DROUGHT –STRESSED KERNEL SECRETS: FOR YOUR EARS ONLY

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The size, placement, and amount of kernel set on a corn ear reveals clues to the environmental history the corn plant experienced during ear growth and development. Understanding how corn ears respond to stress can help determine when stress was present and the severity of this stress. Four critical stages of ear development significantly affect the number and weight of harvestable kernels and subsequent grain yield: (1) approximately V7, when the corn ear is setting the maximum number of kernel rows around the ear; (2) just before pollination, when the ear is establishing the maximum number of ovules along the length of the ear; (3) at pollination, when the maximum number of ovules are pollinated to form developing embryos; and (4) approximately R3-R5, when the ear sets maximum kernel size during the latter portion of grain fill. This presentation illustrates corn ear responses to some of the more common stresses that occur during these stages and explains why corn ears respond as they do. Corn developmental stages used in this article are based upon the Iowa State publication *How a Corn Plant Develops*[1].

A critical point to remember is that meristematic cells — such as developing ovules, embryos, and kernel cells during grain fill — are living in a constant state of near starvation for water and nutrients. These cells must be fed and watered every day for normal cell growth, division, and development to occur. An environmental stress that substantially alters or disrupts water and nutrient flow will cause these meristematic cells to die. Once these cells die, this particular plant part will not recover and the plant itself may only partially recover from this stress event, even if this stress is later removed and subsequent environmental conditions are ideal for corn growth. The expression of the ear response indicates which developmental stages of meristematic tissues were in progress when the stress occurred.

Stress early in ear development results in fewer kernel rows around the ear. Depending upon CRM, the corn plant determines the maximum number of rows around the ear at approximately stage V5-V8. Figure 1 (left side) shows a picture of a developing corn ear at stage V9. The meristematic dome is present at the tip of the ear, indicating the developing ear is still producing new rows of ovules along the length of the ear. The upper two-thirds of the ear show a series of single rows of developing ovules. These ovules eventually divide to produce a pair of rows of ovules from each single row. This paired formation is visible near the base of the ear. This division explains why a corn ear always has an even number of kernel rows around the ear.

Placement of the primary ear varies with corn genetics. The corn parent line in Figure 1 is 103 CRM and the primary ear (the ear to be harvested) is located on the V14 node. In general, corn lines varying from approximately 103 to 118 CRM will produce the primary ear on the V13 or V14 node. Parent lines of earlier maturity will

[1]S. W. Ritchie , J. J. Hanway, and G. O. Benson. 1997. How a corn plant develops: Special Report no. 48. Iowa State University Cooperative Extension Service, Ames, Iowa.

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sometimes place the primary ear on a lower node, such as the V12 node.

The node of primary ear placement is an excellent reference point to determine when ear initiation starts. A general guideline is to determine the node containing the primary ear, then subtract seven. This V stage is approximately when the number of kernel rows around the ear is being established. For example, the corn line in Figure 1 positions the primary ear at the V14 node; thus, the number of kernel rows around the ear is being established at or very near the V7 stage.

Establishment of the number of kernel rows around the ear is a critical event in a corn plant’s life cycle. If a particular corn line normally has 16-18 kernel rows around the ear, and the ear in question has less than the normal number, then some sort of stress was present at or just before this critical stage. From a diagnostic perspective, if an ear has 12 kernel rows around instead of the normal 16, then the stress factor that caused this event was present at approximately V7. This information helps to establish a “time window” in looking for the environmental event that caused this ear response.

A second critical time of environmental stress on ear development occurs approximately one-two weeks before pollination. During this interval, the maximum number of ovules that the entire corn ear will produce is determined. Figure 1 (right side) shows a primary ear harvested when the corn was at V12. The meristematic dome is no longer present, and paired ovule formation is apparent along nearly the entire length of the ear. Maximum potential ovule formation is established sometime shortly after this growth stage. Ovule growth and development between the stages of ear initiation and pollination is a dynamic, two-step process. The first step is the initiation of ovules as previously explained. The second step is the cell differentiation and cell division that must occur to prepare these ovules for fertilization. At any moment between ear initiation and pollination, ovule formation differs along the developing corn ear’s length. Ovules near the ear’s base develop first and newer ovules will continue to form as development progresses toward the ear’s tip. After the corn plant has established the maximum number of ovules, the three essential elements of energy, nutrients, and water to sustain these developing ovules must be supplied. If all resources are adequate, ovules along the entire ear will develop sufficiently to produce silks and be receptive to pollen. Each ovule has the potential to produce a harvestable kernel. From a diagnostic perspective, if an ear has the proper number of kernel rows around, but the ear has fewer than normal kernel rows along its length, then sufficient stress of some sort caused this event while the corn plant was progressing through the later stages of ovule development.

The third, and most critical, time of environmental stress on ear development occurs during pollination. There are two basic parts to the pollination process. First, viable pollen must land on receptive silks. Second, the silks must support formation of pollen tubes to allow male gametes to fuse with female gametes inside the ovule. Corn anthers usually release a large portion of mature pollen in mid-morning, depending upon environmental conditions. Pollen loses viability within a few minutes if air temperature is high (approximately 104° F or 40° C) and water deficit stress is present. Pollen grains contain about 80 percent water when first shed, but die when the water content decreases to about 40 percent. A lot of corn is successfully pollinated under higher temperature conditions. If soil moisture is adequate and the corn plant can transpire rapidly enough to supply the necessary water to the pollen, then the pollen remains viable long enough to properly shed and complete the fertilization process. However, if water supply is inadequate, the pollen will die prematurely.

The second part of successful ovule fertilization is the formation of the pollen tube and deposition of male gametes inside the ovule. This process relies heavily on the female portion of the plant because the silks must supply all necessary nutrients and water for pollen tube growth. Based on all of the pictures we have seen to date, viable pollen grains adhere to silk trichomes, not directly to the silks, to start the fertilization process (Figure 2). Trichomes are hair-like projections that extend from a silk's main stem much like root hairs extend from a plant root. Within a few minutes after landing on the trichomes, the pollen grains initiate pollen tubes. These pollen tubes always seem to grow near the silk vascular bundle (Figure 3). This may occur because these vascular tissues contain a readily available source of water and nutrients essential for growth. Depending upon water availability and environmental conditions, it may take anywhere from a few hours to approximately one day for pollen tubes to grow all the way to the ovules. When the corn plant is under greater drought stress, pollen tube growth is slower and the potential for successful fertilization decreases.

Environmental stress during pollination can have substantial effects on grain yield. For a specific hybrid, approximately 85 percent of grain yield correlates to the number of kernels produced per acre with the remaining 15percent being the weight of individual kernels at harvest (Figure 4). The amount of water available for silk growth substantially influences when silks emerge, their rate of growth, their length of receptivity, and their ability to supply water and nutrients to support pollen tube growth and gamete fusion. From a diagnostic perspective, corn plants under stress during pollination produce ears with portions of the cobs barren (examples shown in Figure 4). Portions of the cob are barren because mature ovules were not properly fertilized. These unfertilized ovules begin to disintegrate and disappear before the ear reaches physiological maturity.

The fourth critical time for environmental stress on ear development occurs during grain fill. A successfully fertilized kernel goes through two phases in the approximately eight weeks between pollination and physiological maturity (approximately 35 percent grain moisture). For approximately the first three weeks after pollination, embryo cells are rapidly differentiating and dividing to produce the tissues necessary for the embryonic corn plant contained within the kernel. The remaining weeks of grain fill are devoted primarily to starch and storage tissue deposition to support new plant growth when this generation of seed is planted. All kernels are attached to the cob, and all kernels compete for available food and water. Only those kernels receiving ample moisture and nutrients live. Typically, kernels near the butt of the ear develop a little earlier and are closer to the source of nutrients than kernels at the tip of the ear. When stress is present, the ear will often sacrifice tip kernels in favor of kernels at the butt of the ear (Figure 5). Depending on the severity of the stress, tip kernel dieback will continue until the point at which the corn plant has the ability to supply adequate water and nutrients to support growth of the remaining kernels. Kernel formation (or lack thereof) indicates the time stress occurred — whether it occurred before or during pollination or during grain fill. If a portion of the cob is barren, with no evidence of viable kernel formation, the stress occurred at or before pollination. If a portion of the cob shows either very small kernels or kernel dieback, the stress occurred sometime during the grain-filling process. If tip kernels did not abort, but their test weight is decreased, the stress occurred only during the very latter part of grain fill.

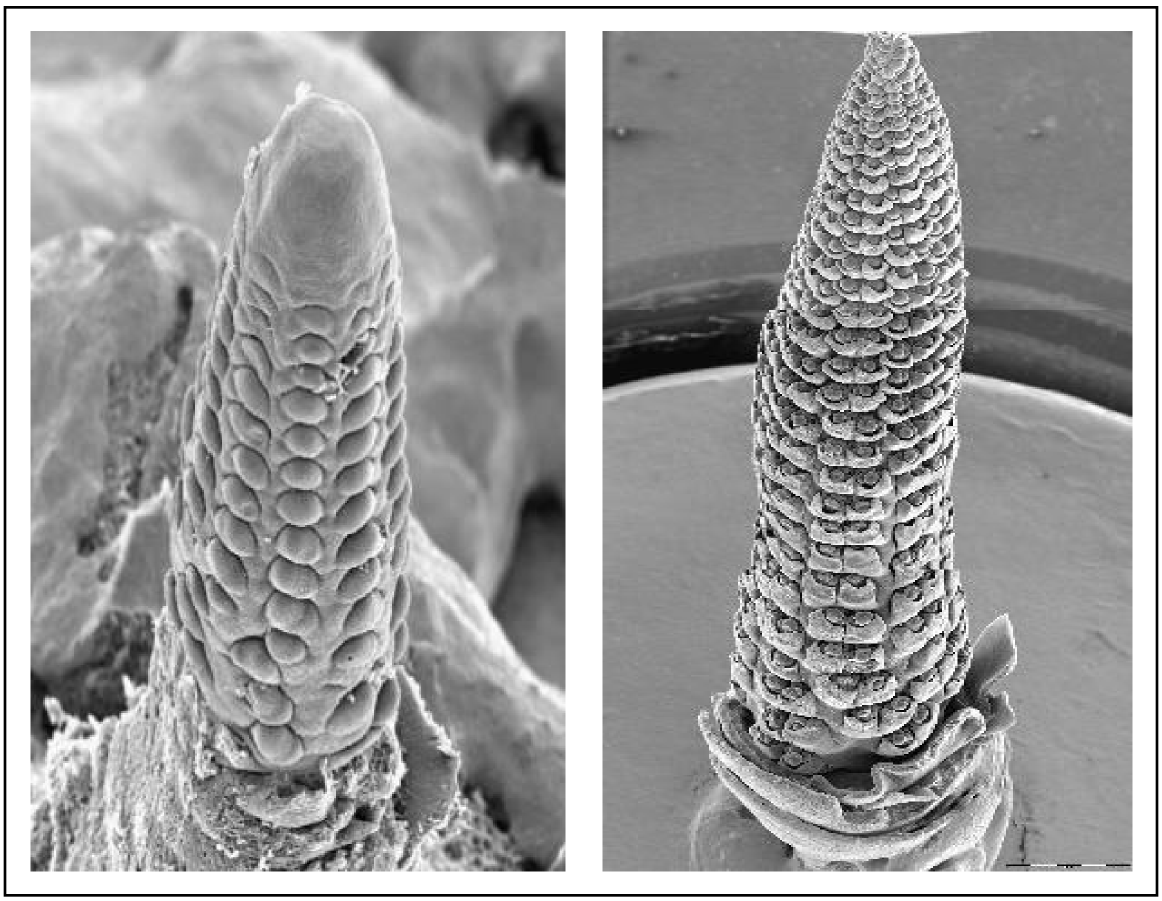

Figure 1. Development of a primary ear, attached to the V14 node, harvested from corn at V9 (left) and V12. Photos courtesy of Dr. Antonio Perdomo, Pioneer Hi-Bred.

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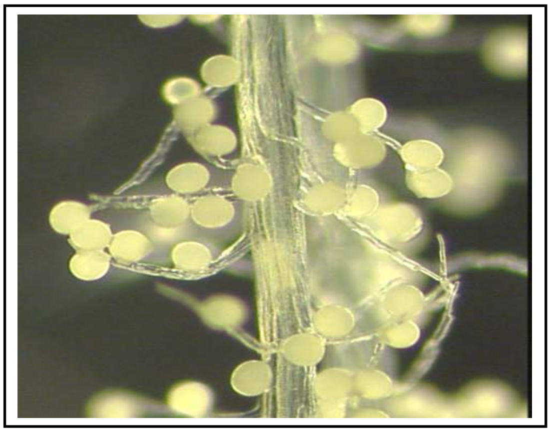

Figure 2. Pollen attachment to silk trichomes. Photo courtesy of Dr. Don Aylor, University of Connecticut.

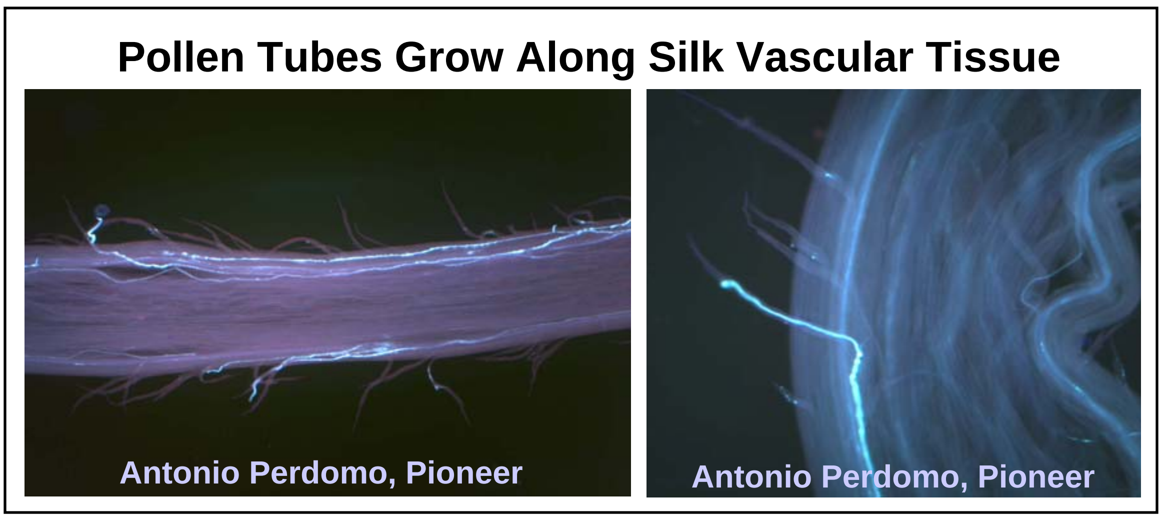

Figure 3. Pollen tube growth in corn silk. Photos courtesy of Dr. Antonio Perdomo, Pioneer Hi-Bred.

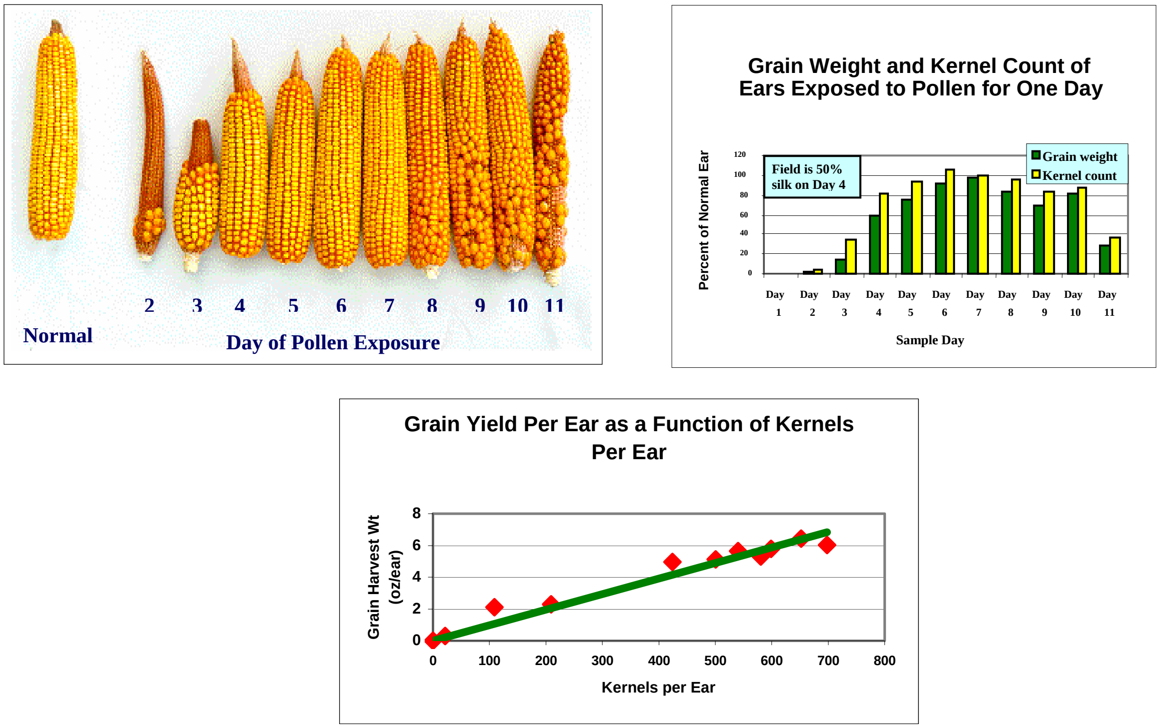

Figure 4. Relating kernel count to grain yield. Silks of ears 2-11 were exposed to open pollination only on the designated day and were covered during the rest of the pollination window. Silks of the "normal" ear were exposed during the entire pollination period.

Figure 5. Stress during grain fill resulting in tip kernel dieback and kernel abortion.

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