TILLERING PATTERNS AND WHEAT PLANT STRESSES

Betty Klepper, Plant Physiologist & Research Leader
USDA, Agricultural Research Service
Columbia Plateau Conservation Research Center
P.O. Box 370, Pendleton, Oregon 97801

The main purpose of this talk is to give you some understanding of the developmental history of healthy cereal plants and the symptoms that develop under stress.

Objectives Include:

- Learning the parts of the cereal plant.
- Learning the names of these parts.
- Becoming familiar with the arrangement of leaves, tillers, and roots on the stem.
- Learning to "read" plants, that is, to identify individual leaves and tillers.
- Using growing degree day concepts to track plant development.
- Discovering the expected tillering pattern for unstressed plants.
- Finding missing tillers and interpreting these absences in terms of plant stresses and when they occurred.
- Deciding on timing and placement of fertilizer and herbicide applications with plant development in mind.

The Parts of the Cereal Plant

Cereal plants are made up of main stems, tillers, and roots. The main stem is the plant that emerges when you seed your wheat; it is the first and usually the strongest culm on the plant. There is one modified leaf-like structure on the main stem that is important in the emergence process. That structure is the coleoptile which elongates and pushes its way up in the soil and protects the first leaf on the plant from damage by the soil. Tillers are branches of the main stem; they appear some time after emergence and serve to increase the number of heads per acre that are present in the final crop. Tillers start off dependent on their parent culm for nutrients and water but later they grow their own root system and become more independent. There are two root systems on cereal plants; one is the seminal root system which develops from root buds or primordia that are present already in the seed and the other is the adventitious or crown root system that is produced at the crown level later in plant development. There are roots which come from the coleoptilar node in some plants and these are considered adventitious roots.

Names of Plant Parts

Each leaf on the main stem has been given a name according to its order of appearance. The first foliar leaf is called Leaf 1 or L1, the second, L2, the third L3, and so on. The point of attachment of a leaf is called a node; nodes of cereals appear later in development as "joints" but at the seedling stage they are not so obvious. Each node takes on the name of its leaf--that is, L1 is attached to N1, L2 to N2 and so on. The same system is used for tillers. Each leaf has in its axil a bud which can either remain dormant or grow to produce a tiller. When a plant does not tiller, these buds are still present but remain small. Tillers are also named for the leaf which subtends them; Tiller 1 in the axil of Leaf 1 and so on. The tiller at the coleoptilar node has the designation of T0; this tiller is especially useful in determining adequate seed and seedbed condition. Roots have also been named according to the node to which they are attached. Thus the crown roots associated with Node 1 are called lA, lB, lX, and lY, depending on the direction of growth with respect to the midrib of the leaf at the node.

Arrangement of Plant Parts

Leaves are arranged on opposite sides of the stem in cereals. For example, if you hold a wheat plant in your hand with Leaf 1 on your left side, then Leaf 2 and all of the other even numbered leaves and tillers will be on your right side, and Leaf 3 and all of the other odd numbered leaves and tillers will be on your left-hand-side. Tiller 0, being even numbered will be on your right-hand-side if it appears. For most seedings, there will be a sub-crown internode between the crown and the coleoptilar node; the length of this internode will determine the depth of the crown. The seminal roots and the roots from the coleoptilar node will be grouped together at the level of the seed. The crown roots will begin to appear at Node 1--that is, at the bottom of the crown. It is because these plant parts always appear in a set sequence and in set places that we are able to identify all of the parts of the plant even when some of them are missing--such as lower leaves being rotted off or tillers that were never produced.

"Reading" Plants

Because cereal plants develop according to a set pattern, it is possible to pick up a strange plant and figure out how old it is, how deep it was planted, whether it has been stressed during early development, and whether it has stopped tillering. All of this information is available from the morphology or form of the plant. To read a plant, we identify all of the parts present, especially leaves and tillers. We can see a distinct line where the soil surface was because all of the below-ground parts will be light-cream to very light green and all of the above-ground parts will be dark-green. The depth of the crown can be measured from the soil-line to the bottom of the crown and the seed depth can be determined in like manner. We can see which tillers are present and how many leaves there are on the main stem. The number of leaves on the main stem is referred to as the Haun Stage, after a person who developed a system for counting the number of leaves on a plant by counting all of those developed and adding to that number the fraction of the next leaf that has appeared. In the case of cereals we determine the Haun stage by counting leaves and adding on the decimal fraction that represents the length of the newest developing leaf compared to the blade of the leaf immediately below the newest one. With the Haun stage, we know that the plant is old enough to have a certain number of leaves on it. We also know when there were stresses because tillers fail to appear when there are stresses. Whenever tillers did not appear is when the plants were stressed. The next section will help you to understand how actual dates can be put onto these events. We also have to remember that the below-ground parts of the plant develop according to a pattern and that our applications of fertilizer materials must take this fact into account.

Growing Degree Days and Plant Development

When plants are grown in environmental control chambers, their temperature and other growing conditions are controlled. We find that it takes exactly the same number of days for each of the main stem leaves to develop. In other words, if it takes six days for the first leaf to grow out, it will also take six days for the second leaf and for every other leaf on the main stem to grow out. This is true also for the leaves on tillers--it will take six days for each leaf on each tiller to grow out. The amount of time required can be shifted by changing the conditions in the chamber, but once they are set, the number of days required for each leaf to grow out is determined. Now you can see how one might use this fact to time events in the life of the plant. Say, for example, that you have some seedlings in a growth chamber that have 5.5 leaves on the main stem. Also say that you know that the conditions in the chamber produce one leaf every five days. Then you know that it has been 5 times 5.5 or 27.5 days since these plants emerged. This gives you an example of how to use plant development to time events in the plant's life.

The growth chamber case is relatively simple because all of the conditions are constant. We never see constant conditions in the field so that we have to resort to a more complex timing system. For winter cereals it turns out that temperature alone is a good predictor of development. We can use "growing degree days" to time cereal development. Here is how to calculate growing degree days. Take the maximum and minimum daily temperatures for all of the days from planting to the present and convert them to centigrade degrees. The formula for that conversion is: $C=5/9(F-32)$. For example, 62 degrees Fahrenheit would be $5/9(62-32)$ or 16.7 centigrade degrees. When you have the centigrade values then you get the average temperature for each day by dividing the sum of the maximum and the minimum temperatures by 2. The average temperatures below the freezing point which is 0 on the centigrade scale are given the value of 0. Then you add up all of these average temperatures you get cumulative growing degree days for the period of time under consideration.

In the field, then, we can measure plant development by using growing degree days. It takes about 100 growing degree days for each leaf to appear. Now if we pick up a plant that has 5.5 leaves on its main stem, we know that it has been about 550 growing degree days since that plant emerged. Of course, this number is an average. We have found values ranging from about 75 to 120 growing degree days per leaf under all sorts of field conditions. The amount of time that it takes for a leaf to grow out is called a phyllochron--literally "leaf-time." By using growing degree days and historical data we can even predict when a crop is expected to reach a given development stage.

Tillering Patterns for Unstressed Plants

Each tiller is produced at its node about three phyllochrons after the leaf first appears at that node. In other words, Tiller 1 will appear as Leaf 4 is elongating. The last leaf on a tillering plant will be no more than three leaves ahead of the last tiller on that plant. To determine whether a plant is still tillering, all you have to do is to count the leaves backwards from the tip of the main stem until you come to the first leaf that has a tiller. If there are more than three leaves in this count, then your plants have ceased tillering. There are also subtillers on tillers from the buds in the axils of the leaves on the tillers. These also have a definite time of appearance with respect to the development of the rest of the plant.

Stress History Through Tillering

You can use this tillering pattern to determine when stresses happened. For example, say that you have a plant that has 6.2 leaves on the main stem and has a T0, a T1, and a very small T3. Since T2 is missing, you can say that there was a severe stress on that plant near to the time that T2 should have been produced but that the stress has been removed in time for the T3 to show up. This could also be interpreted to say that some stress occurred about 100 or so growing degree days ago. You can then look at the weather and the calendar and figure about when the date of the stress might have been. All sorts of stresses will affect tillering from low fertility to cloudy weather.

The plant can tell you when it happened, but it is up to you to figure out what happened. For example, one of my colleagues once brought me in some plants. Some of the plants were dead and had 5.5 leaves on them. Some showed some damage on the fifth and sixth leaves, but had gone on to grow and had 7.8 leaves. That told me that there had been a damaging event about 2.3 phyllochrons ago--or about 230 growing degree days ago. After looking at the weather and back-calculating to determine how long ago it had been to 230 growing degree days, I found that the damage had happened sometime during the second week of February. The weather records showed sudden cold weather then and that was consistent with the plant symptoms that I saw. The dead plants happened to come from an area of the field that had had a double spray of herbicide and they were especially susceptible to the frost damage.

Timing of Operations in Plant Development Terms

Understanding plant development and its meaning can be helpful to you in making decisions in your management. For example, if you are concerned about where to place banded fertilizers, it helps to know where the seedling roots are going to be during the first few weeks of growth in order to put the fertilizer where the roots will have access but not so close that roots are damaged. It helps to know that the crown roots will appear about 300 growing degree days after plant emergence if you wish to spray certain herbicides which recommend having a crown root system in place before use. There are some herbicides that will affect the developing head and cause missing spikelets on the head when they are sprayed during spikelet development. All of these things illustrate how useful it may be to know something about plant development. By having historical weather data to use in predicting what the plant is likely to do over the next several weeks, you can better manage your time and equipment, especially if you have fields that are at different elevations or with different planting dates.