FIELD FACTS

PIONEER
A DuPont Business

Conditions At Pollination Determine Kernel Set In Corn

Introduction

Because of its impact on kernel number and final yield, the pollination process is one of the most critical periods in the development of the corn plant. While number of kernel positions is determined earlier in the corn plant's development, number of kernels actually set is largely determined near the time of pollination. Losses due to reduced kernel set at pollination cannot be fully regained, even if favorable conditions persist the rest of the season. This article will review the process of kernel set in corn, and recent research studies which evaluate the role of stress in early reproductive development.

Kernel Set Is Often Reduced By Stress

Kernel set in corn requires the successful completion of several plant processes, including pollination, fertilization, and embryo and endosperm development. Pollination includes production of viable pollen by the tassel, and interception by functional silks. The pollen grain adheres to the silk, germinates and sends a structure called the pollen tube down the length of the silk. The pollen tube penetrates the ovary and the male gamete unites with the egg cell to complete fertilization. If embryo and endosperm development is maintained, a kernel will be set.

Under good growing conditions, the sequence of events ending in kernel set usually progresses satisfactorily, but under stress conditions, the process may be interrupted at one or more junctures. Tassels may produce less pollen under heat stress, and pollen may lose its viability. When drought stress occurs, silks may delay emergence until pollen shed is nearly over. Drought may also induce ovary dysfunction, or abortion of the newly-formed zygote, embryo, or kernel. High temperatures, drought, reduced sunlight, and loss of leaf area have all been identified as stresses which can affect corn during the early reproductive stage.

Timing Of Stress Investigated

Many studies have shown that stress occurring near the pollination stage has a detrimental effect on yield. Most researchers place the beginning of the stress-susceptible period at about one week prior to silking. Various studies suggest that this critically sensitive period continues for one to two weeks after silking, and some extend the period even more.

Reduced kernel set due to various levels of drought stress.

Yield losses during this period result from reduction in kernel number, and are therefore irreversible. Reduction in kernel number may result from incomplete pollination due to asynchrony of pollen shed and silking ("silk delay"), ovary dysfunction due to low water potential, or abortion of the newly formed zygote or embryo due to insufficient carbohydrate availability. The older the kernel, the less chance that abortion will occur.

Pollen Shed Affected By Heat

The location of the tassel exposes it to both high radiation and potential temperature extremes. Researchers have found that extreme high temperatures, rather than drought per se, have the greatest effect on pollen production and viability. Several studies have shown that in vitro pollen viability decreased as tassels were exposed to high temperature treatments, but viability was not affected by drought conditions, even when visible wilt and lower leaf senescence were induced by the low water potential. It can be concluded from these studies that high temperatures are more detrimental than drought stress to pollen development.

Extreme losses in pollen production or viability may be necessary to affect kernel set. Field studies in which pollen amount was limited using male sterile plants showed that a reduction in pollen amount of at least 80% over the course of the pollen shedding period was required to reduce kernel set.

Effect Of Drought On Silk Growth

Silk elongation requires high water potential. Under drought conditions, most silk elongation occurs at night, when water potential is highest. Inhibition of silk growth due to drought stress often results in asynchrony of pollen shed and silk emergence, commonly referred to as "silk delay." A study by Herrero and Johnson[3] showed that drought stress can add 3 to 4 days to the normal interval between first pollen shed and first appearance of silks. Consequently, the last silks to appear, those emanating from the tip of the ear, may emerge after most of the pollen has shed. This lack of synchronization is considered to be the primary factor limiting kernel set during drought conditions. Barren or poorly-filled ear tips can result from moderate to severe silk delay.

Effect Of Drought On Silk Receptivity

Silks are considered receptive to pollen if they support germination of pollen grains, growth of the pollen tube within the silk, and passage of the pollen tube to the wall of the ovary. Basetti and Westgate[1] showed that silks normally remain receptive for about 7 days after emergence from the ear shoot, after which time they senesce, beginning at the base of the silk. However, silks are usually pollinated within one or two days after emergence, and fertilization occurs within 24 hours of pollination.

Basetti and Westgate[2] examined silk receptivity under drought conditions. As expected, silk elongation was slowed by drought stress, and could be completely inhibited under severe stress. The pollen tube growth rate was also slowed by half or more, such that pollen tubes required over 48 hours to reach the ovary. This slower rate of pollen tube growth was only detrimental if pollination was delayed until five days after silks first emerged, since silks sometimes senesced at the base before pollen tube growth was completed.

In the field, it is highly unlikely that silk senescence or other loss of silk receptivity causes significant kernel loss. Silks typically are pollinated within 24 hours of exposure, and pollen tube growth is completed well before silks senesce. Other studies have shown that silks pollinated at water potentials low enough to prevent kernel formation were still able to support pollen germination and pollen tube growth. Consequently, evidence points to events occurring during or after fertilization as the cause of reproductive failure.

Effect Of Assimilate On Kernel Abortion

Recently, some researchers began to suspect that drought-induced developmental failure soon after fertilization may be due to starvation for substrate. Drought stress is known to inhibit photosynthesis, and carbohydrate reserves are already low at anthesis. This hypothesis is strongly supported by studies designed to alter assimilate supply at flowering. Shading plants during pollination and early kernel growth decreases seed set, while supplemental light increases the number of kernels. Studies with prolific hybrids known to have high carbohydrate availability to the ear showed less sensitivity to water stress. Studies that supplied additional solutes via stem infusion dramatically increased seed set in water-deficient plants. Collectively, these studies suggest that assimilate supply at flowering may regulate kernel set in water- deficient plants.

To further test this hypothesis Schussler and Westgate[4] designed parallel experiments which limited photosynthesis by either drought stress or shading. Drought stress was induced by withholding water to inhibit photosynthesis by 50% or 100% during flowering and early kernel growth. Shading was accomplished by using 50% shade cloth or a dark treatment to likewise inhibit photosynthesis by 50% or 100%. Effect on seed set is shown below:

Treatment	# of plants	Kernels/ear
Control	20	581± 14
Moderate Drought	9	304 ± 27
50% Shade	9	349 ± 50
Severe Drought	9	2 ± 2
Dark	9	0 ± 0

The moderate drought and 50% shade treatments reduced kernel set by a similar amount. The severe drought and dark treatments, which completely inhibited photosynthesis, also inhibited kernel development. A very high correlation was found between leaf photosynthesis at pollination and kernel set. The results of this experiment suggest that assimilate availability to the developing ear was the factor primarily responsible for kernel loss in water-deficient plants. Reduced kernel set was found to be primarily due to zygotic abortion. However, ovary dysfunction can also occur under low water potential, such that fertilization is inhibited.

References

[1]Bassetti, P., and M.E. Westgate. 1993a. Emergence, elongation, and senescence of maize silks. Crop Sci. 33:271-275.

[2]Bassetti, P., and M.E. Westgate. 1993. Water deficit affects receptivity of maize silks. Crop Sci. 33:279-282.

[3]Herrero, M.P., and R.R. Johnson. 1981. Drought stress and its effects on maize reproductive systems. Crop Sci. 21:105-110.

[4]Schussler, J.R., and M.E. Westgate. 1991. Kernel set of maize at low water potential: II. Sensitivity to reduced assimilates at pollination. Crop Sci. 31:1196-1203.