Corn Ear Growth in Response to Foliar Crop Protection Treatments

CORTEVA agriscience

CROP BULLETIN

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SUMMARY

- Abnormal ear growth can result when corn plants experience stress during ear development. Potential yield can be reduced significantly due to the reduction of harvestable kernels.
- Application of foliar treatments that include a nonionic surfactant prior to tasseling has been associated with arrested ear development.
- Corn at the V12 to V14 growth stage is particularly sensitive to exposure of nonionic surfactants.
- Variability in arrested ear response in research studies across locations suggests that environmental factors may also play a role in determining the risk of injury.
- Two hypotheses for arrested ear growth at approximately V14 are proposed, implicating the chemistry of adjuvants:
  - The first hypothesis is that ethylene oxide production as the nonionic surfactant breaks down causes ovule abortion and cell malformation.
  - The second hypothesis is that water washes the nonionic surfactant from the surface of the ear leaf to the developing ear and alters ear cellular integrity.

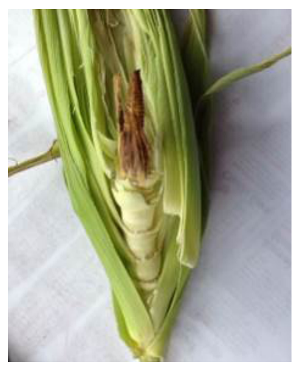
ABNORMAL EAR GROWTH

Abnormal ear growth can result when corn plants experience stress during ear development. The manner in which abnormal growth is manifested provides an indication of the timing and source of the plant stress. Defects in ear development are generally not corrected as the plant matures, so abnormalities resulting from plant stress will be visible past the point when the stress was present. Ear growth occurs at clearly defined stages of plant growth, so abnormalities in the ear serve as a record of stressful events during the growing season. One such abnormality is arrested ear development, sometimes referred to as blunt ear syndrome. Arrested ear development in corn is characterized by ears that have shorter cobs, fewer kernels per ear, and a stunted cob tip. In some cases, ears may have no kernel development.

The appearance of arrested ear development in corn was first reported in the 1980s and subsequently, was detected sporadically throughout corn growing areas of the country (Butzen, 2010). Causes of arrested ear development were not conclusively established. However, because the remainder of affected plants typically developed normally, experts theorized that the problem likely resulted from a single stress event rather than a cumulative or ongoing pattern of stress.

Application of foliar treatments that include a nonionic surfactant prior to tasseling has been associated with arrested ear development.

Figure 1. A severely arrested ear of corn with no kernels developed.



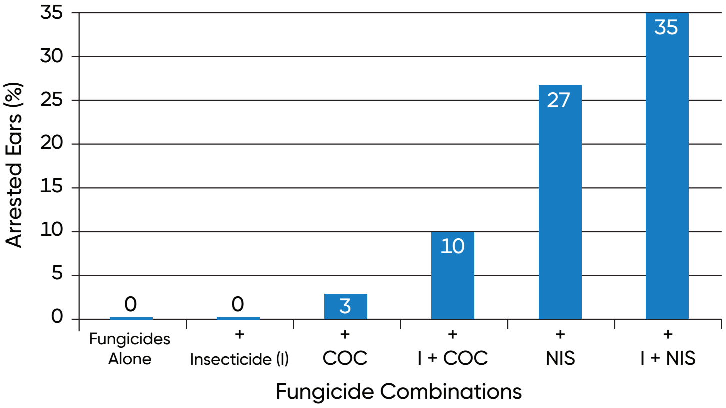
The appearance of arrested ear development increased as foliar fungicide applications to corn came into common practice around 2007 and 2008. At first, fungicides were implicated as the possible cause of the increased prevalence of arrested ears. However, as circumstances associated with arrested ear cases were examined and as researchers studied the formation of arrested ears in greater depth, it was found that in all cases, arrested ears formed when there was a surfactant, and in particular, a nonionic surfactant in the spray. The application of a foliar fungicide, applied according to the label and without added surfactant, did not cause arrested ears. Arrested ears were also found to be associated with foliar treatment at a very specific timing — around the V14 growth stage.

Figure 2. Injured ears and a normal ear from a field receiving a foliar treatment in 2008. Application was made prior to tassel emergence and included a surfactant.

NONIONIC SURFACTANTS APPLIED PRIOR TO TASSELING

Following initial reports in 2007 of arrested ear development in fields treated with foliar fungicides, researchers at Purdue University conducted a series of field tests on arrested ears and possible connections to foliar treatments. In the Purdue studies, researchers tested three fungicide active ingredients. Fungicides were applied in combination with an insecticide, with crop oil, with the same insecticide plus crop oil, with nonionic surfactant, and with insecticide plus nonionic surfactant. All treatments were applied at the V14 growth stage. Ears were harvested for detailed measurements at five days after treatment and at maturity.

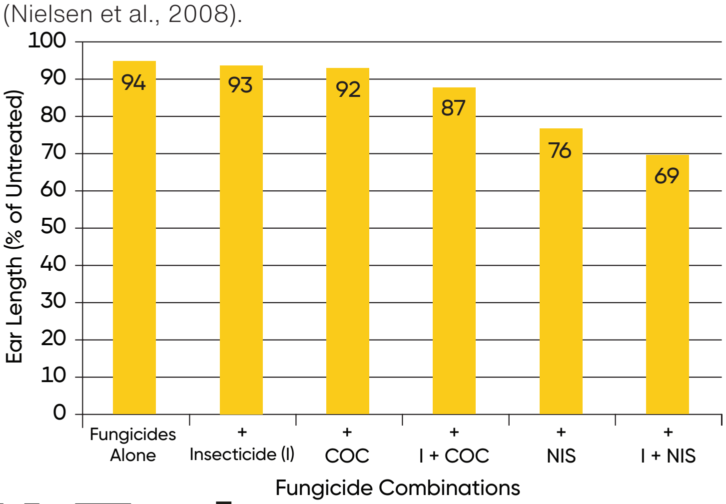
Figure 3. Corn ear response to foliar treatments applied alone or with crop oil concentrate or nonionic surfactant (Nielsen et al., 2008).



Results showed that the application of fungicide alone or in combination with an insecticide produced no arrested ears. Arrested ears were present in only those applications that contained an additional adjuvant. In these studies, arrested ears were much more strongly associated with nonionic surfactant than crop oil concentrate (Figure 3).

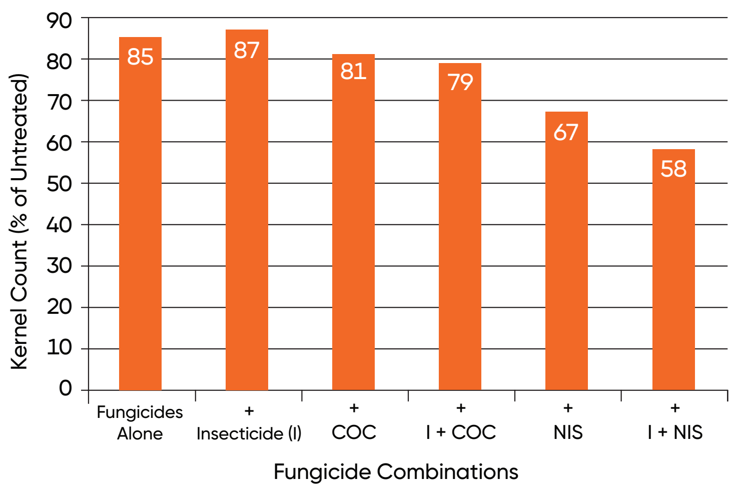
Researchers at Purdue also looked at harvestable ear length and kernel number as a function of foliar treatments. They showed that the application of nonionic surfactant applied at V14 shortened overall ear length relative to the untreated check (Figure 4).

Figure 4. Corn ear length associated with foliar treatments applied alone or with crop oil concentrate or nonionic surfactant (Nielsen et al., 2008).



Foliar treatments with a nonionic surfactant were associated with a reduction in the total number of harvestable kernels per ear (Figure 5). These results are of particular concern from an agronomic perspective because kernel number is the primary determinant of yield. Several published research studies have shown that kernel count per acre determines approximately 85% of the potential yield with the remaining 15% of the yield component being associated with individual kernel weight.

Figure 5. Corn kernel number associated with foliar treatments applied alone or with crop oil concentrate or nonionic surfactant (Nielsen et al., 2008).

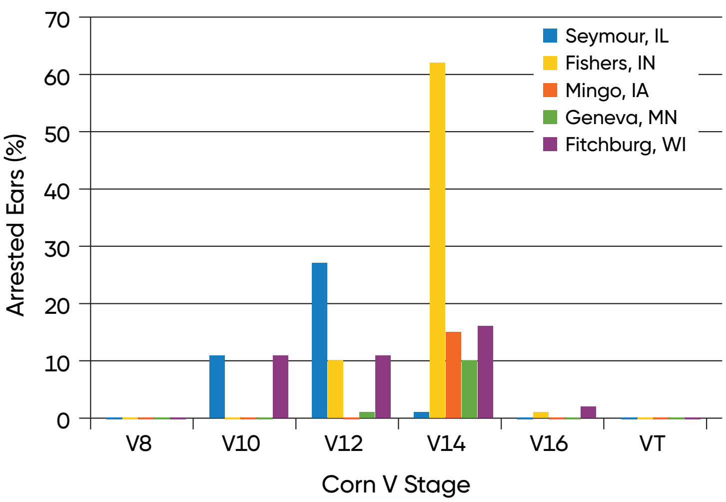


Further studies performed at multiple locations across the Midwestern U.S. produced similar results, showing that plants receiving a foliar treatment that included a surfactant at the V12 to V14 growth stage developed a higher percentage of arrested ears than non-treated plants (Schmitz et al., 2011). In these studies, a strobilurin fungicide, pyraclostrobin, was tested in conjunction with nonionic surfactant. Pyraclostrobin plus nonionic surfactant was applied to corn at V8, V10, V12, V14, V16, and VT. The highest percentage of arrested ears occurred when corn was treated with pyraclostrobin plus nonionic surfactant at V12 to V14.

Only corn that had been treated with nonionic surfactant showed arrested ears, and no arrested ears were observed in corn treated with just the fungicide. The results of this study very strongly suggest that nonionic surfactant or some component of the nonionic surfactant was responsible for the arrested ear response in corn.

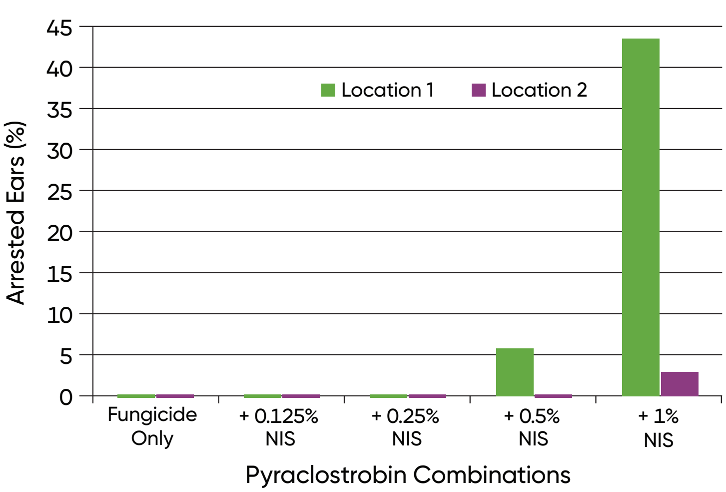
This study was conducted at five locations in the Midwestern U.S. Note that the maximum amount of arrested ears varied from a low of about 10% in Geneva, Minnesota, to a high of about 60% in Fishers, Indiana (Figure 6). The variability in results across locations suggests that corn growth stage at the time of treatment may not be the only critical factor in determining the formation of arrested ears; environmental factors may also play a role.

Figure 6. Corn ear response to pyraclostrobin plus nonionic surfactant applied at several corn growth stages at five locations in the Midwestern U.S. (Schmitz et al., 2011).



Results of these studies also showed that proportionality and severity of arrested ears were related to the amount of the nonionic surfactant applied at V14. The percentage of arrested ears increased as the amount of nonionic surfactant in the spray solution increased. Crop injury increased to as high as 45% in one of the two field test locations (Figure 7).

Figure 7. Corn ear response to pyraclostrobin plus several rates of nonionic surfactant applied at the V14 growth stage (Schmitz et al., 2011).

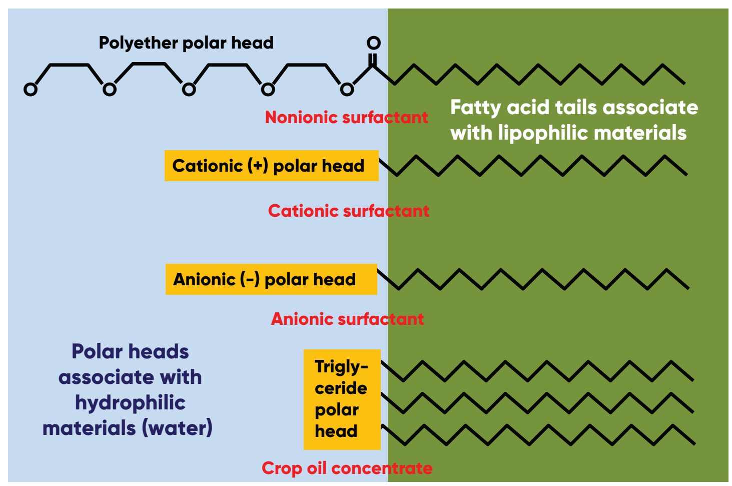


CHEMISTRY OF ADJUVANTS

Many spray mixtures contain adjuvants or emulsifiers in the final formulated product, and these product formulations have characteristics similar to those of nonionic surfactants. The purpose of an adjuvant is to help in the proper formulation, suspension, and application of an active ingredient with the intended purpose of getting more active ingredient to the proper location in the plant.

Adjuvants are designed to have a portion of the molecule that is more polar and thus, helps with dissolving or dispersing an ingredient in water. Adjuvants also contain a lipophilic tail that helps with the solution or dispersion of active ingredient in nonpolar materials, such as plant cuticles and membranes (Figure 8). Each adjuvant type has a specific set of physical properties that make it best suited for a particular use. For crop protection chemicals, nonionic surfactants are often the preferred adjuvant system because these molecules have no ionic charge that would limit penetration across a plant cuticle or membrane, yet they have sufficient water solubility and "combinability" with nonpolar molecules to help these molecules get to the active site in the plant.

Figure 8. Relevant chemical structures of surfactants and crop oil concentrates.

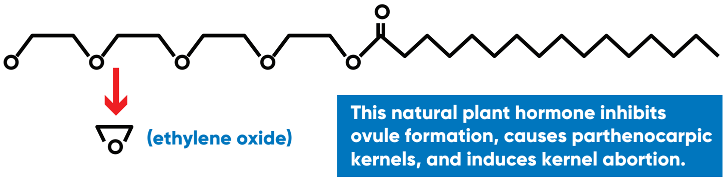


TWO HYPOTHESES FOR EAR ARRESTMENT AT V14

By examining the chemistry of the adjuvant, one can start to generate different hypotheses as to why a nonionic surfactant, applied to corn at about the V14 growth stage can cause corn to produce arrested ears.

The first hypothesis is related directly to the chemical structure of nonionic surfactants. The "water-loving" portion of a nonionic surfactant molecule contains a chain of ethoxy substituents linked together. The oxygen atom in each of the ethoxy units provides the necessary ingredient to improve the water solubility of the surfactant and any molecule that associates with this surfactant. Nonionic surfactants break down in the plant. One of the breakdown products is ethylene oxide (Figure 9). Ethylene oxide is a natural plant hormone that inhibits ovule formation, causes partheno-carpic kernels (kernels with no fertilized embryos), and induces kernel abortion. All of these kernel responses are consistent with arrested ears.

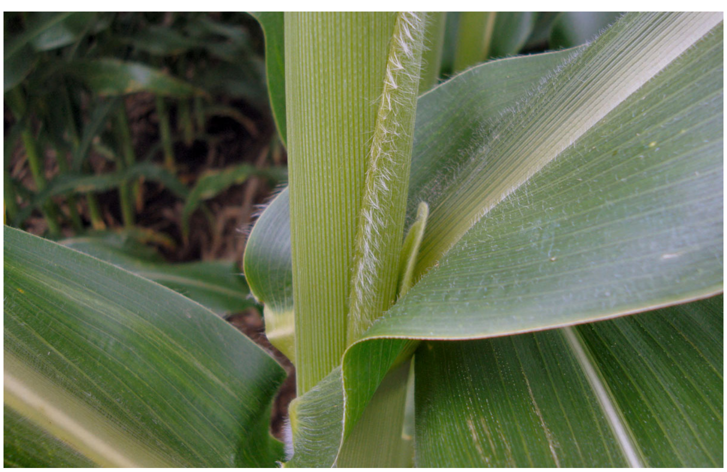
Figure 9. Ethylene oxide is one of the breakdown products of nonionic surfactant in plants.



The second hypothesis is that water washes the nonionic surfactant from the surface of the ear leaf to the developing ear and alters ear cellular integrity. Postemergence sprays of crop protection products place chemicals primarily on the upper surface of the leaf. As rains fall or as irrigation water is applied to the corn field, the architecture of corn leaves will force the water to drain toward the leaf midrib and down through the leaf axil (Figure 10). Any chemical that is washed from the broadly-treated leaf surface will concentrate in the water stream.

As this water stream reaches the leaf axil, the nonionic surfactant may have the right amount of lipophilicity to adhere to the cells that form the husks and tissues that will eventually become the harvested ear. At about V14, the ear shoot is physically emerging from behind the leaf sheath. At this growth stage, the cells critical for ovule, cob, and silk formation are directly in the path of this water stream and may extract some of the surfactant from the water stream. As the corn plant continues to grow beyond V14, the physical placement of these critical cells is above the water stream, no chemical is absorbed into these tissues, and subsequent ear growth is normal. For corn plants younger than about V14, the ear shoot is hidden within the leaf sheath, critical cells are protected as water flows above the developing ear, no chemical is absorbed in these sensitive tissues, and subsequent ear growth is normal.

Figure 10. Corn plant with ear shoot emerging from leaf axil.



Observations of ear growth reported in the research study at Purdue favors the hypothesis that nonionic surfactant moves into the ear cells. They reported in their summary that at V14, ovule formation along the entire ear was complete, silk elongation had started on those ovules at the butt end of the ear, and the tips of the ear shoots were just visible from behind the leaf axils (Figure 10). However, these observations do not disprove the hypothesis that ethylene oxide production as the nonionic surfactant breaks down causes ovule abortion and cell malformation. Researchers who conducted the study at Purdue looked at ear formation at 5 and 21 days after the foliar treatments. At five days after treatment, ovules at the upper end of the cob had begun to dissolve, and the tissue that eventually becomes the cob was physically damaged. Arrested ears could be identified at 21 days after treatment. If the application of a surfactant is going to produce arrested ears, it appears that this corn ear response starts very shortly after treatment.

Variability in the percentage of arrested ears across different plot locations throughout the Midwest may be attributable to differences in rainfall. If no rain fell after the materials were applied to the corn, the materials would remain on the leaf surface and would not move into the leaf axil. The lack of rainfall might explain the lack of ear response observed at some locations. However, for the locations that did see arrested ears, if rain fell at the proper time, the surfactant could be washed down the leaf midrib, into the leaf axil, and into the developing ear. The variability in these corn plant results across locations again favors the hypothesis that surfactant getting into the critical ear cells and destroying cellular integrity (the second hypothesis) is the more likely cause for arrested ears.

In summary, further research should be conducted to conclusively identify the cause of arrested ear development. However, two elements associated with the formation of arrested ears have been identified through studies conducted thus far. Arrested ear formation requires two factors to be present at the same time: (1) the presence of a surfactant, and (2) the application of such a treatment at a critical developmental stage, around V14, when the ear shoot has just emerged or will very soon emerge from behind the leaf sheath.

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