

Cover Crop Termination

Herbicide Application BMPs



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Developing a herbicide program for terminating cover crops requires careful consideration of cover crop and cash crop management goals. In this factsheet series, we share management tips for terminating cover crops in no-till corn and soybean production systems, where cover crops are left on the surface as a mulch.

1. Choose a Base Herbicide Program

Herbicide programs for cover crop termination typically start with either glyphosate or paraquat. Both herbicides have broad-spectrum activity that can provide control of grass and broadleaf cover crop species under the right conditions. However, glyphosate is a systemic herbicide, and paraquat is a contact herbicide, which requires different management practices (Table 1). Using full recommended rates and selecting the correct nozzle, carrier volume, and additives for these herbicides is necessary to ensure adequate coverage and uptake by cover crops.

Table 1. Herbicide application best management practices (BMPs) for glyphosate- and paraquat-based programs

Application considerations	Glyphosate	Paraquat
Nozzle Selection	fine/medium to coarse droplets	fine/medium droplets only
Carrier Volume	>10 gpa (gallons per acre)	>15 gpa minimum 20-40 gpa in dense canopies
Water Conditioner	ammonium sulfate (8.5 lb/100 gal)	optional
Adjuvants	NIS (2 pt/100 gal water) unless a full adjuvant load is included	crop oil concentrate (COC) (1 gal/100 gal water)
Tank-mix antagonism	atrazine and metribuzin 28% nitrogen carrier	--

2. Watch the Weather

Table 2: Weather factors that influence the efficacy of glyphosate and other foliar-active herbicides

Weather Factors	Influence on Herbicide Activity
Day/Night Temperatures	Weed control efficacy is generally greatest between 65 and 85°F. Target applications to a three-day period where daytime temperatures exceed 50-55°F, and night temperatures are close to or above 40°F.
Temperature Fluctuations	Wide temperature fluctuations (> 15°F) in the 1-2 days prior to application may reduce activity and control.
Relative Humidity	High humidity increases glyphosate absorption into the leaves.
Soil Moisture	Absorption, uptake and translocation increase when soil moisture is adequate for plant growth. Dry periods prior to or during termination may result in less adequate control
Dew	Though glyphosate absorption increases when leaves are well hydrated, excessive dew can decrease the rate of uptake.



2. Watch the Weather (con't.)

Spring temperatures (day/night) likely have the greatest impact on glyphosate efficacy for cover crop termination (Table 2). While we recommend using glyphosate-based programs when terminating cover crop stands that contain grass species, it's important to know that glyphosate activity in plants can be slow, particularly in cool springs. Glyphosate generally takes longer (7-10 days) than paraquat for complete kill. If killing winter cereal cover crops before stem elongation is the management goal, waiting for a warm stretch of weather in early spring (>55 F) is a good strategy. During this time, grasses will be greening up and resuming growth, which will optimize the efficacy of glyphosate applications.

3. Consider Tank-Mix Interactions

Herbicide tank mix partners can influence the efficacy of glyphosate and paraquat (Table 1). Atrazine and metribuzin are known to antagonize glyphosate activity, which can potentially reduce control levels under some scenarios. In comparison, atrazine and metribuzin are known to improve, or enhance, the activity of paraquat. In many cases, antagonistic or synergistic effects have only small effects on control levels (Fig 1). But understanding these interactions can help improve cover crop termination efficacy under more challenging scenarios, such as suboptimal weather conditions or for tough-to-control cover crop species.

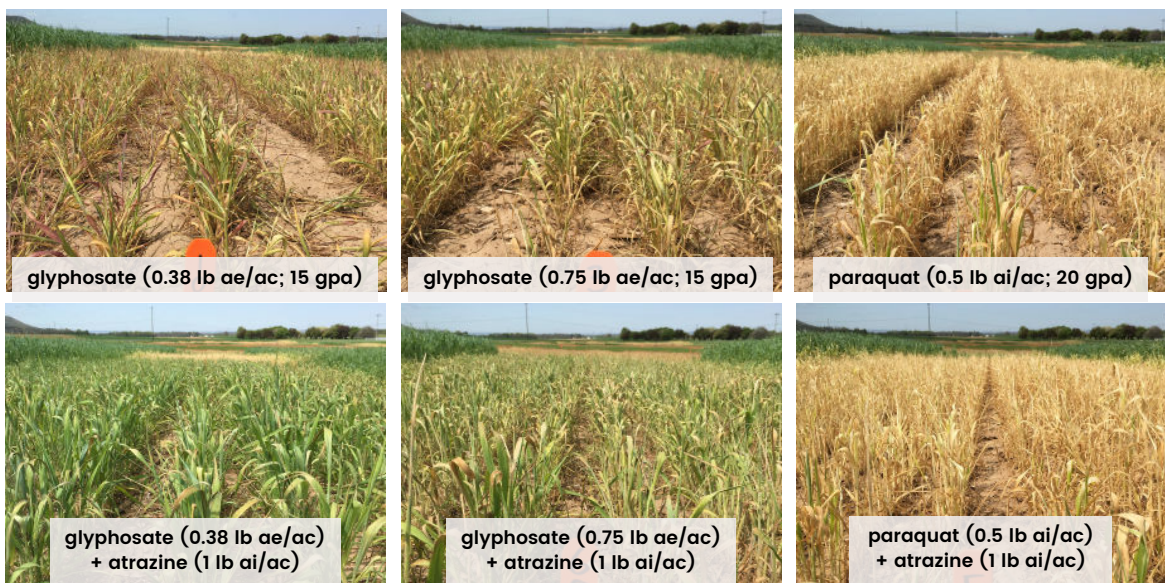


Fig 1. Effect of glyphosate and paraquat with and without atrazine on control of cereal rye seven days after termination (7 DAT) when targeting the cereal rye boot stage. (Penn State Field Trials, 2021-22; Wallace).

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How to Select Herbicide Programs



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When terminating cover crops, consider the need for additional tank-mix partners in glyphosate- or paraquat-based burndown programs to control emerged weed populations, as well as the grass, legume and/or brassica cover crop species. We recommend three keys for developing cover crop burndown programs:

1. Know which weeds are present in your cover crop stand.

A well-established cover crop stand suppresses many fall- and spring-emerging weed species. But some species, such as glyphosate-resistant horseweed, may also be present within cover crop stands. Consequently, it may be necessary to adjust your cover crop burndown program or application timing to achieve effective weed control.

2. Tank-mix synthetic auxins for legumes and brassicas.

Though both glyphosate and paraquat have activity on broadleaf cover crops, Mid-Atlantic field trials consistently show that including dicamba or 2,4-D LVE in the tank improves control of legumes and brassicas (Table 4 - other side).

3. Understand pre-plant application restrictions for tank-mix partners.

Make sure to check herbicide labels to understand restrictions in both corn and soybeans (Table 3). For example, cover crop termination timing and soybean seed trait technology (i.e., Enlist 3, Xtend, XtendFlex, LibertyLink) will determine which herbicide formulations and rates can be used.

Table 3: Herbicide restrictions and BMPs in cover crop termination scenarios within field crops

Tank Mix Partners	Herbicide Group	Restrictions and BMPs (Always consult herbicide labels)
Sharpen (saflufenacil)	14	Apply 0-14 days pre-plant in corn at 1-3 oz/ac and in soybean at 1 oz/ac. Add MSO (1% v/v) + AMS.
2,4-D LVE	4	Apply >7 days pre-plant in corn at 0.5-1.0 lb ae/ac.
dicamba	4	Apply >7 days pre-plant in corn at 0.5-1.0 lb ae/ac.
clethodim	1	Apply SelectMax >6 days pre-plant at 6 fl oz in corn and pre-emergence up to 8 fl oz in soybean. Restrictions and adjuvants will differ for other clethodim products.
metribuzin	5	Tank mix with paraquat before soybean at 0.2 lb ai/ac. Check label for rate restrictions based on soil type. Metribuzin is not labeled for pre-plant applications before corn.
atrazine	5	Tank mix with paraquat at 1 lb ai/ac in corn only.
rimsulfuron	2	Apply Resolve 25 DF or Basis Blend 30WDG at 1 oz/ac in corn only.



Table 4: Effectiveness of burndown herbicides and tank mixtures

Control ratings (1-10) based on Mid-Atlantic field trials. Ratings of 9 or greater should be selected for optimal cover crop control.

Corn or soybean program*	Annual ryegrass	Winter cereal**	Med. red clover	Crimson clover	Hairy vetch	Austria winter pea	Brassica spp***
glyphosate (0.75 lb ae)	8	9	7	8	7	8	6
glyphosate (1.5 lb ae)	9	9+	7+	8+	8	8+	7+
glyphosate (0.75 lb ae) +							
<i>Sharpen (1 oz/ac)</i>	8+	9	7	8	8+	8+	7
<i>2,4-D LVE (0.5 lb ae)</i>	8	9	8	9	9+	9	8
<i>2,4-D LVE/choline (1 lb ae)</i>	8	9	9	9	9+	9	9
<i>dicamba (0.5 lb ae)</i>	8	9	9	9	9+	9	7
<i>clethodim (6-8 oz)</i>	9+	9+	7	8	7	8	-
paraquat (0.75 lb ai)	6	8	8	8+	8	8	8
paraquat (0.75 lb ai) +							
<i>2,4-D LVE (0.5 lb ae)</i>	6	8	8+	9	9+	8	8+
<i>dicamba (0.5 lb ae)</i>	6	8	8+	9+	9+	8	8
Soybean program only							
paraquat (0.75 lb ai) +							
<i>metribuzin (0.2 lb ai)</i>	7	8+	8+	9+	9	8+	8+
Corn program only							
glyphosate (0.75 lb ae) +							
<i>rimsulfuron (0.015 lb ai)</i>	9+	9+	7	8	7	8	6
paraquat (0.75 lb ai) +							
<i>atrazine (1 lb ai)</i>	7	8+	8+	9+	9	8+	9

*glyphosate at 0.75 lb ae is equivalent to Roundup PowerMax 3 at 19 fl oz; paraquat at 0.5 lb ai is equivalent to Gramoxone SL 3 at 1.3 pt; metribuzin at 0.2 lb ai is equivalent to metribuzin 75DF at 4.3 oz wt;**winter wheat, triticale, cereal rye; ***overwintering brassica spp, winter canola, rapeseed

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How to Integrate Herbicides with Roll-Crimping

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Delaying cereal rye termination until at or after cash crop planting, known as “planting green,” results in additional considerations for herbicide burndown programs. Depending on your cash crop planting date, planting green may allow cereal rye to advance to the stem elongation or anthesis (flowering) growth stages. In this scenario, many growers use roll-crimpers as a residue management tool to improve crop establishment, which may influence herbicide selection and application timing management decisions.

1. Know the limits of roll-crimping termination efficacy.

In the Mid-Atlantic region, targeted corn and soybean planting dates typically occur prior to cereal rye growth stages that permit high levels of control with a roll-crimper (Fig 2). Previous studies in this region have demonstrated that roll-crimping efficacy does not exceed 90% until late-anthesis. This work and previous cropping systems experiments have also demonstrated that even well-timed roll-crimping does not result in complete cereal rye control, which can result in volunteer cereal rye weed management challenges.

Therefore, we recommend that herbicide programs be used as the primary method for controlling cereal rye regardless of its growth stage at termination. Consider focusing on roll-crimping to create a surface mulch for improved crop establishment and weed control.

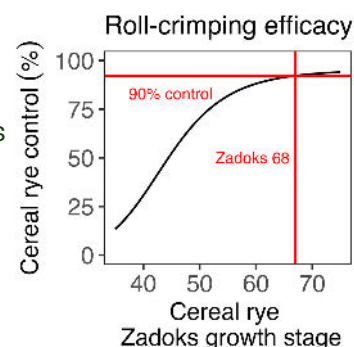


Fig. 2. Adapted from Mirsky et al. 2009

2. Optimize the roll-crimping & burndown sequence for cereal rye control.

In this region, glyphosate-based burndown programs are equally effective for controlling cereal rye whether applied before or after roll-crimping operations (see Table 5 - other side). Delaying cover crop termination likely results in warmer weather conditions at the time of burndown application, which improves the activity of systemic herbicides such as glyphosate. However, we also continue to see slower mortality and reduced efficacy when glyphosate is tank-mixed with atrazine at these later growth stages.

In contrast, the efficacy of paraquat decreases when cereal rye termination is delayed until later growth stages (Table 5). Tank-mixing paraquat with atrazine improves control of cereal rye at later growth stages, and our results indicate that the combination of roll-crimping and burndown applications results in better control compared to applications made to standing cereal rye stands.

3. Combine roll-crimping and burndown applications for legumes and brassicas.

Applying systemic herbicide combinations (glyphosate + 2,4-D LVE or glyphosate + dicamba) after roll-crimping operations is effective for controlling grass-legume mixtures such as cereal rye/hairy vetch or cereal rye/crimson clover. Research in the southern Mid-Atlantic region suggests that the combination of roll-crimping and glyphosate + 2,4-D LVE or glufosinate + 2,4-D LVE may be necessary for consistent control of rapeseed and other hard-to-control brassica species, especially at late flowering stages.

**Table 5: Effectiveness of herbicides for cereal rye termination**

Effectiveness of burndown herbicides and tank-mixtures for control of cereal rye 28 days after treatment (DAT) at various growth stages (flagleaf, boot, mid-heading, early-anthesis) and residue management strategies (roll-crimping).

Control ratings (1-10) based on Mid-Atlantic field trials.

Control ratings of 9 or greater should be selected to optimize control of cover crops.

Corn or soybean program*	Flagleaf to Boot Stage	Mid-heading to early-anthesis	
		Application into standing cover	Application after roll-crimping
glyphosate (0.75 lb ae; 15 gpa)	9+	9+	9+
paraquat (0.5 lb ai; 20 gpa)	9	8+	8+
Corn program			
glyphosate (0.75 lb ae) + atrazine (1 lb ai)	9+	8+	8+
paraquat (0.5 lb ai) + atrazine (1 lb ai)	9+	9	9+

*glyphosate at 0.75 lb ae is equivalent to Roundup PowerMax 3 at 19 fl oz; paraquat at 0.5 lb ai is equivalent to Gramoxone SL 3 at 1.3 pt

Citations

- Askew et al. (2019) Chemical termination of cover crop rapeseed. Weed Technology 33:686-692
- Mirsky et al. (2009) Control of cereal rye with a roller-crimper as influenced by cover crop phenology. Agronomy Journal 101:1589-1596
- Keene et al. (2017) Cover crop termination timing is critical in organic rotational no-till systems. Agronomy Journal 109:272-282
- Kumar et al. (2023) Cover crop termination options and application of remote sensing for evaluating termination efficiency. PLOS ONE.

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How to Control Annual Ryegrass



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Annual ryegrass is a cool-season cover crop that is often used because its dense root system can improve nitrogen scavenging and water infiltration, while contributing to improved soil structure. Many growers also use annual ryegrass as a dual-purpose spring forage crop, often in mixture with a winter cereal such as triticale.

Annual ryegrass is often called Italian ryegrass. Though they are the same species, cover crop seed may be either Westworld annual ryegrass, which has been selected and bred to produce annual life cycle traits, or Italian ryegrass, which behaves like a short-lived perennial (or biennial) species and has a vernalization requirement to produce seed.



Volunteer Italian ryegrass has evolved resistance to several herbicide sites-of-action in various production regions, and all annual ryegrass species are generally more tolerant to glyphosate than winter cereals. Annual ryegrass species are wind-pollinated, which means that annual ryegrass cover crops have the potential to be pollinated by weedy types on roadsides or elsewhere in the landscape, which can transfer herbicide resistance. As a result, it is extremely important to optimize burndown herbicide programs to achieve complete control and prevent seed production when using annual ryegrass as a cover crop in your system.

KEYS to annual ryegrass control:



1. Use glyphosate-based programs.

To achieve complete control, it is necessary to use full rates (1.12 – 1.5 lb ae) while also using application BMPs (include AMS, avoid tank-mix antagonism). Reduced control has been observed when atrazine, metribuzin, or flumioxazin is tank-mixed with glyphosate.

2. The warmer, the better

Warmer conditions often found in late springtime result in greater glyphosate control, likely due to better systemic activity. It is often recommended to terminate annual ryegrass when it is small (< 8" tall), but this growth threshold may coincide with cooler weather conditions in mid-spring. Our studies suggest that weather conditions are of greater importance than size thresholds.

3. Prevent control failures with additional effective sites-of-action

Our research suggests that tank-mixing another herbicide with systemic grass activity (clethodim, Group 1; rimsulfuron, Group 2), improves the consistency of annual ryegrass control in burndown programs (Fig 3 - other side). Clethodim can also be used postemergence in soybeans and rimsulfuron can be used postemergence in corn in combination with glyphosate to target annual ryegrass escapes. Always consult herbicide labels for restrictions.



Figure 3. Annual ryegrass control with different treatments 14 days after treatment.

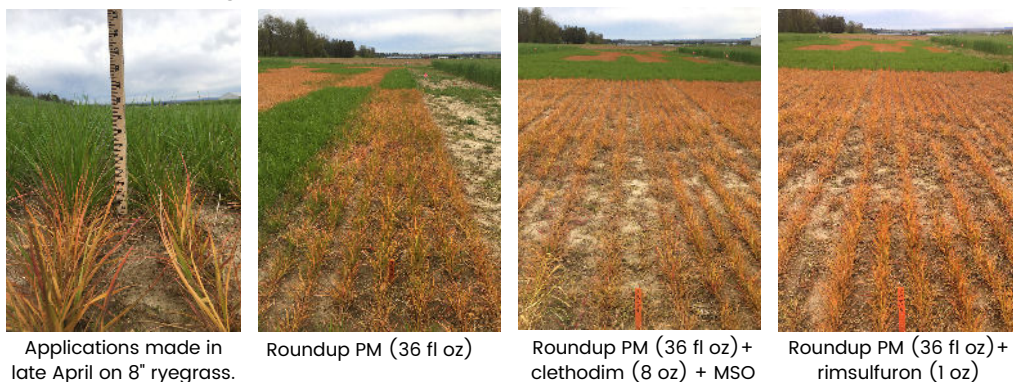


Table 6: Herbicide program recommendations for control of annual ryegrass.

Effectiveness of burndown herbicides and tank-mixtures for control of annual ryegrass 28 days after treatment (DAT) at different timings. Control ratings (1-10) based on Mid-Atlantic field trials. Control ratings of 9 or greater should be selected to optimize control of cover crops.

Glyphosate rates*	Annual ryegrass growth stage	
	mid-Apr (<12" height)	mid-May (>12" height)
glyphosate (0.75 lb ae) + AMS (2.5% v/v)	< 5	+7
glyphosate (1.12 lb ae) + AMS (2.5% v/v)	7	8
glyphosate (1.25 lb ae) + AMS (2.5% v/v)	+7	9
Corn and soybean programs		
glyphosate (1.12 lb ae) + AMS (2.5% v/v) + Sharpen (1 oz) + MSO (1% v/v)	9+	9
glyphosate (1.12 lb ae) + AMS (2.5% v/v) + 2,4-D LVE (1 pt) + Sharpen (1 oz) + MSO (1% v/v)	9+	9
Corn only		
glyphosate (1.12 lb ae) + AMS (2.5% v/v) + Select Max (6 fl oz)**	9+	9+
glyphosate (1.12 lb ae) + AMS (2.5% v/v) + Resolve (1 oz)	9+	9
Soybean only		
glyphosate (1.12 lb ae) + AMS (2.5% v/v) + Select 2E (8 oz) + MSO (1% v/v)	9+	9+

*glyphosate at 0.75 lb ae is equivalent to Roundup PowerMax 3 at 19 fl oz; **Select Max can be applied up to 6 days prior to corn planting in Roundup Ready corn using NIS plus AMS; DO NOT use MSO.

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