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Corn Diagnostics:

Ear Development Issues

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Crop problem diagnosis…

- Is both art and science…
  - **Science**, in that quite a bit is known about symptom identification, related conditions, and causes of many crop problems.
  - **Art**, in that expertise in crop diagnostics comes from experience as a crop detective.
    - Powers of observation.
    - Ability to integrate observations & evidence to arrive at a conclusion…

Image: mosingo.blogspot.com/

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A secret to crop diagnostics…

- If you understand what constitutes normal growth & development, then you are better equipped to diagnose the causes of abnormal growth & development.

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Meristems in plants are…

- Regions where cell division and differentiation occurs.
  - Synonymous with "growing points"
- Apical meristems in corn give rise to…
  - Leaf primoridia
  - Following initiation of the final leaf primordium, the tassel primordium is initiated at the apical meristem.

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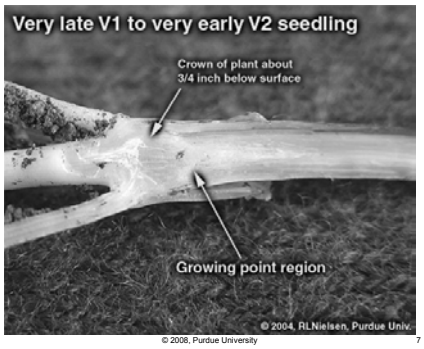
Apical meristem at early V2



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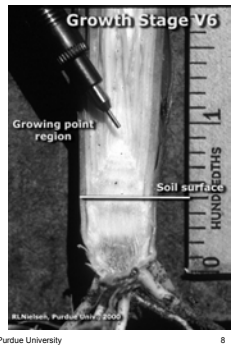
Apical meristem at V6

- Stalk elongation has elevated growing point above the surface of the soil by V6.

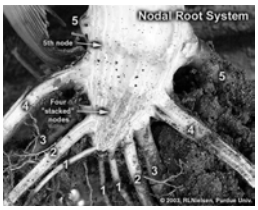


Ear development in corn

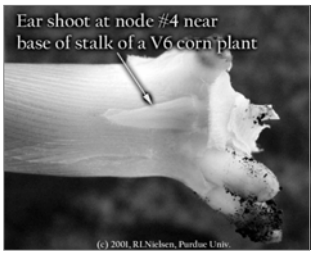
- Ear shoots initiate **acropetally** from axillary meristems, one per stalk node, in an alternating fashion, beginning at the lowermost stalk node and finishing at about the 7th stalk node below the tassel.
  - Roots also initiate from axillary meristems at the stalk nodes.

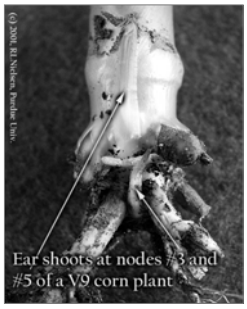
Ear shoot location…

- Ear shoots are located behind the base of their respective leaf sheaths and can be found even at the lowermost nodes below ground.
  - Remember, first 4 nodes are located in the triangle of pithy stalk tissue.
  - The #5 node is also usually below ground.



Ear shoots at lower nodes…





Ear shoot prioritization

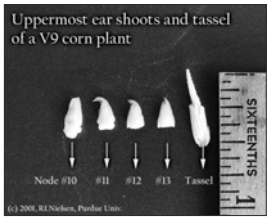
- Initially, ear shoots at lowermost stalk nodes are the longest simply because ear initiation is acropetal.
- With time, the upper one or two ear shoots assume priority over all the lower ones and become the harvestable ears.
  - Due to hormonal apical dominance & proximity to active photosynthetic area.

Tassel & upper ear are linked…

- The uppermost, harvestable, ear forms at about V5 at the same time that the tassel is initiated at the apical meristem (Lejeune & Bernier, 1996).
  - No further ears are initiated at upper nodes once the tassel is initiated (apical dominance).
  - For typical central Corn Belt hybrid maturities, the node # of the uppermost ear ranges from #11 through #14 on the stalk.

Not much to look at…

- By V9 (about thigh-high), the uppermost ear shoots and the tassel can be visually identified.
  - Fraction of an inch long.
  - Visible tassel branches.
  - Ears are mostly husk leaves at this point, yet cob length is about half-way complete.



Ear size determination…

- Maximum row number is determined no later than V8 (Strachan, 2004).
  - Influenced more by genetics than by environment.
- Maximum ovule number per row determined by at least V15, perhaps as early as V12 (Strachan, 2004).
  - Influenced less by genetics and more by environment.

Postlethwait & Nelson (1964)

- An elegant article on ear development.
  - *"An organism matures through a series of sequential steps ordered by the genetic complement."*
  - *"The succession of stages in development can be diverted by hormones, surgery, control of nutrition, and by light and temperature."*

CHARACTERIZATION OF DEVELOPMENT IN MAIZE THROUGH THE USE OF MUTANTS. I. THE POLYTYPIC (Pt) AND RAMOSA-1 (ra_1) MUTANTS[1]

S. N. Postlethwait and O. E. Nelson
Department of Botany and Plant Pathology, Purdue University, Lafayette, Indiana

Postlethwait & Nelson, 1964, Amer. J. Bot. 51(3):238-243.

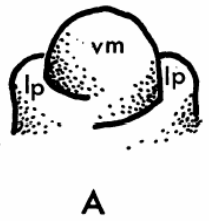
Postlethwait & Nelson (1964)

- *"There is no point at which a meristem can be considered to be irrevocably determined for a particular course of development. The meristem is, rather, a plastic system which must be programmed at successive intervals."*

Postlethwait & Nelson, 1964, Amer. J. Bot. 51(3):238-243.

Developmental "switch points"

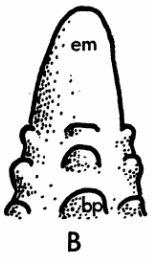
- The vegetative meristem (vm) is synonymous with the "growing point" region of the main stalk or the ear shank.
- The leaf primordia (lp) give rise to the leaves on the main stalk or the husk leaves on the ear shank.



Postlethwait & Nelson, 1964, Amer. J. Bot. 51(3):238-243.

Developmental "switch points"

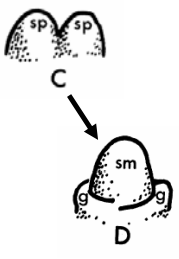
- Following initiation of the final husk leaf, the vegetative meristem transitions to become the ear meristem (em) with longitudinal rows of branch primordia (bp) that differentiate acropetally.
  - The branch primordia will differentiate into spikelet (eventual ovule) pairs, thus an 18-row hybrid will initiate 9 vertical rows of branch primordia.



Postlethwait & Nelson, 1964, Amer. J. Bot. 51(3):238-243.

Developmental "switch points"

- Each branch meristem differentiates into paired spikelet primordia (sp).
- Each individual spikelet meristem (sm) initiates two glume primordia (g).
  - A spikelet meristem eventually gives rise to an ovule and its attached silk.



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Paired row formation…

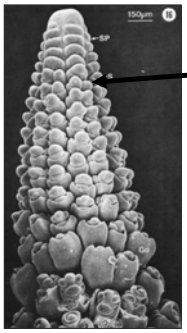


Image: Cheng et al., 1983 Amer. J. Bot., 70(3): 459-62.

- Scanning electron micrograph illustrating acropetal sequence of paired spikelet primordia differentiation from branch primordia.
  - Missing rows result from failure of the spikelet-pair primordia to differentiate into pairs of spikelets or from failure to develop at all.

Remember…

- The uppermost ear forms ~ V5 at the same time that the tassel is initiated (Lejeune & Bernier, 1996).
  - Maximum row number is determined no later than V8 (Strachan, 2004).
  - Maximum ovule number per row determined by at least V15, perhaps as early as V12 (Strachan, 2004).

Problems with ear development

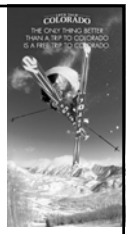
- More prevalent in recent years?
  - Beer cans, beer bottles, bar-bells, scrambled kernels, baby corn ears, bouquets, general stunted development, defective kernels, deformed development.
- Why?
  - Post-emerge chemical app's more prevalent?
  - Weather extremes more prevalent?
  - Today's genetics hyper-sensitive?

Blunt ear syndrome…

A "classical" beer can ear

- This anomaly can be described as an ear with a normal number of kernel rows at the base, but kernels per row and overall cob length abruptly truncate.
  - aka "beer can ear" symptom.
- In most cases, the remainder of the plant appears normal.

Blunt ear syndrome…



- First reported in commercial dent corn grown in Western Colorado in 1989 (Pearson & Golus, 1990).
- Farmers indicated that the problem had been observed for a number of years, but that the 1989 occurrence was the most severe with reported yield losses as great as 75 percent.

Blunt ear syndrome…

- A rash of reports occurred in 1992 throughout the Corn Belt and beyond.
- Scattered reports have occurred every year since.
  - Some years more prevalent than others.
  - Severity ranges from minor to nearly 100% of plants in a field.
  - Some claim repeatability of BES symptoms year to year in the same fields.

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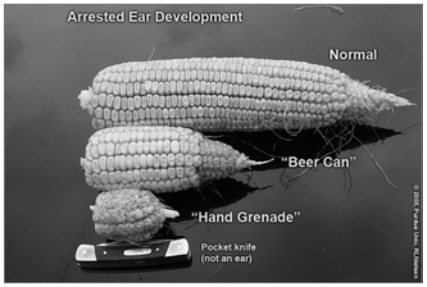
Blunt ear syndrome…

- Symptoms of BES encompass a range of severity.



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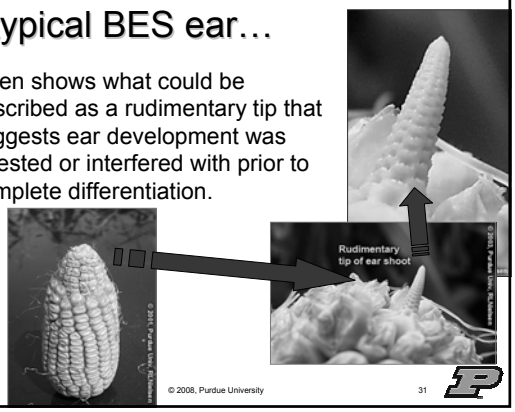
A typical BES ear…

- Often shows what could be described as a rudimentary tip that suggests ear development was arrested or interfered with prior to complete differentiation.



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Colorado research…

- Research into the causes of the phenomenon, eventually termed "blunt ear syndrome" or BES, continued at the Colorado State University experimental farm near Fruita, Colorado where the phenomenon appeared regularly every year.
  - *"BES symptoms develop soon after the ear tip differentiates, with ear shoots of leaf stage 12 plants showing initial symptoms and size differences."* (Fithian, 1999)

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Colorado research…

- Fithian (1999) reported that hybrid selection and lower plant density reduced the severity of BES.
  - Other management practices had no effect, including fertilizer zinc applications, fertilizer potassium and potassium plus sulfur applications, in-season deep tillage, and foliar applications of amino acids, growth regulators and an anti-transpirant.

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Others have postulated…

- High soil pH
- Unknown disease
  - Reminiscent of "crazy top" (Sclerophthora macrospora)
- Herbicide injury
- Early stress by ponded soils
- Chilling injury (my personal favorite)

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Support for chilling injury…

- Chilling injury prior to ear initiation can cause ear abortion in cold-sensitive inbreds(Lejeune & Bernier, 1996).
- Ear abortion due to chilling injury likely due to disrupted auxin:cytokinin ratio in apical shoot tissue (Lejeune et al, 1998).
  - Cold shock significantly decreased levels of certain cytokinins in the apical meristem & upper 3-4 axillary buds.

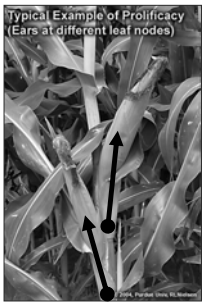
Nielsen's leap of faith…

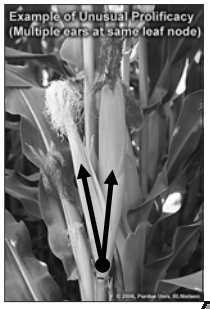
- Given the evidence that early chilling injury can cause complete ear abortion, could later-occurring cold shock similarly interfere with the normal completion of ear size determination?
  - Prior to ~ V12; especially certain hybrids?
  - Circumstantial evidence tends to support, but admittedly we could not mimic the symptom with growth chamber studies.

"Bouquets"

- Prolificacy usually is defined by multiple ears that develop at different leaf nodes.
  - The so-called "two-eared" hybrids.
- The latest anomaly is characterized by the development of multiple ears from nodes of the same ear shank.
  - Reports from Iowa, Illinois, Indiana, Michigan.
  - As much as 80% of plants affected.
  - Few common threads among affected fields.

Typical vs unusual prolificacy





Bouquets

- A "bouquet" of 3 ears originating from the same ear shank.
- Pollination of main ear often incomplete.

Bouquets

- Husks removed from "bouquet" revealing barren cobs.
  - Upper two of which resulted from persistent silk clipping by rootworm beetles.
  - Lower two simply silked too late.

Bouquets not unheard of…

- Bonnett, 1966
  - "In some varieties of corn, ear shoots are initiated in the axil of the husks."
- Nielsen, 1998-99
  - Described MESS symptom in Corny News articles based on limited number of reports received.

Image source: Bonnett, 1966 (Fig 9, G)

Apical dominance…

- Development of axillary buds on shank nodes is normally restricted due to apical dominance by the terminal ear.
- The ratio of auxin to cytokinin controls the degree of apical dominance (Klee & Estelle, 1991).
  - Auxins inhibit axillary bud growth, while cytokinins promote.

Nielsen's question…

- Do environmental "triggers" exist that can alter the auxin:cytokinin ratio in the ear shoot and "release" the development of axillary buds at nodes of the ear shank?
  - Post-emergence chemicals?
  - Cold shock? Heat shock? Wide temperature swings?
  - Other stresses to the primary ear?
    - Insect clipping of silks?

Nielsen's conjecture…

- Some of today's hybrids simply have a greater genetic propensity to develop these "bouquets".
- The multiple-ears develop in response to damage/stunting/poor kernel set on the primary ear and the possible consequent reduction in apical dominance.
- Multiple "triggers" exist that cause the damage/stunting/poor kernel set of the primary ear (thus, the lack of common threads).

Odd problem reported in 2007…

- Some fields treated with foliar fungicides in 2007 prior to tassel emergence (VT) suffered unusual levels of arrested ear development.
  - Cause and effect still being investigated, but circumstantial evidence certainly points to fungicides or other late-applied products (glyphosate, adjuvants, insecticides, foliar fertilizer).

Alleged fungicide injury…

- Ears from side-by-side plants, SW Indiana

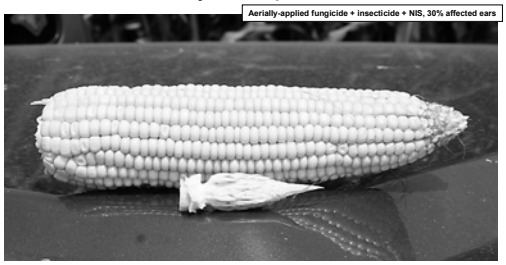
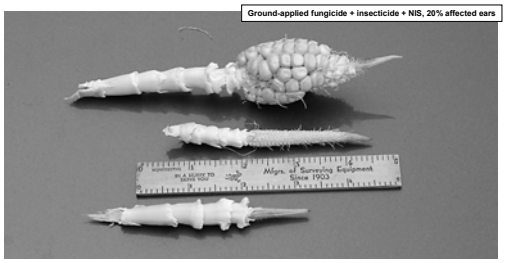


Image: RLNielsen, © Purdue Univ.

Alleged fungicide injury …

- Range of symptoms, WC Indiana



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Alleged fungicide injury …

- "Baby ear corn", WC Indiana

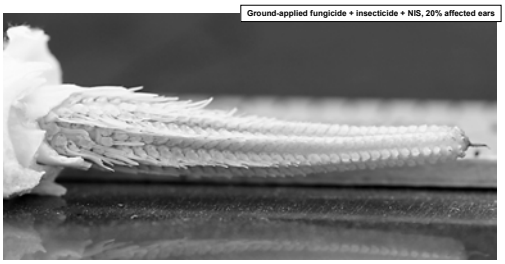

Image: RLNielsen, © Purdue Univ.

No clear answers…

- Though variable in severity and appearance, the symptomology of arrested ear development resembles that caused by plant growth regulators and thus might reflect the consequences of hormone-mediated responses to more than one type of stress…

Previous research…

- Indeed, Lejeune et al. (1998) suggested that alteration of the ratio of indole acetic acid (IAA) to cytokinin might be involved with the ear abortion they induced with chilling treatments in corn grown under controlled conditions.
- Grossmann & Retzlaff (1997) documented that the strobilurin fungicide kresoxim-methyl showed auxin-like properties in a series of bioassays and inhibited ethylene formation in treated leaf discs, intact plants, and water-stressed shoots of wheat

One possible cause…

- Hormonal signaling from the tassel to the yet developing ear, causing malformation or an extreme expression of apical dominance?
  - Could "over the top" pesticide applications during the week or two prior to silking alter the hormonal balance in the upper canopy or tassel?
    - Strobilurins may have hormone-like properties (Grossmann & Retzlaff, 1997) .

A simpler cause?

- The answer may simply be direct injury to the developing ear by contact with one or more spray additives…
  - Non-ionic surfactants
  - Crop oil concentrate
  - AMS
  - Drift retardants
  - Acidifiers

Image: http://www.istockphoto.com