wheat planted early planted with lots of growth

When winter wheat is planted at the earliest part of the planting window and we have a warm fall and/or spring, more growth can occur than intended. The wheat may have high tiller numbers going into winter dormancy, or an unseasonably warm spring may increase tiller number quickly after greenup. When stands are thicker than expected plants compete for the available space and may lay down easier.

Taller wheat varieties more prone to lodging

Variety selection is one of the most important decisions for any farmer. It is particularly important when planning for high input wheat. Taller or weaker-stemmed varieties are more prone to lodging and may require the use of a plant growth regulator when used for high-input/high yield goal wheat.

We report average height for wheat varieties tested in the North Carolina Official Variety trials in the Variety Selection Tool (https://ncovt.medius.re/)

Wheat with high nutrient inputs planned for the season and high potential yield

No matter the variety, wheat produced with high nutrient inputs, particularly nitrogen, has greater potential for lodging.

Wheat grown on ground with history of animal waste applications (hog waste, poultry manure)

Fields with a history of animal waste applications tend to have a lot of nitrogen fertility available during the stem elongation period of wheat growth, which can contribute to higher lodging potential. Animal manures release nutrient over a period of time and the farmer does not have control of when those nutrients are available to the plant compared to direct applications of conventional fertilizers during the season.

Timing a PGR Application

There are many plant growth-regulating products on the market registered for use in winter wheat. As of the printing of this guide August 2021, cdms lists 29 such products. The most commonly used products in North Carolina contain ethephon (many trade names) or trinexepac-ethyl (Palisade). Timing the plant growth regulator application correctly is critical. Follow all label instructions for the product you choose to apply.

Trinexepac-ethyl (Palisade) inhibits the production of gibberellic acid to reduce shoot growth and prevent lodging. It is recommended for applications of 10.5 to 14.4 fl oz/A from Feekes growth stage 4 through 7 though it can be applied all the way to Feekes 8. Results are best with applications near the first node formation Feekes 6 (Zadoks 30). This product is also labeled for use in barley, oats, rye, and triticale. Though a single application is most common, split applications are also allowed as long as the annual rate does not exceed 14.4 fl oz/A.

Ethephon reduces cell elongation to reduce lodging potential. It is recommended for applications of 16 to 32 fl oz/A from Feekes 8 through 10. Crop injury can occur if plants are already stressed due to disease or insect pressure, or low moisture status. This product is also labeled in barley.

A plant growth regulator is a useful tool to help manage lodging potential for intensively managed wheat. Other tools the grower can utilize to prevent lodging are variety selection to include shorter varieties with greater stem strength, proper plant populations, and appropriate timing and rate for nitrogen fertility to meet the wheat's needs with realistic yield goals.

11. Freeze Injury in Wheat

By Angela Post and Ryan Heiniger

Winter wheat becomes more and more susceptible to injury the more mature it becomes. It is most susceptible in the flowering stage when it cannot withstand temperatures below 30°F without being injured. At jointing winter wheat cannot withstand temperatures below 24°F without being injured. For more information on temperature tolerances of winter wheat at varying growth stages see Kansas State publication C-646 (Shroyer et al. 1995). Start your scouting efforts 5 to 7 days after a freeze event and begin with varieties that have the most advanced maturity.

Leaf Injury

Leaf tip damage after freezing temperatures is a common symptom in winter wheat. It does indicate that the entire tiller probably froze overnight. But it usually does not significantly contribute to yield losses. Leaf tips may turn purple, yellow, gold, or bronze depending on variety and the severity and duration of the freeze (Figure 11.1A). Transverse bands of yellow or white tissues may show up several days following freeze events (Figure 11.1B).

Figure 11.1. A) Whole plot in Rowan County where wheat leaf tips are bronzed and necrotic from freeze injury. B) Varying degrees of leaf injury following 5 nights of freezing temperatures.

New leaves may emerge twisted yellow and necrotic, or even pinched. Many of these symptoms will show some recovery over time and new leaves and tiller growth following the freeze will usually compensate for this type of tissue damage. In contrast to leaf tip damage, injury to the flag leaf during freeze can be detrimental to yield.

Flag Leaf Injury

A completely yellow flag leaf following freeze indicates severe injury to the growing point and the head from that tiller is unlikely to produce normal grain if any at all (Figure 11.2). Flag leaves appearing normal following a freeze may still have damage in the form of a pinch. Where the cold air settles in the wheat canopy the tissues expand and some of the cells will die. In that layer of the canopy a tight band of frozen cells will occur on almost every leaf including the flag leaf. Later when the developing head tries to push through that layer, awns will become trapped and the wheat head will emerge deformed, twisted, or kinked. These heads can still fill grain but the grains do not have the normal space or proper orientation to fully form. This can result in lower test weight and shriveled grain. This is not as pronounced in beardless and short-awned varieties.

Figure 11.2. Flag leaf, indicated by the black arrow, emerging completely yellow in color indicating the growing point has died.

Stem Injury

Injuries to the wheat stem can be more damaging than those in leaf tissues. Stem symptoms include stem splitting (Figure 11.3, left), browning at the crown (Figure 11.3, right), darkening of internodes (Figure 11.5), stem softening or weakening, and swollen nodes. In cross section the tissues just below a joint (node) which has frozen will turn brown approximately 7 days following a freeze (Figure 11.4). These tissues will continue to deteriorate and limit water and nutrient uptake by that particular tiller. Depending on the length and severity of the freeze stem injuries like this can greatly reduce or eliminate grain production from that tiller. Leaf sheaths may split at a joint (Figure 11.3, left) which has frozen due to expanding tissues when freezing occurs. The split leaf sheath does not cause a problem, but indicates the joint has likely frozen and you should continue to scout looking for brown transverse bands in the split stem as shown in Figure 11.4.

Some stems may be damaged by freeze but not show signs of outward discoloration. Damage can manifest simply as a weak point in the stem contributing to lodging later in the season. It may feel soft and flimsy to the touch and may be water-soaked in appearance but not darkly discolored.

Figure 11.3. Left image depicts leaf sheath splitting at a swollen joint (node); right image depicts brown transverse discoloration at the crown where the stem has

These stems will bend easily and not stand back up. As grain begins to fill, the heads will become too heavy for the stem to hold and they fall over at the weak point damaged by the freeze. In very tall wheat, lodging may appear within 2 weeks after a freeze. In shorter wheat it may not occur until later during grain fill. No management practice can correct standability issues due to freeze once it occurs.

Figure 11.4. Left: Stem is partially opened to show extensive tissue damage and brown discoloration of stem below the joint which has frozen. Right: stem cut in cross section showing transverse band of brown, necrotic tissue just below the joint. AND Figure 11.5. Left: Brown lesions appearing on the lowermost internode and just below the first joint. These freeze lesions may be a single layer or multiple layers deep. Right: Healthy wheat stem cut in cross section.

Growing Point Injury

Injury to the growing point and developing head are most detrimental to yield in winter wheat. A normal growing point and developing wheat head is shown in Figure 11.6B. Normal heads should be white to green and stand up on their own when slipped out of the stem. They should appear turgid and floral structures should look full, translucent to white and glossy. Off-white to tan heads indicate the developing head has frozen and is starting to deteriorate. Affected heads will progress from light tan to brown and mushy 7 to 10 days following the freeze. Figure 11.6A & B depicts a healthy wheat head and a completely dead wheat head. These heads are at the same growth stage, are the same variety, and came from the same field.

Figure 11.6. A) Developing wheat head killed by freeze. **B)** Healthy wheat head of the same variety from the same field.

Figure 11.7. Developing wheat head with 30% blasted florets circled in red. This image is prior to heading.

Sometimes the entire head is not affected as in Figure 11.7. Here only the upper third of the head has frozen. Flowers in that portion of the head will be sterile and not produce a grain. Awns connected to empty florets will be straw colored instead of their normal green and may appear twisted or in disarray. Normally they would be upright and uniformly spaced. See also Figure 11.8.

Figure 11.8. Sterile "blasted" kernels on freeze damaged heads that were emerged from the boot at the time of freeze. Sometimes only partial heads are sterilized depending on the timing, length and severity of a freeze event.

It is important to scout each field location. Yield losses due to freeze injury are relative to the duration and severity of the event **at a specific site**. Aside from developmental growth stage, topography, soil moisture, nutrient content of the plants, and wind speed and direction at a site during a freeze event can all impact potential yield losses. To assess yield potential after the freeze wait 5 to 7 days allowing damage to manifest. Count the number of viable tillers remaining in one square foot. Any tillers with severe symptoms as described in this guide should not be counted as viable.

Yield Optimizing Tip

Yield losses due to freeze injury are relative to the duration and severity of the event at a specific site. To assess yield potential after the freeze wait 5 to 7 days allowing damage to manifest.

Other Small Grains

Similar scouting methods can be used for barley, oats, triticale, cereal rye and ryegrass. Symptomology of freeze injury is similar in all of these small grain crops and will again depend on severity and duration of freeze coupled with the developmental stage of the crop.

References

Shroyer, J.P., M.E. Mikesell, and G.M. Paulsen. C-646. Spring Freeze Injury to Kansas Wheat, Kansas State University, March 1995.

Klein, R. N. EC-132. Freeze Injury to Nebraska Wheat. http://extensionpublications.unl.edu/assets/pdf/ec132.pdf. Accessed 3-23-2017

12. Estimating Wheat Yield

By Angela Post and Ryan Heiniger

Wheat yield estimations are an important step in determining the potential yield for your crop. These estimations can be done by almost anyone on the farm. They are easy to do, and can be crucial in determining management and marketing decisions for your wheat. Our target timing for estimating wheat seed yield is just after flowering, well after the wheat is fully headed. At this time the grains are well developed and will be easier to count. Estimations made prior to this timing will not be as accurate. In order to make a yield estimation we must look at the number of heads in a square foot of the field, the number of seeds per head, and the seed weight of the planted variety. All three components make up the final wheat yield.

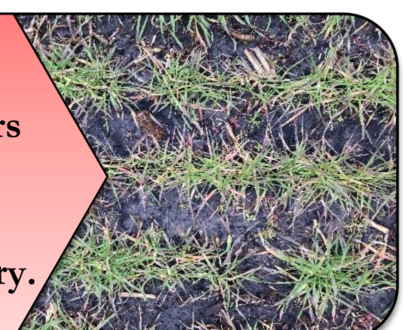
Early Season Yield Estimations

Wheat yield estimations can be made prior to head development by counting the number of tillers present in your wheat field. These estimations are not as accurate as those made after heading because you do not know the number of seeds per head, however these estimations can be critical in determining an appropriate nitrogen application to maximize your yield potential. To determine yield potential at this stage of wheat development, count the number of tillers per row foot in a representative section of your field. In order to get the best estimate, we recommend counting in multiple sections of a field and averaging these values together to account for any field variation. Tillers are any shoot with three leaves fully unfurled (Photo 12.1). Once you have your tiller count per row foot, use equation 1 to convert that value to tillers per square foot. **A good target for growers in North Carolina is to have 50 to 70 tillers per square foot by late January.** If you have broadcast wheat, we recommend counting the number of tillers in a square foot area of the field. This will bypass the need to use equation 1.

Photo 12.1. Individual tiller with 3 completely emerged leaves.

Yield Optimizing Tip

A good target for growers in North Carolina is to have 50 to 70 tillers per square foot by late January.



Now that you have a number of tillers per square foot for your wheat, you will need to convert this number to grain yield using the number of seeds per head and the seeds per pound value of the variety planted using Equation 2 or Table 1.1. At this stage of wheat development, the number of seeds per head is unknown. So we recommend using a minimum value of 20. A typical range of seeds per head in North Carolina is 18 to 36. The seeds per pound of the variety planted can be found on the seed tag or bag of any certified seed grown in North Carolina. The 726 value in the equation is a constant from simplifying the equation.

Equation 1: Tillers or heads per square foot= $\frac{\text{(tillers or heads per row foot x 12)}}{\text{Row spacing in inches}}$

Equation 2: Grain Yield = $\frac{\text{Tillers or heads per square foot x seeds per head x 72612)}}{\text{Seeds per pound}}$

Late Season Yield Estimations

Wheat yield estimations made after flowering are the most accurate method for determining yield potential for your field. After heading you can count the number of productive heads per square foot in the field, as well as the actual number of grains per head. During early season yield estimations, the number of grains per head are estimated, and the number of heads per square foot are assumed based on the number of tillers per square foot present. However, numerous factors during the growing season can influence the ability of a tiller to produce a productive head. These factors include weather, disease pressure, insect pressure, and nutrient availability, which will also influence the number of grains produced per head.

The process for estimating wheat yields at this stage of growth are similar to those during early season yield estimations. Count the number of heads in a row foot in a representative section of your field. Use Equation 1 to convert that number to heads per square foot.

Next, count the number of seeds on a head in your measured area. The easiest way to do this is to count the number of seeds on one row on the side of the wheat head. Then multiply that number by three, since most heads should have three rows of kernels. Sometimes it is possible to thresh the un-ripened grain from the head and get a true count.

Finally, refer to the seeds per pound of the variety planted. This number can be found on the seed tag or bag of any certified seed grown in North Carolina. You can also find a representative number for each variety in the NCOVT Variety Selection Tool (https://ncovt.medius.re/). The seed tag or bag will be the most accurate number.

Using the three numbers above; heads per square feet, seeds per head, and seeds per pound, use Equation 2 to determine your potential grain yield for that field. Alternatively, you can use the values in Table 12.1 to determine your estimated yield range. As with early season yield estimations, we recommend performing this measurement across multiple areas of your wheat field and averaging those values together to get an accurate prediction for your crop.

Video Resources

Orange County 2020 Whistle Stop Tour: Estimating grain yield: https://youtu.be/rw7vfjNXbDQ

Heads per ft^2	10,000 seeds per pound						12,500 seeds per pound						15,000 seeds per pound					
	Seeds per head						Seeds per head						Seeds per head					
	20	22	24	26	28	30	20	22	24	26	28	30	20	22	24	26	28	30
	grain yield estimate (bu/A)						*grain yield estimate (bu/A)*						*grain yield estimate (bu/A)*					
40	58	64	70	76	81	87	46	51	56	60	65	70	39	43	46	50	54	58
42	61	67	73	79	85	91	49	54	59	63	68	73	41	45	49	53	57	61
44	64	70	77	83	89	96	51	56	61	66	72	77	43	47	51	55	60	64
46	67	73	80	87	94	100	53	59	64	69	75	80	45	49	53	58	62	67
48	70	77	84	91	98	105	56	61	67	72	78	84	46	51	56	60	65	70
50	73	80	87	94	102	109	58	64	70	76	81	87	48	53	58	63	68	73
52	76	83	91	98	106	113	60	66	72	79	85	91	50	55	60	65	70	76
54	78	86	94	102	110	118	63	69	75	82	88	94	52	57	63	68	73	78
56	81	89	98	106	114	122	65	72	78	85	91	98	54	60	65	70	76	81
58	84	93	101	109	118	126	67	74	81	88	94	101	56	62	67	73	79	84
60	87	96	105	113	122	131	70	77	84	91	98	105	58	64	70	76	81	87
62	90	99	108	117	126	135	72	79	86	94	101	108	60	66	72	78	84	90
64	93	102	112	121	130	139	74	82	89	97	104	112	62	68	74	81	87	93
66	96	105	115	125	134	144	77	84	92	100	107	115	64	70	77	83	89	96
68	99	109	118	128	138	148	79	87	95	103	111	118	66	72	79	86	92	99
70	102	112	122	132	142	152	81	89	98	106	114	122	68	75	81	88	95	102
72	105	115	125	136	146	157	84	92	100	109	117	125	70	77	84	91	98	105
74	107	118	129	140	150	161	86	95	103	112	120	129	72	79	86	93	100	107
76	110	121	132	143	154	166	88	97	106	115	124	132	74	81	88	96	103	110
78	113	125	136	147	159	170	91	100	109	118	127	136	76	83	91	98	106	113
80	116	128	139	151	163	174	93	102	112	121	130	139	77	85	93	101	108	116
82	119	131	143	155	167	179	95	105	114	124	133	143	79	87	95	103	111	119
84	122	134	146	159	171	183	98	107	117	127	137	146	81	89	98	106	114	122
86	125	137	150	162	175	187	100	110	120	130	140	150	83	92	100	108	117	125
88	128	141	153	166	179	192	102	112	123	133	143	153	85	94	102	111	119	128
90	131	144	157	170	183	196	105	115	125	136	146	157	87	96	105	113	122	131

Table 12.1. Wheat grain yield estimations by heads per square foot, seeds per head, and seeds per pound. Representative values are included in this table for all 3 factors. Use equation 2 to calculate specific values for other situations

13. Milling Quality Wheat

By Angela Post and Ryan Heiniger

The majority of wheat and other small grains in North Carolina are sold for animal feed. The quality and cleanliness of grain is less important when selling wheat for feed. For example, it can include some chaff or certain weed seed and still be acceptable as a feed product. However, more and more growers are entering the milling and baking market for wheat, and quality is an important measure for these markets. Falling number is a relative measure of the enzymatic activity in a living wheat seed following harvest, specifically alpha-amylase activity. It is a measure of end-use quality of milling and baking wheat and purchasers use it along with protein and test weight to evaluate wheat quality and determine the price for a grower. Alpha-amylase breaks down starches in the endosperm of the seed as it begins to germinate. Higher alpha-amylase activity will result in a lower falling number and indicates that the grain is pre-sprouted. Higher alpha-amylase activity also results in decreased final flour quality. Acceptable falling number, protein and test weight values will vary depending on the purchaser and the product they intend to make from the milled wheat. Please be in touch with your purchaser to determine their specific requirements.

Harvest Considerations

Harvest wheat as early as practical to maintain milling quality. Harvest once it reaches 18% moisture if you are able to dry it and once it reaches 15% if drying is not feasible in your operation. Foreign material and other grains should be segregated from milling quality wheat. If you are harvesting other small grains or feed quality wheat with the same equipment, be mindful of cleanliness. Make sure combines, trucks and bins used for harvest, transport, and storage of milling quality wheat are clean and ready to accept the crop so that discounts and rejections are not a part of your future. Premiums for milling quality wheat are usually very good in our state if you can maintain quality standards required for grain acceptance.

Additional Resources

Protein and falling number metrics are now available in the NCOVT Wheat Variety Selection Tool (https://ncovt.medius.re/). Data for 2018, 2019 and 2020 are available but should not be taken as averages. These metrics are environment-dependent and should be evaluated on an annual basis. But it is possible to look at varietal consistency across years to help in making a variety selection to grow for milling quality wheat. Most commercial varieties are suitable for this purpose if they are managed correctly in-season.

Submitting a Sample

The Small Grains Extension program at NC State University has a new Grain Quality Analysis Laboratory. We are located in 4215 Williams Hall on Main Campus. NC Small Grain Growers Assessment dollars supported the purchase of several pieces of analysis equipment including a Perten 9500 NIR, a Perten Falling Number 1500, a Hammer Mill for processing grain into flour and a Vertu Strip Reader for detecting DON levels in four samples. North Carolina Farmers can submit whole grain samples for analysis in this lab free of charge if those samples are submitted through their local County Extension office. Call your local agent to submit a sample and they will complete the Grain Quality Analysis Lab Submission form. Once submitted by your agent they will receive an email confirmation that should be printed to send with your sample. Send a one-quart whole seed sample to: Grain Quality Analysis Lab Attention Angela Post 3709 Hillsborough Street Raleigh NC 27607 The lab can assess % protein content using NIR, % moisture, test weight, falling number, DON level in ppm (upon request).

Find more at: https://smallgrains.ces.ncsu.edu/grain-quality-analysis

14. Insect Pests of Stored Small Grains

By Dominic Reisig

Many types of insects attack small grains in storage. Because fall-planted 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 14.1). 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 14.2). 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 14.1. Rice weevil (adult). Joseph Berger, Bugwood.org

Photo 14.2. Lesser grain borer (adult). Bugwood.org

Grain Moths

Indianmeal moth and angoumois grain moth larvae (Photos 14.3 and 14.4) usually feed on the exposed surface of the stored grain mass. They

Photo 14.3. Angoumois grain moth (adult). Photo Credit: Matthew Bertone.

Photo 14.4. Indianmeal moth (adult). Photo Credit: Matthew Bertone.

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 14.5), 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. Indianmeal 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 14.5. 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 Centynal, Defense, Suspend, or Tempo, 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, diatomaceous earth, pyrethrums, Sensat, 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 (not labeled for corn) 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 50ºF as soon as possible. Stored-grain insects generally do not reproduce at temperatures below 60ºF or feed below 50ºF.

Inspect the grain at monthly intervals (weekly when the temperature is greater than 60ºF). 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 50º 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.

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

1,500 copies of this public document were printed at a cost of $4,500 or $3.00 per copy.

This publication is also available on the Internet at **http://www.smallgrains.ncsu.edu**
Select **Publications** and **Small Grain Production Guide**

COLLEGE OF AGRICULTURE & LIFE SCIENCES
ACADEMICS ▲ RESEARCH ▲ EXTENSION

AG-580 (Revised)