CROP FOCUS

Corn Ear Injury Risk with Off-Label Glyphosate Applications

Injury Risk with Late Applications

- Applying glyphosate in glyphosate-resistant corn later than recommended according to product label guidelines can result in damaged ears and reduced yield
- Injury symptoms associated with late, off-label glyphosate applications are commonly referred to as bubble kernel or jumbled kernel syndrome.
  - Affected ears have some kernels that fail to develop properly.
  - Healthy kernels expand to fill the gaps left by the injured kernels, resulting in the ear having a jumbled appearance.
- Injury symptoms may also occur along field edges due to glyphosate treatment in adjacent soybean fields or spot treatment of weeds in fence rows .

Erratic kernel set of ear on left, caused by late application of glyphosate, compared to normal ear on right. Photo by Clyde Tiffany, DuPont Pioneer field agronomist, 2010.

Injury Mechanism

- Damage can occur when glyphosate is present in the developing ear at a time when it's susceptible to damage.
- Glyphosate is phloem-mobile in the plant and therefore tends to translocate to and accumulate in sink tissues such as developing shoots and roots (Hetherington et al., 1999).
- There is little to no metabolism of glyphosate molecules in the plant, meaning that the herbicide remains in its active form and can damage developing tissues that have inadequate expression of the resistant form of the target site (Feng et al., 2010).

Application Timing

- Roundup WeatherMax® can be applied over the top to corn with Roundup Ready® 2 Technology up to the V8 stage or until the corn reaches 30 inches tall, whichever comes first; according to label guidelines.
- For corn 30 to 48 inches tall, treatments can only be made using a ground applicator equipped with drop nozzles.
- **Always read and follow label guidelines.**

A dissected corn plant at the V9 growth stage showing developing ear shoots present at several nodes.

Photo courtesy of Iowa State University Extension.

Why are only some kernels affected?

- Many glyphosate-resistant hybrids are not homozygous for the trait – one parent (typically the female parent) is resistant and the other is not.
- The resulting F1 hybrid plants are all heterozygous for the trait, with one resistant and one susceptible allele. The resistant allele is dominant, so the hybrid plants are all glyphosate-resistant.
- The fertilized kernels on the plant represent the F2 generation. Since the F2 embryos are all the product of two heterozygous F1 parents, they will segregate out into 25% homozygous resistant, 50% heterozygous resistant, and 25% homozygous susceptible.
- This means that approximately 25% of the developing kernels on an ear are susceptible to damage if exposed to glyphosate.

		Parent 1 R	Parent 1 r
Parent 2	R	RR	Rr
Parent 2	r	Rr	rr

F2	
RR	25%
Rr	50%
rr	25%

Left – Ear showing translucent "bubble" kernels as a result of injury from a late glyphosate application. Right – An injured ear later in development where the affected kernels have shrunk and collapsed. Photos by Dan Emmert and Curt Hoffbeck, DuPont Pioneer field agronomists, 2010 (L) and 2014 (R).

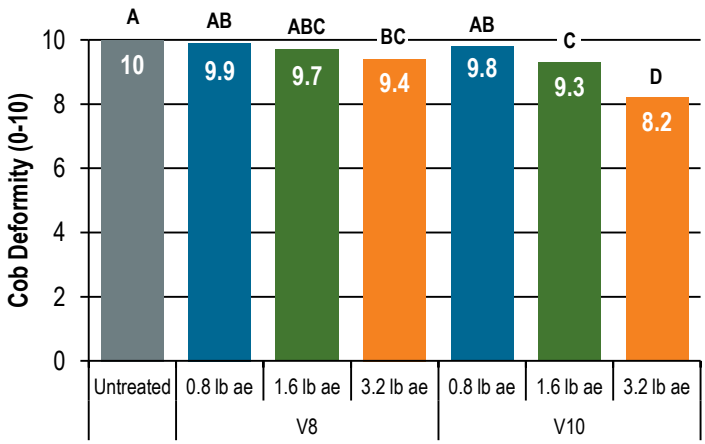
- In affected kernels, the germ will die while the seed coat and endosperm remain alive.
  - Initially, this results in the characteristic translucent "bubble" appearance.
  - As ear development progresses, the damaged kernels will appear hollow and eventually collapse.
  - The adjacent kernels expand to fill the gaps left by the injured kernels, resulting in the ear having a jumbled appearance.

Corn ears on the right showing the effects of late (off-label) application of glyphosate on corn. Two corn ears on the left are from an area in the same field that was not sprayed with a late application of glyphosate. Photo by Curt Hoffbeck, DuPont Pioneer field agronomist, 2014.

Factors that influence injury Risk

- The primary risk factor for corn ear injury with glyphosate is late, off-label applications.
- Injury risk also increases with glyphosate rate, meaning that sprayer overlap areas or plants along field edges exposed to high-rate spot treatments in fencerows can be affected.
- Injury symptoms can vary due to environmental conditions. A three-year study of off-label late and high-rate applications in Michigan and Ontario found injury resulting in yield loss at only about half of the locations (Mahoney et al., 2014).

Cob deformity associated with glyphosate treatment at two timings and three rates at five Ontario and Michigan locations in 2009-2011. Cob deformity visually rated on a 0-10 scale; 10 = no injury, 0 = completely deformed.

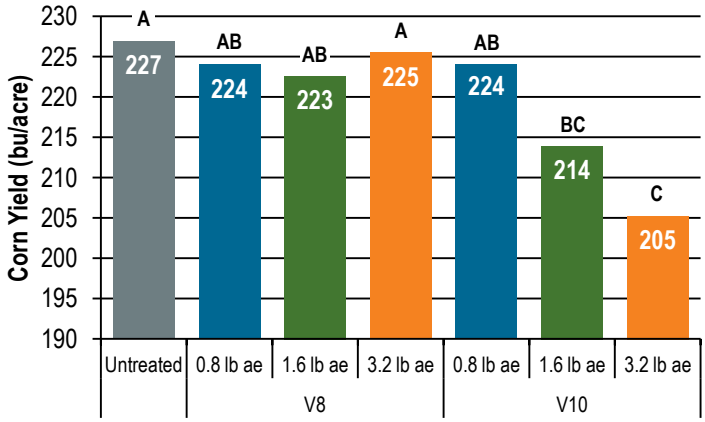


Means noted with the same letter are not significantly different according to Fisher's Protected LSD (P < 0.05)
0.8 lb ae/acre rate of glyphosate equivalent to 22 oz/acre of Roundup WeatherMax®

Yield Impact

- Since in most cases, 25% of kernels on an ear would be susceptible to glyphosate injury, theoretical yield loss could be up to 25%.
- Actual yield loss is likely to be less than this, although could still be significant.
- Kernels adjacent to those affected will expand into the gaps on the ear, partially compensating for the missing kernels.
- The greatest yield loss observed in a 3-yr field study was 10% on average across five locations with an above-labeled rate of glyphosate applied at the V10 stage

Corn yield associated with glyphosate treatment at two timings and three rates at five Ontario and Michigan locations in 2009-2011.



Means noted with the same letter are not significantly different according to Fisher's Protected LSD (P < 0.05)

Management Recommendations

- Always read and follow product label guidelines for timing and rate of glyphosate applications.
- Do not apply later than recommended and use drop nozzles when treating in larger corn.

Feng, P.C.C., C.A. CaJacob, S.J. Martino-Catt, R.E. Cerny, G.A. Elmore, G.R. Heck, J. Huang, W.M. Kruger, M. Malven, J.A. Miklos, and S.R. Padgette. 2010. Glyphosate-resistant crops: developing the next-generation products. *In* Nandula, V. K. (ed.) Glyphosate Resistance in Crops and Weeds. John Wiley and Sons, Inc., Hoboken, NJ.

Hetherington, P.R., T.L. Reynolds, G. Marshall, and R.C. Kirkwood. 1999. The absorption, translocation and distribution of the herbicide glyphosate in maize expressing the CP-4 transgene. J. of Exp. Bot. 50:1567-1576.

Mahoney, K.J., Nurse, R.E., Everman, W.J., Sprague, C.L. and Sikkema, P.H. (2014) Tolerance of Corn (*Zea mays* L.) to Early and Late Glyphosate Applications. *American Journal of Plant Sciences*, **5**, 2748-2754. http://dx.doi.org/10.4236/ajps.2014.518291

Nielsen, RL. 2013. Jumbled kernel symptom in corn & late glyphosate applications. Purdue Univ. http://www.ppdl.purdue.edu/PPDL/weeklypics/12-13-10.html