

DEPARTMENT OF HORTICULTURE AND CROP SCIENCE

# Ohio Soybean and Wheat Research Report 2017



**THE OHIO STATE UNIVERSITY**

COLLEGE OF FOOD, AGRICULTURAL,  
AND ENVIRONMENTAL SCIENCES



To Ohio Farmers and Agricultural Industry Personnel:

The Soybean and Small Grain Crop Production Lab at The Ohio State University is pleased to present the second edition of the *Ohio Soybean and Wheat Research Report*. This publication contains the final reports of soybean and wheat research trials published in 2017. Here, we present our research findings of our most recently published research in a concise manner.

The goal of the Soybean and Small Grain Crop Production Lab is to maximize yield and profits while maintaining environmental sustainability.

This research was generously funded by the Ohio Soybean Council, the Ohio Soybean Council Moser Award, and DuPont Pioneer. We also wish to thank our cooperating-farmers and OARDC staff for helping establish, maintain, and harvest our research trials.

We look forward to continuously provide you with relevant and useful crop production research.

Sincerely,

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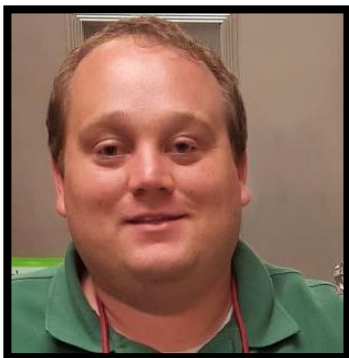
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# Low Soil Phosphorus and Potassium Limit Soybean Grain Yield in Ohio

Aaron P. Brooker, Laura E. Lindsey, Steven W. Culman, Sakthi K. Subburayalu, and Peter R. Thomison

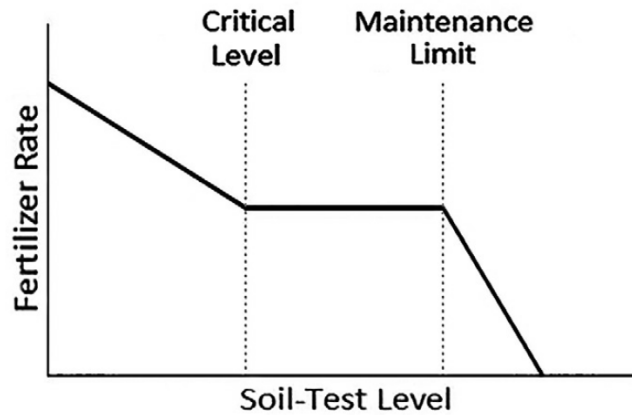
A soil survey was conducted in Ohio with the following objectives: (i) to assess the status of soil fertility; (ii) to examine soybean grain yield in areas with fertility levels in the build-up range, where soil test levels were less than the critical level (CL); the maintenance range, where soil test levels were between the CL and maintenance range; and the drawdown range, where soil test levels were greater than the ML; and (iii) to determine if the soil test and yield data collected support the state-established fertility recommendations. Soil sampling was conducted from 2013 through 2015 resulting in 593 total samples. Soil phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg); pH; organic matter (OM); and cation exchange capacity (CEC) were measured. Soil grain yield was also collected from the sampling areas.

## QUICK TAKE-AWAY:

- 21% of the soil samples collected were within the build-up range for P where P is likely limiting.
- 23% of the soil samples collected were within the build-up range for K where K is likely limiting.
- On average, grain yield was 7 bu/acre lower in sampling areas associated with soil P levels in the build-up range.
- On average, grain yield was 4 bu/acre lower in sampling areas associated with soil K in the build-up range.
- In sampling areas, there was no difference in grain yield associated with soil P and K levels within the maintenance and drawdown range.
- Our data suggest that soil test levels within the build-up range were associated with lower soybean grain yields.

**Methods.** In Ohio, a survey to assess the status of soil fertility and associated soybean grain yield was conducted annually from 2013 through 2015. Farmers volunteered to participate and selected fields that they manage to be used in the survey. In total, 199 fields were sampled by Ohio State University Extension educators and graduate students using a common protocol (Lindsey et al., 2014). Soil samples were collected from three sampling areas within each field and GPS coordinates of each area recorded. There were 593 soil samples collected in total. Soil samples were collected in the spring just prior to soybean planting. Each soil sample consisted of 10-15 homogenized 1-inch-diameter by 8-inch deep soil cores in a zig-zag pattern within each sampling area as recommended.

The soil-test nutrient level from each sampling area was assigned to one of three categories: build-up range, maintenance range, or drawdown range as shown in Figure 1 (Vitosh et al., 1995). The build-up range, maintenance range, and drawdown ranges are shown in Table 1. (Note: Original Bray-P and ammonium acetate extraction values were converted to Mehlich-3.)



**Figure 1. Fertilization recommendation scheme used in the Tri-State Soil Fertility Recommendations (adapted from Vitosh et al., 1995). The critical level is defined as the soil test level above which the soil can supply adequate quantities of a nutrient to support optimum yield, and maintenance limit is defined as the soil test level above which there is no agronomic reason to apply fertilizer.**

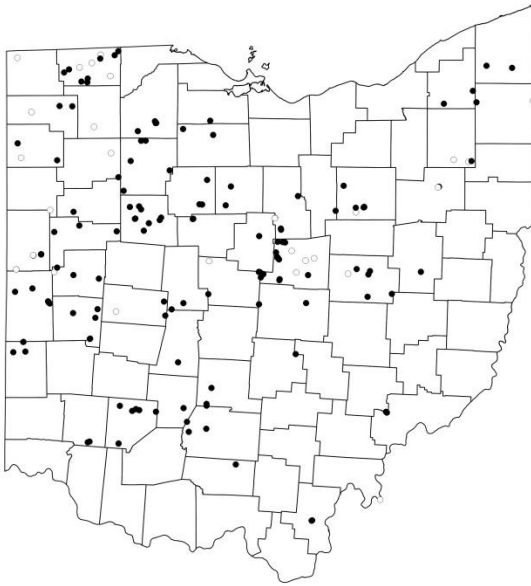
Soybean grain yield data were collected from the soil sampling areas using the recorded GPS coordinates by either weigh wagon or using calibrated yield monitors. Yield was reported at 13% moisture content. Yield information was obtained from 35% of the sampling areas ( $n = 219$ ).

**Soil fertility results.** In Ohio, 21% and 23% of the soil samples collected were within the build-up range for P and K, respectively. Thirty-five percent and 44% of the soil samples were within the drawdown range for P and K, respectively. There were no soil samples within the build-up range for Ca and only three soil samples within the build-up range for Mg. Nineteen percent of the soil samples had a pH less than 6.0, 59% were within the recommended range for soybean production of 6.0-6.8, and 23% were higher than 6.8. Organic matter levels ranged from 1.1 to 33.7%, with an average of 3.2%. The soil CEC ranged from 4.4 to 38.3 meq/100 g with a mean of 14.4 meq/100 g.

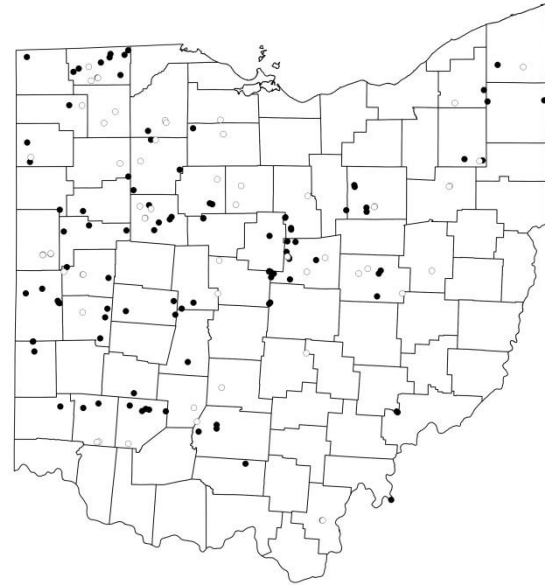
**Table 1. Mehlich-3 extractable P, K, Ca, and Mg build-up range, P and K maintenance range, and P and K drawdown range.**

Soil nutrients	Build-up range	Maintenance range	Drawdown range
P (ppm)	<23	23-51	>51
K (ppm)			
CEC 5 meq/100 g	<88	88-140	>140
CEC 10 meq/100 g	<100	100-150	>150
CEC 20 meq/100 g	<125	125-175	>175
CEC 30 meq/100 g	<150	150-200	>200
Ca (ppm)	<200		
Mg (ppm)	<50		

Of the fields sampled, 65% had at least one area of the field that had a soil P level within the build-up or maintenance range, for which fertilizer application would be recommended (Figure 2). Fifty-eight percent of the fields had at least one area of the field where soil K level was within the build-up range or maintenance range, for which fertilizer application would be recommended (Figure 3). Nineteen percent of the soybean fields had at least one area with soil pH less than 6.0, for which lime application would be recommended. These data indicate that many fields in Ohio have at least one area where P fertilizer, K fertilizer, or lime application would be recommended. Soil sampling and precise fertilization and soil amendment application may help reduce the risk of yield loss in specific areas of a field.



**Figure 2. Fields with at least one sampling area where P fertilizer is recommended (closed circles).**



**Figure 3. Fields with at least one sampling area where K fertilizer is recommended (closed circles).**

**Association between soil fertility factors and soybean grain yield.** Grain yield ranged from 22 to 82 bu/acre, and the average yield was 56 bu/acre. Sixty-nine percent of the sampling areas with soil P in the build-up range were below the average yield. No sampling area had a yield greater than 63 bu/acre when soil P was within the build-up range. A grain yield reduction of 7.4 bu/acre was associated with soil P levels within the build-up range. Sampling areas with soil P within the maintenance range yielded 56 bu/acre compared with those above the maintenance range, which yielded 59 bu/acre, but this difference was not statistically significant.

Fifty-eight percent of the sampling areas with soil K in the build-up range were below the average yield. A grain yield reduction of 4.0 bu/acre was associated with K levels within the build-up range. Sampling areas with soil K within the maintenance range yielded 56 bu/acre compared to those above the maintenance range, which yielded 57 bu/acre, but the difference was not statistically significant.

**Recommendations.** Data in this survey support the Tri-State Fertility Recommendations. We recommend soil sampling and applying fertilizer to maintain soil test levels within the established state guidelines.

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# Seed Yield and Quality of Transgenic High Oleic and Conventional Soybean as Influenced by Foliar Manganese Application

Douglas Alt, Sin Joe Ng, John Grusenmeyer, and Laura E. Lindsey

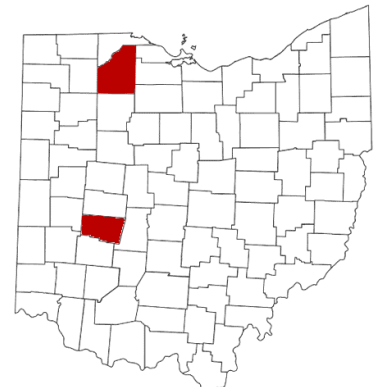
Soybean growers are interested in specialty crop soybeans with modified oil profiles providing price premiums to help offset low soybean grain prices. High oleic soybeans have been modified to produce high levels of oleic fatty acid, improving frying quality and shelf stability while reducing trans fat (Warner and Gupta, 2005).

Plenish® high oleic soybeans (DuPont® Pioneer®, Johnston, IA) are specialty soybean cultivars that have been genetically modified to limit the amount of linolenic acid and increase the amount of oleic acid in the soybean grain (DuPont® Pioneer®, 2017; Syed, 2015). The effect of manganese (Mn) foliar fertilizer on the oil profile of Plenish® soybean has not previously been examined. The objective of this study was to evaluate the effect of foliar Mn fertilizer on seed yield, protein and oil concentration, and oil profile of transgenic high oleic soybean (Plenish®) and soybean with a normal oil profile (referred here as “conventional”).

## QUICK TAKE-AWAY:

- In 2014, the Mn-SO<sub>4</sub> application increased soybean grain yield by 2.1 bu/acre at the Wood County location where soybean plants were deficient in Mn. At the other three site-years, soybean grain yield was not affected by Mn application.
- Manganese application did not influence the oil protein content of the soybean grain or alter the oil profile.
- The high oleic cultivars and cultivars with normal oil profile yielded the same at the Wood County location both years.
- In 2014 and 2015 at the Clark County location, the high oleic cultivars yielded 6.1 and 4.0 bu/acre less than cultivars with a normal oil profile, respectively.
- Growers considering planting Plenish® soybean cultivars do not need to alter their Mn foliar fertilizer management.

**Methods.** The trial was established in 2014 and 2015 at the Ohio State University Northwest Agricultural Research Station in Wood County and the Western Agricultural Research Station in Clark County.



Treatments included cultivar and manganese foliar fertilizer:

**Soybean cultivar (Note: Cultivar names ending in “PR” were Plenish®):**

- 2014- Pioneer P29T68PR, P31T11R, P33T34PR, P33T72R, P34T90PR, and P35T33PR
- 2015- Pioneer P29T40PR, P31T11R, P31T96PR, P32T49PR, P33T34PR, P33T72R, P34T90PR, and P35T66PR

**Manganese foliar fertilizer (applied at label rate):**

- Mn-EDTA (Feast® Micro Master Chelated Manganese, Conklin Company, Inc.)
- Mn-SO<sub>4</sub> (Max-In Ultra Manganese Winfield United)
- None (control)

***Effect of Mn application on soybean grain yield.***

Soybean grain yield was influenced by Mn application at the Wood County location in 2014, but not at the other three site-years. The Mn-SO<sub>4</sub> treatment increased grain yield by 2.1 bu/acre compared to the control treatment. At the Wood County location in 2014, Mn leaf concentration prior to Mn application averaged 23 ppm and visual deficiency symptoms of interveinal chlorosis were noted. Manganese is likely sufficient when the concentration of Mn in the uppermost fully developed leaf prior to initial flowering is at least 20 ppm (Vitosh et al., 1995). The increase in soybean grain yield with Mn-SO<sub>4</sub> application may be attributed to Mn deficiency due to low Mn in the soybean leaves and accompanying visual deficiency symptoms. Below average rainfall at the Wood County 2014 location from May through August and soil pH of 7.7 may have reduced Mn availability causing Mn deficiency in the soybean plants (Scăețeanu et al., 2013). Although Mn-SO<sub>4</sub> also supplies sulfur (S), the concentration of S in the leaf tissue prior to Mn treatment averaged 2.8% which was within the sufficiency range of 2.1-4.0% and was not likely limiting (Vitosh et al., 1995).



**Manganese deficiency symptoms include interveinal chlorosis.**

Manganese application did not influence grain yield at the Wood County location in 2015 and the Clark County location in 2014 and 2015. Leaf Mn concentration prior to Mn application averaged 44.3, 44.6, and 64.2 ppm at the Wood County location in 2015, Clark County location in 2014, and Clark County location in 2015, respectively. Grain yield increases were not associated with Mn application at these locations because leaf Mn concentration was within the established sufficiency range of 21-100 ppm and not likely deficient (Vitosh et al., 1995).

***Grain yield comparison of high oleic soybean to soybean with normal oil profile.***

When comparing high oleic cultivars to cultivars with normal oil profile, there was no difference in grain yield at the Wood County location in 2014 and 2015. At the Clark

County location, high oleic soybean cultivars yielded 6.1 and 4.0 bu/acre less than the soybeans with the normal oil profile in 2014 and 2015, respectively.

**Recommendations.** The oil profile from the high oleic soybean cultivars was unaffected by foliar Mn fertilizer application despite the Mn deficiency detected at one site-year. High oleic soybean cultivars do not require different Mn management compared to normal soybean cultivars. The normal oleic cultivars showed a slight yield advantage over the high oleic cultivars at the Clark County location.

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# Wheat Growth Stages and Associated Management

Laura E. Lindsey, Pierce Paul, and Edwin Lentz

Key wheat management decisions need to be made at certain growth stages. Exact growth stages cannot be determined by just looking at the height of the crop or based on calendar dates. A careful examination of the developing crop is needed to tell growth stages apart. Correct growth stage identification and knowledge of factors that affect grain yield can enhance management decisions, avoiding damage to the crop and unwarranted or ineffective applications. These decisions can make wheat production more profitable. Several scales can be used to identify wheat growth stages, including the Feekes and Zadoks scales. Here we focus on the Feekes scale. Using this scale, growth stages are identified and assigned numerical codes based on the occurrence of key developmental events such as tillering, leaf and head emergence, and flowering. Since growth and development usually vary among tillers and across the field, it is important to sample and examine primary tillers at multiple locations to come up with a representative growth stage for the field. Commonly used sampling schemes include walking and examining tillers across the field at regular intervals along a zig-zag or M-shaped pattern, but the uniformity of the field and visual differences in crop development are also very useful for determining how and where to sample tillers. Usually the crop (or a section of a field) is said to be at a given growth stage when approximately 50% of the primary tillers reach that growth stage.

## Feekes 1.0: Emergence

The number of leaves present on the first shoot (main stem) can be designated with a decimal. For example, 1.3 is a single shoot with three leaves unfolded. The most significant event in achieving high yields is stand establishment, i.e., the number of plants or tillers per square foot. Late-planted wheat has less time to tiller and should be planted at a higher seeding rate to compensate for fewer tillers.

## Feekes 2.0: Beginning of Tillering (usually in fall)

A tiller is a shoot that originates at the coleoptilar node. Tillers share the same root mass with the main stem (Figure 1). During tillering, the major management consideration is whether stands are adequate to achieve yield goals. Management inputs will not compensate for skimpy or erratic stands caused by insects, seedling diseases, poor seed quality, herbicide injury, etc. A producer may want to apply 20 to 30 pounds per acre starter N to promote tillering especially if planting without tillage. Excess N applied at this time leads to a lush,

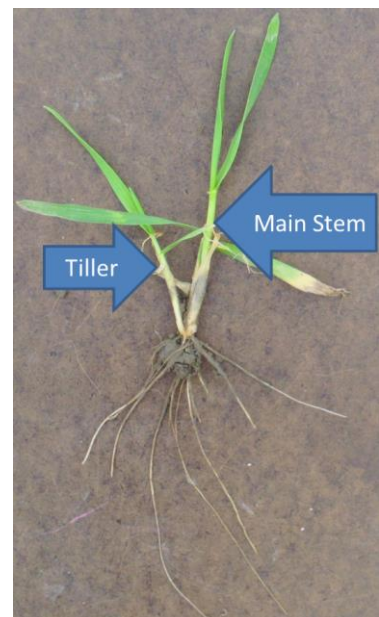


Figure 1. Wheat main stem and tiller.

vegetative growth which makes the crop more susceptible to winter-kill and foliar fungal diseases. Adequate phosphorus (P) and soil pH above 6.0 are needed for good root and tiller development.

### **Feekes 3.0: Tillers Formed (late fall or early spring)**

Winter wheat can continue to tiller for several weeks. Depending upon the planting date and weather conditions, tillering can either be interrupted by or completed prior to the onset of winter dormancy. Most of the tillers that contribute to grain yield are completed during this stage. Winter wheat plants are prostrate or “creeping” at this stage. In the spring, between Feekes 3.0-4.0, wheat “greens-up.” Green-up is not a definable growth stage, but occurs when the new growth of spring has covered the dead tissue from winter giving the field a solid green color. Spring N should not be applied before green-up.

### **Feekes 4.0: Beginning of Erect Growth (March-April)**

Most tillers have been formed by this stage, and the secondary root system is developing. Winter wheats, which may have a prostrate growth habit during earlier vegetative developmental stages, begin to grow erect at Feekes 4. Leaf sheaths thicken. The key management step at Feekes 4.0 is continued scouting for insects and weed infestations.

### **Feekes 5.0: Leaf Sheaths Strongly Erect (early- mid-April)**

Further development of the winter wheat plant beyond Feekes 4 requires vernalization, or a period of cool weather between Feekes 1 and Feekes 4. After the appropriate amount of chilling, followed by the resumption of growth, the growing point (located below the soil surface) differentiates. At this stage of growth, the size of heads, or number of spikelets per spike, is determined. No effect on yield is expected from tillers developed after Feekes 5.0.

Nitrogen applied at Feekes 5.0 can affect the number of seeds per head and seed size, but not the number of heads per square foot or the number of spikelets per head. This is an ideal stage of growth for the spring topdress N application. Weed control decisions should be made before or during Feekes 5.0 with 2,4-D and similar phenoxy herbicides being applied during Stages 5 and 6. This is also a good stage to begin scouting for foliar diseases.

### **Feekes 6.0: First Node Visible (mid-late April)**

Prior to Feekes 6.0, the nodes are all formed but sandwiched together so that they are not readily distinguishable. At 6.0, the first node is swollen and appears above the soil surface. This stage is commonly referred to as “jointing.” Above this node is the head or spike, which is being pushed upwards



**Figure 2. Split wheat stem showing developing spike.**

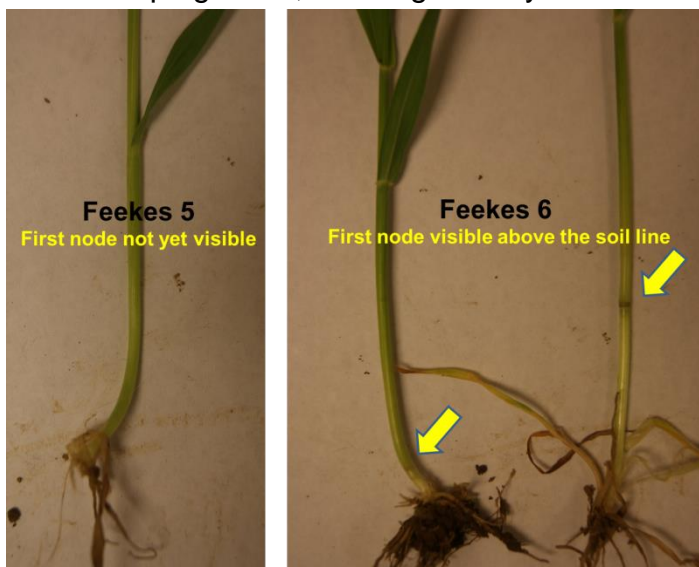
eventually from the boot. The spike at this stage is fully differentiated, containing future spikelets and florets. Figure 2 shows a split wheat stem showing the developing wheat spike.

Growers should remove and carefully examine plants for the first node. It can usually be seen and felt by removing the lower leaves and leaf sheaths from large wheat tillers (Figure 3). A sharp knife or razor blade is useful to split stems to determine the location of the developing head. The stem is hollow in most wheat varieties behind this node.

By Feekes 6.0, essentially all weed-control applications have been made. Do not apply phenoxy herbicides such as 2,4-D, Banvel, or MCPA after Feekes 6.0, as these materials can be translocated into the developing head, causing sterility or distortion. Sufonyl-urea herbicides are safe at this growth stage, but for practical reasons, weed control should have been completed by now. Small grains can still show good response to N topdressed at this time.

### **Feekes 7.0: Second Node Becomes Visible (late April-early May)**

This stage is characterized by the rapid expansion of the head and a second detectable node. Look for the presence of two nodes – one should be between 1.5 and 3 inches from the base of the stem and the other should be about 4 - 6 inches above the base of the stem. These nodes are usually seen as clearly swollen areas of a distinctly different (darker) shade of green than the rest of the stem. Note: the upper node may be hidden by the leaf sheath – you may have to run your fingers up the stem to feel for it: if only one node is present, then your wheat is still at Feekes growth stage 6. Wheat will still respond to N applied at Feekes 7.0 if weather prevented an earlier application; however, mechanical damage may occur from applicator equipment.



**Figure 3. Feekes growth stage 5 showing no node on the main stem and Feekes growth stage 6 with the first node visible. Note: Lower leaves and leaf sheaths have been removed.**



**Figure 4. Feekes growth stage 8 where flag leaf is visible, but still rolled up.**

### **Feekes 8.0: Flag Leaf Visible, but Still Rolled Up (late April-early May)**

This growth stage begins when the last leaf (flag leaf) begins to emerge from the whorl (Figure 4). This stage is particularly significant because the flag leaf makes up approximately 75 percent of the effective leaf area that contributes to grain fill. It is therefore important to protect and maintain this leaf healthy (free of disease and insect damage) before and during grain development. When the flag leaf emerges, three nodes are visible above the soil surface. To confirm that the leaf emerging is the flag leaf, split the leaf sheath above the highest node. If the head and no additional leaves are found inside, Stage 8.0 is confirmed, and the grower should decide whether or not to use foliar fungicides to manage early-season and overwintering foliar fungal diseases.

This decision should be based upon the following considerations:

- 1.) Is a fungal disease present in the field?
- 2.) Is the variety susceptible or are weather conditions favorable (wet and humid) for rapid spread and development of the disease(s) found in the field?
- 3.) Does the crop yield potential warrant the cost of application of the fungicide in question to protect it?
- 4.) Is the crop under stress?

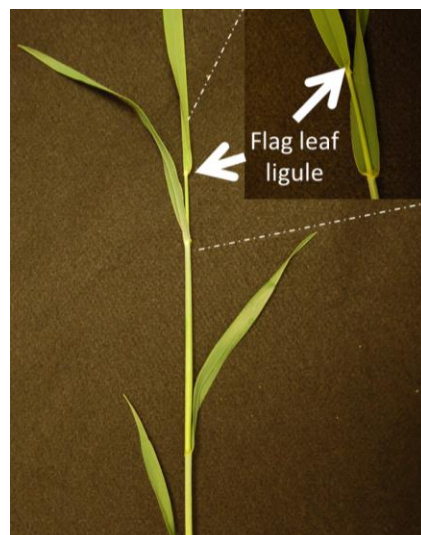
If a positive answer applies to the first three questions, and a negative response to the last, plans should be made to protect the crop from further damage. Check product labels and apply as soon as possible. In most situations, the greatest return to applied foliar fungicides comes from application at Feekes Stages 8-10. Nitrogen applications at or after Feekes 8.0 may enhance grain protein levels but are questionable with respect to added yield. Moreover, additional N may increase the severity of some foliar diseases, particularly the rusts.

### **Feekes 9.0: Ligule of Flag Leaf Visible (early May)**

Stage 9.0 begins when the flag leaf is fully emerged from the whorl with the ligule visible (Figure 5). From this point on, leaves are referred to in relation to the flag leaf (i.e., the first leaf below the flag leaf is the F-1, the second leaf below is the F-2, and so forth). After the flag leaf emergences, army worms can seriously damage yield potential.

### **Feekes 10.0: Boot Stage (mid-May)**

At the boot stage, the head is fully developed and can be easily seen in the swollen section of the leaf sheath



**Figure 5. Feekes growth stage 9 where the ligule of the flag leaf is visible.**



**Figure 6. At the boot stage, the head is fully developed and can be easily seen in the swollen section of the leaf sheath below the flag leaf.**

below the flag leaf (Figure 6). This is another important growth stage for making fungicide applications for foliar disease management, particularly late-season diseases such as *Stagonospora* leaf and glume blotch and rusts.

### Feekes 10.1-10.5: Heading (mid- to late-May)

Heading marks the emergence of the wheat head from the leaf sheath of the flag leaf, and is subdivided into stages based on how much of the head has emerged. Stage 10.5 is shown in Figure 7.

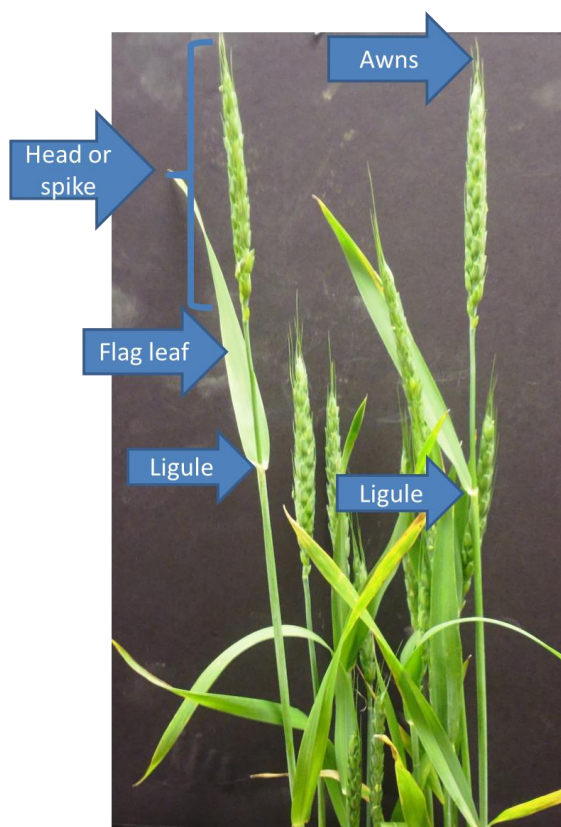
- 10.1 Awns visible, head beginning to emerge through slit of flag leaf sheath
- 10.2 Heading  $\frac{1}{4}$  complete
- 10.3 Heading  $\frac{1}{2}$  complete
- 10.4 Heading  $\frac{3}{4}$  complete
- 10.5 Heading complete

### Feekes 10.5.1-10.5.3: Flowering (mid-May to early-June)

**10.5.1 Beginning flowering.** This stage is often marked by the extrusion of anthers from florets in the center of the spike (Figure 8). For that reason, this growth stage is also referred to as anthesis, although on rare occasions under growing conditions in Ohio, flowering may occur without anthers being extruded or with anther extrusion occurring after flowering, depending on the weather and the variety. Feekes 10.5.1 is the growth stage at which fungicides are recommended and are most effective against wheat head scab and vomitoxin.

**10.5.2** Flowering complete at the top of the spike

**10.5.3** Flowering complete at the base of the spike



**Figure 7. Wheat flag leaf, ligule, awns, and spike (or head) at Feekes 10.5.**

Wheat is self-pollinating. Most florets are pollinated before anthers are extruded. Although tillers have developed over several weeks, bloom in a given wheat plant is usually complete four to five days after heading. The grain-fill period of wheat varies somewhat, depending upon climate. It is typically as little as 13 days in high-stress environments, and may exceed 20 days in high-yield, low-stress environments. After Feekes Stage 10.5.3, remaining growth stages refer to ripeness or maturity of the kernel.



**Figure 8. Feekes 10.5.1 or beginning flowering is often marked by the extrusion of anthers from florets in the center of the spike.**

**Feekes 10.5.4-11.4: Ripening and Maturation**

- 10.5.4**     Kernels watery ripe, clear fluid can be squeezed from the developing kernel
- 11.1**        Milky ripe, milk-like fluid can be squeezed out of the kernels when crushed
- 11.2**        Mealy ripe, material squeezed out of the kernel has a doughy consistency
- 11.3**        Kernel hard, but dividable with thumbnail (late June)
- 11.4**        Harvest ready. Kernel is hard and not dividable with thumbnail (late June-early July)

At maturity, timely harvest is important. Risks of delayed harvest include disease, lodging, and seed sprouting which ultimately reduce grain yield and test weight.

**Table 1. Wheat morphological terms.**

Anther	The male (pollen-producing) part of the flower.
Awn	The bristles on the wheat head (spike).
Coleoptile	Protective sheath covering the emerging shoot.
Flag leaf	The last leaf to emerge before the head (spike).
Floret	Each individual flower (containing anthers and stigma). Several florets form a single spikelet.
Spike	Also known as the wheat head.
Spikelet	The basic unit of a wheat flower. Each spikelet consists of at least three florets.
Stigma	The female (pollen-receptor) part of the flower.
Tiller	A shoot originating from the main stem from the coleoptilar node.

**Revised FactSheet:** Lindsey, L.E., P. Paul, and E. Lentz. 2017. Wheat growth stages and associated management. Ohio State University FactSheet AGF-126. Available online at: <https://ohioline.osu.edu/factsheet/agf-126> (verified 23 August 2017).

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# COMING SOON!



## What is the minimum wheat stand required in the spring to maximize yield?

Graduate student, Allen Goodwin, is wrapping up his final year of research examining wheat stand in the spring and utilizing alternative methods to evaluate stand.



## What is the optimum soybean relative maturity in Ohio?



## How does variable rate seeding affect soybean plant architecture?



## How susceptible is wheat to spring freezes?



THE OHIO STATE UNIVERSITY

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