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Connecting and supporting farmers, millers, bakers, and grain artisans to build a vibrant, integrated, equitable, and regenerative grain economy in the Mid-Atlantic

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Growing Grain Handbook

Chapter 2.1 Fusarium Head Blight

By Heather Coiner

September 21, 2023

Perhaps the most important disease of cereals in the Mid-Atlantic is Fusarium head blight (FHB) (Keller et al., 2011). The focus of most research is on FHB in wheat, though it also impacts corn, sorghum, rice, and other cereals (Bergstrom & Schwarz, 2016; McMullen et al., 2012). FHB is a fungal infection caused by several Fusarium species, the most common of which is *F. gramineareum* (Birr et al., 2020). FHB reduces yields by damaging the flower, or spikelet, and it reduces quality by leaving behind mycotoxins, which can make animals refuse food or vomit. What's more, FHB damages the starch in grain, which degrades baking quality (Keller et al., 2011; Martínez et al., 2020).

FHB degrades the quality and quantity of cereals

Blighted wheat seed heads display some degree of premature bleaching, standing out against otherwise green heads and foliage. They can also appear dark and water-soaked, and sometimes one can spot the orange spore masses on the spikelets (De Wolf, 2019; Keller et al., 2011). Sometimes a whole section of the head will be bleached; this occurs when the rachis, or internal stem is blocked by the fungus so that downstream spikelets die (De Wolf, 2019). In corn, the disease is called Gibberella ear rot, and it enters through the female pistil (silks) (Bowden et al., 2010; Bergstrom & Schwarz, 2016). The fungal hyphae then fill in the space between kernels and leave patches of pinkish or whitish shriveled kernels. On sorghum, it causes stalk rot (Bowden et al., 2010) and a type of grain mold with fuzzy white hyphae around the grain and whitish or pinkish kernels (Thomas County Ag, 2014). Thus, one impact of FHB is to reduce the yield.

Another impact of FHB is that it leaves residual mycotoxins in the grain that reduce its quality, even if the fungus is killed. Deoxynivalenol (DON) causes vomiting in non-ruminants, while zearalenone (ZEA) interferes with reproduction (Keller et al., 2011) because it is an estrogen analogue (Bowden et al., 2010). Mycotoxins are generally concentrated in the grain heads, leaving the straw alone (Bowden et al., 2010). As if that weren't enough, *Fusarium* infection also reduces the starch content in bread wheat, reducing its baking quality. This impact will depend on which strains of *Fusarium* are present; *F. graminearum* attacks glutenins, while *F. poae* attacks gliadins (Martínez et al., 2020), thereby altering the otherwise stable ratio of glutenins to gliadins that leads to consistent bread results (see Chapter 2.3). The bad news is that FHB is ubiquitous in the Mid-Atlantic. The good news is that a grower has options in how they manage their crops, and in how they market them.

Sustainable management of FHB in cereals

Conventional growers manage FHB with fungicides, but that option is not available to organic growers. The most important practice to protect against FHB is to ensure that cereal crops are always separated in a rotation by a non-cereal crop like beans or buckwheat (see Chapter 3.2) (A. Cooper, personal communication, January 2022; Keller et al., 2011). Growers can do other things as well. FHB infections occur when the weather is wet and humid during the 7-10 days that a cereal plant is flowering; conditions that are practically guaranteed in the Mid-Atlantic (Keller et al., 2011; Birr et al., 2020). But FHB infection is much higher during flowering than a few days before or after (Birr et al., 2020), so one way to hedge against weather may be to stagger planting dates (Keller et al., 2011) which also spreads out farm labor tasks. Choosing resistant varieties is another method, but most breeding programs don’t test for FSM resistance; currently the best source of this information is the other growers in the Common Grain Alliance network.

In garden or small-size plots, heads can be scouted and removed by hand. On larger plots, harvesting fields with low levels of infection first protects that part of the harvest from the worst contamination (De Wolf, 2019). But because FHB is so prevalent in the Mid-Atlantic, inspecting a crop for FHB damage is not sufficient. Not all infected spikelets appear damaged, because the extent of the damage depends on when during development the infection began (De Wolf, 2019). Increasing the air flow in the combine can remove some damaged kernels at harvest (De Wolf, 2019), but those kernels may germinate, adding to FHB pressure in your field in later years. Plus, diseased barley and oat kernels are not as easily removed this way (Keller et al., 2011). Blighted seeds can be cleaned out (see Chapter 4.5), but this lowers the yield, requires equipment, and is time-consuming. Whatever strategy is employed, mycotoxin testing of the final lot is still a necessity.

With test in hand, growers can find an appropriate buyer. DON requirements vary dramatically depending on the end use (see Table 1.3). Common Grain Alliance millers may be willing to buy grain that has levels of DON that are too high for human consumption if they can blend it with another crop that has low levels. That said, even if DON levels are acceptable, the starch and protein may still be degraded for use in bread baking. Still, the wheat may be useable in bakeries if it can be used for food applications other than bread (like quick breads or crackers) that don't place such high demands on starch and protein quality (see Chapter 1.3). Breweries may be a harder sell, since barley DON levels are not good predictors of the level on malt, since DON can continue to develop during malting (Bergstrom & Schwarz, 2016). A craft distiller, on the other hand, may accept high DON grain because the DON does not come through distillation. But this depends on what happens to the spent grain, which still contains high DON and should not be fed to animals (Grigsby, 2017). In sum, Fusarium Head Blight is unavoidable in the Mid-Atlantic, but there are agronomic, processing, and marketing strategies that allow growers to avoid fungicides and still produce quality grain.

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Chapter 2.2 Pre-harvest Sprouting and Falling Number

By Heather Coiner

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Humid conditions at harvest time can result in physiologically mature grain germinating in the field. Germination is measured in a lab and reported as the falling number. The falling number is reported on a scale of 0-400, with 400 meaning no germination, and intact starch (Brouillette, 2020). In most cases[1], germination degrades the grain quality for most end uses because most applications require intact starch (see Table 1.3). This quality risk is common enough in the Mid-Atlantic that growers should have a toolbox of strategies at hand to manage the risk.

The main decision comes at harvest time. Grain is physiologically mature before it is dry enough to store. In dry climates, the mature grain is left to stand in the field until it is dry enough to safely store. In humid climates, the grain may need to be harvested and dried another way. Conventional growers sometimes kill crops at physiological maturity with herbicide, though this is expensive and a non-starter for most sustainable growers.

Instead, growers are faced with a tricky decision. They must weigh the weather forecast, the falling number trend of their crop, and their ability to dry the crop in the event of early harvest. Falling number can be tracked by hand threshing some grain and submitting it for testing (Pennington 2017). Doing this twice a few days apart can give the grower a sense of the trend

[1] Rye for bread may be an exception—amylases break down starches quickly in low-acid rye breads, so having abundant sugars available (in pre-sprouted flours) may help hurry along fermentation (Brouillette, 2020)

and help with the decision-making process.

If early harvest is required in a small or garden size plot, not much needs to change. Growers are probably reaping and binding the grain for later threshing anyway (see Chapter 4.4 Harvesting). If humid weather looms, grain can be reaped and bound as soon as it is physiologically mature, then stooked and allowed to dry in the field (the stooks shed rain), or transported to a covered barn to air dry. Small growers have a clear advantage over larger growers in this case, since the harvest process does not need to be altered much.

At larger scales where combine harvesters are used, growers can harvest early and dry the grain in a batch dryer, or swath the grain and pick it up later. Batch drying can be done with or without heat (see Chapter 4.4 Harvesting, drying, and storage), and is probably the most common way sustainable growers manage sprouting risk in the Mid-Atlantic.

A less-tried and riskier method is swathing. Swathing is like stooking, but with equipment. The swather reaps the grain high on the straw, and then windrows it in the field on top of its own stubble, allowing airflow and some rain shedding. This works for varieties with strong straw in drier climates, but hasn't been tried much in the Mid-Atlantic. If a heavy rain comes, swathing may make things worse; we know of at least one swathed crop that was lost to a freak storm (W. Thomason, personal communication, December 6, 2022). If grain does sprout, it may still be usable as feed or, in some cases, seed (Jones et al 2017, Nagelkirk, 2009), but it will surely be a disappointment. Investing in a drying setup and staying on top of falling number trends is a better choice.

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Chapter 2.3 Protein Quality & Quantity in Wheats

By Heather Coiner

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Protein content is often used as a proxy for baking quality in bread wheat. Customary agronomic advice to growers is to add more nitrogen to boost protein levels. But the picture is more nuanced than that. Varieties that are called “soft” wheats, meaning they tend to have lower protein contents, can have protein levels similar to the “hard” wheats that are typically grown for bread (Kissing Kucek et al., 2017). Low protein flour blends can still have excellent baking qualities (Woodward, 2022), possibly due to interactions between starch and gluten (Schuster et al., 2022). Moreover, protein is but one type of nutrient in wheat that growers have influence over (Shewry et al., 2020). This sounds obvious, but the focus on N to boost protein content comes at the expense of other macro-and micronutrients that may influence quality and flavor–qualities buyers of regional grain tend to value. Here, we make an effort to understand some of this puzzle.

The ability of a grower to influence the flavor and quality of a grain crop depends on how responsive, or plastic, the genetics of the crop are. The more responsive the genetics (G) are to environmental factors (E), the more influence a grower has. In wheat, while this G x E interaction is not well studied, results of one study that evaluated the baking performance of a variety grown in different locations did observe quality differences, suggesting that growing conditions and not genetics underlay the differences (Kissing Kucek et al., 2017). At least one baker in the Common Grain Alliance network has observed this effect in Redeemer wheat grown on two different farms (H. Thomet, personal communication, December 23, 2022). Modern wheat strains like Redeemer tend to have genetic protein content and quality set points that show genetic uniformity while maintaining vast genetic diversity because of the complexity of its genome (Santantonio et al., 2019; Shewry, 2009; Geisslitz et al., 2019). The uniformity is why common wheat is such an important and reliable staple crop, the diversity provides scope for improvement and response to environmental factors. Here we will focus on growing quality protein, recognizing that growing quality starch may be just as important, but is less well studied.

In modern, durum, and ancestral wheats (see Chapter 5.1), the term “protein” stands in for “gluten”, which itself stands in for the macromolecules people mean when they say a flour has “strong protein”. Glutens, the macromolecules in question, are storage proteins, which make up about 80-90% of the total protein content of white flours and 60-80% of whole grain flours. Total protein is strongly correlated with total gluten in both modern and heritage varieties of common wheat (as most people assume) (Geisslitz et al., 2019). But the relationship is weaker in spelt, and disappears entirely in emmer and einkorn (Geisslitz et al., 2019). Moreover, high total gluten does not always lead to better baking quality. Quality depends on the ratio of gliadins to glutenins (what may be called the ‘baking ratio'). The baking ratio is highly preserved in common wheat, such that a low protein (e.g. 9%) wheat has a nearly identical baking ratio to a high protein (e.g. 14%) wheat (Geisslitz et al., 2019). This helps explain why, in the hands of a skilled baker, low protein common wheats can still perform well in bread applications (Woodward, 2022).

Total gluten is also a weak predictor of baking performance in ancestral wheats. Most strains of spelt, durum, emmer, and einkorn contain much more gluten than common wheat (Geisslitz et al., 2019). Most of this extra gluten is in the form of gliadins rather than glutenins. Wheat processors like bakers and pasta makers experience an excess of gliadins as extensibility (rather than elasticity, or “bounce back”) in a dough. Intriguingly, the ratio of gliadins to glutenins (the baking ratio) varies dramatically in these ancestral types (in common wheat it is stable). It is not clear whether this variation is due to seed source (G) or growing conditions (E), or both. This means that, until breeding and variety trials catch up (see Box 2.1), if a strain of ancestral wheat doesn't perform well on a particular farm, the grower would do well to try a different seed source, rather than conclude that the ancestral wheat can't be grown.

[Box 2.1

The study by Geisslitz et al may contain some clues that could lead to better breeding outcomes for ancestral wheats. For example, it appears that some varieties of emmer that contain more than 1.4% gluten (not total protein) had a baking ratio very similar to that of spelt (Geisslitz et al., 2019). This suggests that some emmer strains, like their spelt relatives, could make excellent bread. Below the 1.4% gluten content threshold, baking quality (as indicated by the baking ratio) deteriorates quickly with decreasing gluten. All this could suggest that 1.4% gluten might be a threshold after which emmer starts making more glutenin relative to gliadins. If so, this could point to a trait that can be used to breed ancestral wheats with better baking qualities.]

One way growers can influence gluten quality seems to be by foliar feeding at flowering. Growers aiming for 50 bushels per acre wheat yields need to apply 75 lbs per acre nitrogen, or have the soil organic matter necessary to produce that much (Rossmann et al., 2019). At these lower N levels, foliar N at flowering improves baking performance (Rossmann et al., 2019; H. Thomet, personal communication, December 23, 2022; Longin et al., 2016). At higher N, the practice increases total protein in the crop but leads to no additional improvements in baking quality (Rossmann et al., 2019). Evidence from VA field trials suggests that late season (boot stage) application of sulfur along with N can improve the ratio of gluten proteins for bread making (Thomason et al., 2007). These foliar applications require specialized equipment, and require driving over part of the crop (unless wheel tracks were left during planting), reducing yields. Still, the quality improvement may be worth that tradeoff.

We would expect that another way to improve grain quality would be by enhancing soil health, but to our knowledge this has not been explicitly studied. There is still substantial scope for research that links agronomic practices to end-use quality. Until then, growers can learn a lot by talking to the end users of their grain, and then thinking back to what they did to produce that grain. It is our hope that the improved understanding of what constitutes quality outlined here will aid in that process.

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