

# Management of Herbicide-Resistant Corn Volunteers in Corn and Soybean

Mandeep Singh, Graduate Research Assistant, University of Nebraska–Lincoln

Amit J. Jhala, Professor/Nebraska Extension Weed Management Specialist

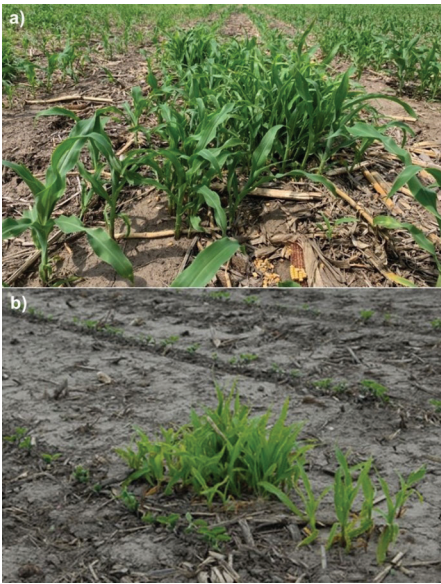


Fig. 1. (a) Cornfield infested with corn volunteers in a field near Clay Center, Nebraska (b) A clump of corn, which is more competitive than an individual volunteer corn plant.

## Introduction

Volunteer corn refers to corn that grows from kernels or ears that were not harvested or were lost from the combine during the previous season (Figure 1). Often, not all of the corn kernels and ears get harvested during the season and may fall on to the ground due to mechanical harvest problems, insect damage, or natural events such as late-season windstorms. Despite advancements in mechanical harvesting, some level of harvest loss still occurs.

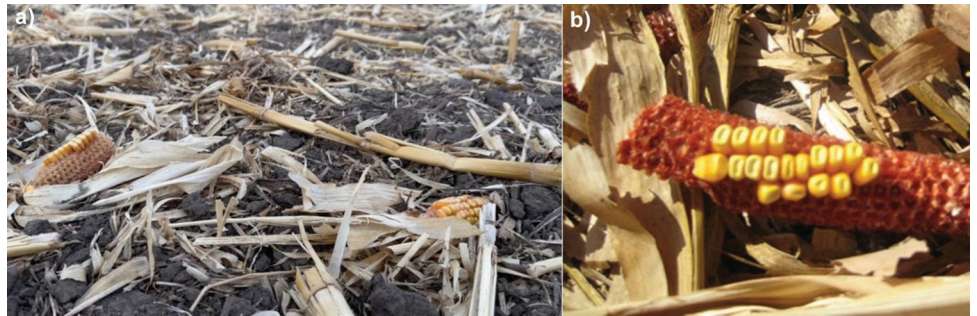


Fig 2. (a and b) Dropped or lost corn kernels from the combine. These kernels overwinter and germinate in the spring as volunteer corn and compete with crops grown in rotation.

## Objective

Provide recommendations for management of corn volunteers in corn or soybean grown in rotation.

## Harvest Loss in Corn

A recent University of Nebraska–Lincoln (UNL) study that included post-harvest sampling of corn harvest loss from growers' fields that yielded between 128 and 290 bushels/acre revealed that about 2 to 3 bu/ac of corn kernels were lost in south-central Nebraska in 2020 and 2021 (Stephens et al., 2023; Figure 2). These kernels can overwinter and emerge as corn volunteers the following season. Alternatively, in some cases, corn needs to be replanted because of a failed crop stand due to low emergence caused by cold and wet weather, poor water drainage, drought, or hailstorms during the early crop season (Figure 3). In such cases, plants remaining from

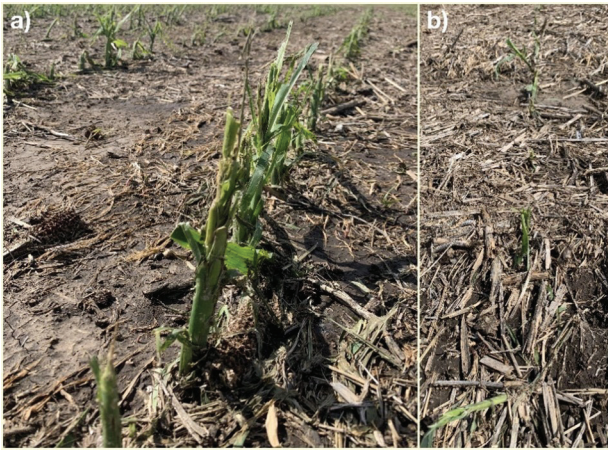


Fig. 3 (a and b). Cornfields damaged by a hailstorm in early June 2022 in south central Nebraska, with replanting required in many fields (b).

a failed/poor corn stand serve as corn volunteers, which can be problematic in corn-based cropping systems in Nebraska and other Midwestern states.

### Volunteer Corn: A Problematic Weed

Volunteer corn not only attracts corn rootworms, but is a very competitive weed with the next crop grown in rotation. This, in turn, can cause significant yield losses. Yield loss from volunteer corn infestation depends on the density, clump size, and crop grown in rotation. However, volunteer corn clumps are usually more aggressive than individual plants irrespective of crop type (Table 1). Research studies by UNL found that if 3,500 plants/ac of volunteer corn populations are left uncontrolled, they can cause a 2% yield loss in corn and a 10% yield loss in soybean. If this density is doubled to 7,000 plants/ac, yield loss can increase to 5% in corn and 27% in soybean (Rees and Jhala, 2018). Therefore, it is very important to control volunteer corn to prevent yield reduction.

### Factors Affecting Germination of Volunteer Corn

Volunteer corn seeds from the previous season start germinating when the weather begins warming in the spring. A UNL study conducted in 2012–13 found that volunteer corn can germinate optimally well (84–97%) in a wide range of day/night temperature; 59/50 to 108.5/86°F (Chahal, 2014). The optimum pH for germination was found to be slightly acidic at 5–6 pH, resulting in 87–88% germination. The germination decreased with more acidic (47–68% at 3–4 pH), neutral (78% at 7 pH), or alkaline (62–74% at 8–9 pH) pH levels compared with the optimal. Moreover, volunteer corn seeds were found to be non-photoblastic, meaning that they will germinate regardless of whether they are exposed to

light (Chahal, 2014). This indicates that shading due to crop canopy or residue will have little impact on volunteer corn germination.

## Management

### Chemical Control

The herbicide options for controlling herbicide-resistant corn volunteers depend on the specific herbicide-resistant trait(s) that they possess. Additionally, the choice of herbicide(s) depends on the type of crop that the volunteer corn has infested (Table 2). Soybean has generally more in-season herbicide options, because of the selectivity of soybean to graminicides such as quizalofop (e.g., Assure<sup>®</sup> II), fluazifop (e.g., Fusilade<sup>®</sup> DX), fluazifop + fenoxaprop (e.g., Fusion<sup>®</sup>), sethoxydim (e.g., Poast<sup>®</sup>), and clethodim (e.g., Select Max<sup>®</sup>). Similarly, volunteer corn with no herbicide-resistant traits (i.e., conventional corn) generally has more herbicide options available to control it. Typically, non-selective herbicides such as glyphosate (e.g., Roundup<sup>®</sup>) and glufosinate (e.g., Liberty<sup>®</sup>) can effectively control conventional corn volunteers; however, these herbicides will not be effective for control of glyphosate/glufosinate-resistant corn volunteers if the hybrid planted was stack resistant (e.g., Roundup Ready<sup>®</sup>/LibertyLink<sup>®</sup>).

### Volunteer Corn Control in Soybean

- Glufosinate (Liberty) will suppress/control volunteer corn unless it has the LibertyLink (LL) trait. It can only be applied to soybean that has the LL or stacked Roundup Ready<sup>®</sup> and LibertyLink (RR/LL) trait, such as Enlist<sup>®</sup> soybean or XtendFlex<sup>®</sup> soybean.
- Glufosinate (Liberty) can be applied at 32–43 fl oz/ac. One additional cultivation can be made 7–10 days after application, or two applications of Liberty (with a second application 10–21 days after the first application) can be made to control corn volunteers that form dense clumps.
- Glyphosate (Roundup) will typically control volunteer corn unless it has the Roundup Ready (RR) trait. It can only be used in soybean cultivars tolerant to glyphosate.
- Glyphosate (Roundup PowerMAX<sup>®</sup>) application rates for controlling volunteer corn are 22 fl oz/ac for 0–6 inches, 26 fl oz/ac for 6–12 inches, and 32 fl oz/ac for 12–20 inches tall volunteer corn.

Several graminicides that can control volunteer corn irrespective of the herbicide-resistant trait (RR, LL, or RR/LL) are registered in soybean. The rate of these herbicides is volunteer corn stage-dependent, and they are often applied with adjuvants (Table 2).

**Table 1: Yield loss reported due to volunteer corn infestation in corn and soybean.**

Crop	Volunteer corn density	Yield Loss	References
Corn	32,376 plants/ac	22–23%	Marquardt et al., (2012b)
	2,024–48,564 plants/ac	3–34%	Piasecki and Rizzardi, (2019)
	2,024–48,564 clumps/ac (7 plants/clump)	6–42%	Piasecki and Rizzardi, (2019)
Corn (replanting situation)	2,024–4,047, 8,094–16,188, and 16,188–32,376 plants/ac	7–20, 44–58, and 59–81%	Shauck and Smeda, (2014)
	8,094 plants/ac	19%	Terry et al., (2012)
	12,141–32,376 plants/ac	Approximately 882 lbs/ac	Steckel et al., (2009)
Soybean	1,214–2,024 plants/ac	9–10%	Alms et al., (2016); Marquardt et al., (2012a)
	3,500–7,000 plants/ac	10–27%	Wilson et al., (2010)
	2,024–64,752 plants/ac	10–41%	Marquardt et al., (2012a)
	One clump/94 inches row length at 1,616–2,152 clumps/ac	31%	Andersen et al., (1982)
	1–10 plants/clump at 2,152 clumps/ac	6–22%	Beckett and Stoller, (1988)

**Table 2: Herbicide options for controlling volunteer corn in corn and soybean.**

Herbicide (Trade Name)	Active ingredient	Rate (fl oz/ac)	Volunteer corn size (inches) for application	Adjuvants*	Crop for her- bicide use	Traits of volun- teer corn that can be suppressed/ controlled**
<b>Non-selective herbicides</b>						
Liberty	Glufosinate	32–43	-	AMS 1.5–3 lb/ac	Corn and Soybean (LL, RR/ LL)	CC, RR
Roundup PowerMAX†	Glyphosate	22–32	0–20	AMS 8–17 lb/100 gal	Corn and Soybean (RR, RR/LL)	CC, LL
<b>Graminicides</b>						
Assure II	Quizalofop	4	0–12	NIS 0.25% v/v or COC 1% v/v***	Corn (Enlist† corn only)† and Soybean	CC, RR, LL, RR/LL
		5	12–18			
		8	18–30			
Fusilade DX	Fluazifop	4	0–12	COC 0.25% v/v	Soybean	CC, RR, LL, RR/LL
		6	12–24			
Fusion	Fluazifop + Fenoxaprop	4	0–12	COC 0.25% v/v NIS 0.25% v/v or COC 0.5% v/v	Soybean	CC, RR, LL, RR/LL
		6	12–24			
Poast	Sethoxydim	12	0–12	AMS 2.5 lb/ac	Soybean	CC, RR, LL, RR/LL, EC
Select Max	Clethodim	6	0–12	AMS 8–17 lb/100 gal	Soybean	CC, RR, LL, RR/LL, EC
		9	12–24			
		12	24–36			

\*AMS, ammonium sulfate; COC, crop oil concentrate; NIS, non-ionic surfactant.

\*\*CC, conventional corn; RR, Roundup Ready; LL, LibertyLink; RR/LL, a stacked trait with both Roundup Ready and LibertyLink; EC, Enlist corn.

\*\*\*%v/v, percent volume/volume.

†For Enlist corn, Assure II is labeled at rates of 5–12 fl oz/ac.

For effective and economical control, it is better to apply herbicides when volunteer corn is less than 12 inches in height; otherwise, higher rates of herbicides may be required for taller volunteer corn, which can increase herbicide cost. UNL research conducted at South Central Agricultural Laboratory near Clay Center, Nebraska found that quizalofop (Assure II), fluazifop (Fusilade DX), fluazifop + fenoxaprop (Fusion), and clethodim (Select Max) provided  $\geq 93\%$  control of 10- to 12-inch-tall glyphosate-resistant volunteer corn in LibertyLink soybean 15 days after application (DAA) (Chahal and Jhala, 2015). However, the control with sethoxydim (Poast) was lower (76%) in the same experiment.

### Herbicide Antagonism

Graminicides such as quizalofop, sethoxydim, clethodim, and others are commonly mixed with broadleaf herbicides such as dicamba and 2,4-D, especially when applied in soybean. This can often result in reduced grass control i.e. reduced control of volunteer corn in soybean due to antagonism from the broadleaf herbicides. Antagonism can be minimized or avoided by using a higher labeled rate of graminicide, or by applying graminicide  $\geq 1$  day before or  $\geq 7$  days after broadleaf herbicide application. For example, Assure II (quizalofop) is labelled at 4–8 fl oz/ac when applied alone for controlling 6–30 inches volunteer corn as compared with 8–12 fl oz/ac when tank-mixed with broadleaf herbicide to minimize/avoid potential antagonism (Anonymous, 2021).

### Volunteer Corn Control in Corn

Compared to soybean, there are fewer herbicide options for volunteer corn control in a corn crop.

- If the volunteer corn is conventional corn with no herbicide-resistant trait, and this year's corn crop has the Roundup Ready trait, glyphosate (Roundup) is the better option due to: (1) volunteer corn's higher sensitivity to glyphosate; and (2) the lack of planting interval restriction under corn replant situations.
- When corn needs to be replanted and the existing failed stand has stacked resistance (Roundup Ready/LibertyLink), clethodim (Select Max) can be used. However, it is important to note that a waiting period of 6 days is required before corn can be replanted. For corn replanting, Select Max should be used at 6 fl oz/ac + 2.5 to 4 lb/ac ammonium sulfate. If growers want to avoid the 6-day waiting interval associated with Select Max, paraquat (e.g., Gramoxone) + metribuzin (e.g., TriCor, Sencor) is an alternative option to control Roundup Ready/LibertyLink corn in replanting situations.



Fig. 4. Glufosinate (Liberty) applied at 32 fl oz/ac controlled volunteer corn in LibertyLink soybean in an experiment conducted in 2013 at UNL's South Central Agricultural Laboratory near Clay Center, Nebraska.

- Research at Purdue University and Ohio State University found that V1–V3 volunteer corn can be effectively controlled with paraquat (Gramoxone) at 2–3 pt/ac + dry metribuzin (TriCor) at 4–6 oz/ac applied at replanting (Terry et al. 2012). However, it is worth considering that paraquat applied without metribuzin is less effective, and that volunteer corn beyond the V3 stage is more challenging to control (Terry et al., 2012; Zimmer and Johnson, 2020). When applying contact herbicides such as glufosinate (Liberty) and paraquat (Gramoxone), it is advised to spray when volunteer corn plants are greater than 4 inches, perhaps 5–12 inches tall. If the volunteer corn plants are too small, the growing point will be belowground, and the plant may recover from the application of contact herbicides (Anderson, 2021).
- If the corn from the previous year had the Roundup Ready trait, then during the following year LibertyLink or Roundup Ready/LibertyLink corn can be planted, and two applications of Liberty at 32–43 fl oz/ac can be made to control RR corn volunteers (Figure 4).
- If the corn from the previous year had both RR/LL traits, then Enlist corn can be planted, and herbicides from the aryloxyphenoxypropionate (FOPs) family of Acetyl CoA Carboxylase (ACCCase) inhibitors can be used to control glyphosate/glufosinate-resistant (RR/LL) volunteer corn, because Enlist corn is tolerant to aryloxyphenoxypropionates (FOPs), 2,4-D choline, glyphosate, and glufosinate.
- Assure II (quizalofop) is labeled for control of volunteer corn in Enlist corn. Assure II should be applied with crop oil concentrate (COC) 1% volume/volume (% v/v) or non-ionic surfactant (NIS) 0.25% v/v at 5–12 fl oz/ac for selective control of glyphosate/glufosinate-resistant (Roundup Ready/LibertyLink) volunteer corn in Enlist corn (Figure 5). Assure II should be applied to the V2–V6 stage of Enlist corn.
- Assure II can be applied a maximum of two times with a cumulative total of 12 fl oz/ac per crop year. In the case of



Fig. 5. Dead glyphosate/glufosinate-resistant (Roundup Ready/Liberty Link) volunteer corn plants 14 days after application of 6 fl oz/ac Assure II in Enlist corn in a study conducted at South Central Agricultural Laboratory near Clay Center, Nebraska in 2021.

split applications, two applications should be separated by > 7 days to allow the volunteer corn to regrow.

- The applicator is always required to maintain a downwind buffer of at least 36 feet between the last treated row and the closest downwind edge (the direction in which the wind is blowing) of the field. Assure II can be applied when winds are blowing at less than 15 mph speed. However, the optimal wind speed for application is between 3 and 10 mph.
- Do not apply Assure II to any type of corn other than Enlist corn, as this will lead to severe crop injury.
- A research study by UNL at South Central Agricultural Laboratory near Clay Center, Nebraska in 2018–19 found that 4 fl oz/ac of Assure II provided 99% control (28 DAA) when applied to 12 inches of glyphosate/glufosinate-resistant (Roundup Ready/LibertyLink) corn volunteers in Enlist corn (Striegel et al., 2020).

If Enlist corn was planted the previous year, there is no selective herbicide that can control Enlist corn volunteers during the following year in continuous corn. Therefore, it is best to plant soybean the following year, and to use a cyclohexanedione (“Dim”) herbicide, such as clethodim (Select Max) or sethoxydim (Poast). Otherwise, if the grower decides to plant corn again, the only option to control Enlist corn volunteers in corn is through tillage, such as by using an inter-row cultivator.

### Strategic Tillage

Strategic tillage is usually a reliable option, especially for pre-plant control of corn volunteers or failed corn stands under replant conditions. Tillage should be intense enough to uproot corn plants along with their roots to prevent re-sprouting. Tillage may increase the soil-to-seed contact of corn seeds from deeper soil layers by bringing them to the top, which can promote delayed emergence of



Fig. 6. Volunteer corn in a cornfield in south-central Nebraska. A wind-storm the previous year resulted in lodging and loss of corn kernels.

corn volunteers. This can happen if the field is tilled before volunteer corn germination. In this case, a two-pass tillage program may be required, where the second pass occurs after volunteer corn emergence. Therefore, tillage might be a better option for organic crop growers who do not have an in-season herbicide option to control corn volunteers (Anderson, 2021). However, tillage may not be feasible for growers who have (1) adopted no-till as a long-term management practice; (2) adopted cover crops; (3) highly erodible soils; or (4) dryland fields where conserving soil water is extremely important (e.g., western Nebraska) (Anderson, 2021).

For in-season inter-row cultivation in soybean, it is preferred to cultivate around the V5–V6 growth stage of the volunteer corn. This is because the corn growing point does not emerge from the ground until the V6 stage, and any cultivation before that may lead to regrowth, and hence, may require additional cultivation, especially in the case of shallow cultivation (Knezevic, 2007)

### Crop Rotation

Crop rotation is especially useful for corn-on-corn production fields with Enlist corn planted in the previous season, in cases of heavy pressure from volunteer corn populations, or when there is storm damage during the late crop season (Figure 6). Rotating to soybean or other broadleaf crops provides flexibility in using graminicides that are registered for those crops. In addition, because no selective post-emergence herbicides exist for control of Enlist corn volunteers in corn, rotating to soybean is a much more viable option.

### Take-Home Messages

- Volunteer corn is a competitive weed, with the potential to cause significant yield loss in the crop grown in rotation; therefore, a well-thought-out and executed plan is critical for successful management.

- Volunteer corn management with herbicides is dependent upon herbicide resistance trait(s) that is/are present in volunteer corn and the crop grown in rotation. Therefore, herbicides should be chosen carefully to avoid control failures and crop injury.
- Strategic tillage is usually a reliable mechanical control option. However, to avoid delayed volunteer corn emergence or regrowth, special consideration should be given to the emergence timing and growth stage of volunteer corn.

#### DISCLAIMER:

The trade names of the herbicides are given for information and clarity, and do not imply endorsement or exclusion of any product, nor does it warrant/guarantee the product standards. Always refer to the most current herbicide label for up-to-date information on herbicide use, application rates, precautions, and restrictions, and always read the herbicide label before use, and then carefully follow the label during mixing and application.

#### ACKNOWLEDGMENTS

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