Weed Technology

www.cambridge.org/wet

Effects of paraquat application at cover crop planting on cover crop biomass and weed suppression

Cynthia Sias[1], Kevin W. Bamber[2], Vipin Kumar[3], Vijay Singh[4] and Michael L. Flessner[5]

[1]Graduate Research Assistant, Virginia Tech, School of Plant and Environmental Sciences, Blacksburg, VA, USA; [2]Research Specialist Senior, Virginia Tech, School of Plant and Environmental Sciences, Blacksburg, VA, USA; [3]Graduate Research Assistant, Virginia Tech, Eastern Shore Agricultural Research and Extension Center, Painter, VA, USA; [4]Assistant Professor, Virginia Tech, Eastern Shore Agricultural Research and Extension Center, Painter, VA, USA and [5]Associate Professor, Virginia Tech, School of Plant and Environmental Sciences, Blacksburg, VA, USA

Research Article

Cite this article: Sias C, Bamber KW, Kumar V, Singh V, Flessner ML (2023) Effects of paraquat application at cover crop planting on cover crop biomass and weed suppression. Weed Technol. **37**: 494–499. doi: 10.1017/wet.2023.59

Received: 15 May 2023
Revised: 17 July 2023
Accepted: 17 August 2023
First published online: 29 August 2023

Associate Editor:
Robert Nurse, Agriculture and Agri-Food Canada

Nomenclature:
Paraquat; cereal rye, *Secale cereale* L.; crimson clover, *Trifolium incarnatum* L.; hairy vetch, *Vicia villosa* Roth; corn, *Zea mays* L.; soybean, *Glycine max* (L.) Merr.

Keywords:
Burndown; establishment; growing degree days

Corresponding author:
Michael Flessner; Email: flessner@vt.edu

Abstract

Successful cover crop (CC) establishment in the fall is important to maximize CC production, which is critical for achieving many objectives of CCs. Competition from winter weeds may reduce CC establishment and biomass production. A preplant herbicide, such as paraquat, at the time of CC planting in the fall will reduce winter weed pressure resulting in better establishment and growth. An experiment was conducted between 2019 and 2021 to test this hypothesis by evaluating a no-CC check, cereal rye, hairy vetch, crimson clover, and cereal rye + hairy vetch drilled with and without paraquat applied at planting (mid-October to mid-November) following either a corn or soybean crop. Visible weed suppression ratings were collected in mid-April, and total CC and weed biomass was collected in late April. More CC biomass was accumulated following corn than soybean, regardless of preplant herbicide application, because corn is typically harvested before soybeans. Therefore, CCs should be planted early to accumulate more biomass. Weed suppression varied by weed species from all factors, but in general weed suppression was best from a CC mixture containing cereal rye and paraquat applied at planting. If weed suppression is the main goal of the CC, then a preplant herbicide at CC planting is recommended. However, if CC weed suppression goals can be achieved through biomass accumulation, no preplant herbicide is needed. This information is useful for producers to achieve various CC objectives while managing costs.

Introduction

Successful integration of cover crops (CCs) into cash crop rotations can provide benefits such as improved soil health through increased soil organic matter, nitrogen fixation in legumes, and weed suppression. Benefits of CCs generally increase with CC biomass production (Fageria et al. 2005; Osipitan et al. 2018; Teasdale 1996). During a survey conducted in 2012, growers indicated that soil health and erosion prevention were among the main drivers for using CCs, followed by weed control and nitrogen fixation (Myers and Watts 2015). Previous research indicates that the primary driver of weed suppression during CC growth is the competition from the CC (Teasdale 1996). Additionally, with increased CC competition there is typically more biomass left on the surface after the CC has been terminated (Mirsky et al. 2013). Therefore, maximizing CC establishment in the fall and during early-spring growth is necessary to ensure maximum biomass production at the time of termination (MacLaren et al. 2019).

Two important factors for CC establishment and accumulated biomass are planting timing and competition from fall-emerging weeds. Timing of CC planting is often dependent on the preceding cash crop and the geographical region. In the mid-Atlantic, a CC planted earlier will typically accumulate more growing degree days (GDDs) that contribute to successful establishment and growth due to earlier planting compared to a later-planted CC (Baraibar et al. 2018). Weed competition at the time of cash crop planting can hinder establishment, and the speculation is that the same is true for CCs (Cardina et al. 1995; Dieleman et al. 1996). In the case of a cash crop, starting weed free by applying a preplant herbicide is a best-management practice to give the cash crop a competitive advantage over weedy species (Buhler 2004). It stands to reason that starting weed free at planting will increase CC biomass accumulation to achieve the goal(s) of the CC. Currently, no peer-reviewed literature has evaluated if preplant herbicide applications such as paraquat prior to CC planting in the fall increases CC biomass accumulation.

Therefore, the objectives of this research were to evaluate winter weed suppression and CC biomass accumulation as a result of paraquat application at CC planting and timing of CC planting (i.e., following corn or soybean harvest). We hypothesized that paraquat, applied prior

Table 1. Inventory of experimental site-years with planting date, preceding crop, and weed species present.

Cover crop planting date	Site	Preceding crop	Weed species present	Growing degree days
10/14/2019	Blacksburg, VA	Corn	Cutleaf evening primrose Hairy bittercress Mouse-ear chickweed Purple deadnettle Persian speedwell Purslane speedwell	590[a]
10/18/2019	Blacksburg, VA	Soybean	Cutleaf evening primrose Hairy bittercress Henbit Mouse-ear chickweed Persian speedwell Purple deadnettle	846
11/14/2019	Suffolk, VA	Soybean	Cutleaf evening primrose Henbit Mouse-ear chickweed Persian speedwell	866
09/21/2020	Blackstone, VA	Corn	Hairy bittercress Henbit Mouse-ear chickweed Persian speedwell Purslane speedwell	1,166
9/22/2020	Suffolk, VA	Corn	Cutleaf evening primrose Henbit Mouse-ear chickweed Persian speedwell Purslane speedwell	1,301
10/16/2020	Blacksburg, VA	Corn	Mouse-ear chickweed Persian speedwell Purple deadnettle	531
10/27/2020	Suffolk, VA	Soybean	Hairy bittercress Henbit Mouse-ear chickweed	817
10/28/2020	Blackstone, VA	Soybean	Hairy bittercress Henbit Mouse-ear chickweed Purple deadnettle Purslane speedwell	720
10/30/2020	Painter, VA[b]	Corn	Cutleaf evening primrose Henbit Persian speedwell	625
11/16/2020	Blacksburg, VA	Soybean	Mouse-ear chickweed Persian speedwell Purple deadnettle	313

[a]Growing degree days (GDDs) were calculated for each day using the average daily temperature minus the base temperature (4.4 C) for cereal rye (Mirsky et al. 2009). Total GDDs were calculated by adding individual GDDs from the time of cover crop planting and April 14, which was the timing of termination.
[b]Weed biomass and CC biomass data were not collected from the Painter, VA site. Additionally, only three of the seven weed species evaluated were included in the analysis for this site-year.

to CC planting, will increase CC biomass as a result of decreased interspecific competition from weedy species. These studies were established to provide recommendations to growers that can help them make more informed financial decisions and best achieve CC goals.

Materials and Methods

Field experiments were conducted between 2019 and 2021, including 10 different site-years (Table 1). Sites include the Tidewater Agricultural Research Station (TAREC) (36.66° N, 76.73° W) near Suffolk, VA, the Southern Piedmont Agricultural Research Station (SPAREC) near Blackstone, VA (37.09° N, 77.96° W), the Eastern Shore Agricultural Research and Extension Center (ESAREC) (37.58° N, 75.82° W), near Painter, VA, and Kentland Farm (Kentland) (37.19° N, 80.57° W) near Blacksburg, VA. The mean annual temperature range for these sites are 0 to 32 C, –1 to 32 C, –4 to 29 C, 5 to 26 C, respectively, and mean annual rainfalls are 122 cm, 114 cm, 101 cm, and 50 cm for these sites, respectively. All experiments were arranged as a randomized complete block design with four replications per treatment with 3-m by 7.6-m plots. Treatments were arranged as a five by two factorial with five levels of CCs and two levels of preplant herbicide treatment (with and without paraquat). The five levels of CC species factor were cereal rye 'Elbon' (78 kg seed ha^{-1}), crimson clover 'Dixie' (22 kg ha^{-1}), hairy vetch 'MT' (28 kg ha^{-1}), cereal rye + hairy vetch mix (78 kg ha^{-1} + 28 kg ha^{-1}), and a no-CC check. Cover crops were planted using a no-till 1.52-m drill with 19.5-cm row spacing. All CC species were planted in October if following corn harvest and November if following soybean harvest in each experimental year. Herbicide programs varied in the previous crop but achieved commercially acceptable weed control in season and are not a concern for carryover to the cover crops. Paraquat + nonionic surfactant (Gramoxone® SL 2.0; Syngenta Crop Protection, LLC, Basel, Switzerland + Top Surf® Winfield Solutions, LLC, St. Paul, MN) was applied at 0.85 kg ha^{-1} and 0.25% v/v, respectively, at the

https://doi.org/10.1017/wet.2023.59 Published online by Cambridge University Press

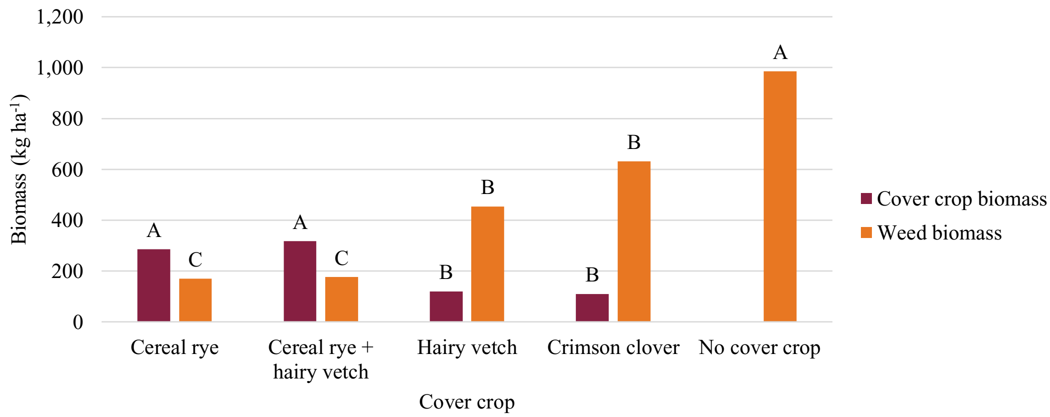

Figure 1. Total cover crop and weed biomass production by species from field experiments in Virginia in 2019-2021. Letters indicate significant differences according to Fisher's protected LSD (P < 0.05) within cover crop (maroon bars) or weed (orange bars) biomass as a result of the cover crop species.

time of CC planting. Applications were made using a CO_2-pressurized backpack sprayer fitted with four TeeJet® Flat-Fan XR 11002 nozzles (Spraying Systems Co., Wheaton, IL) calibrated to deliver 147 L ha^{-1} at 275 kPa. Records were also collected at the time of CC planting describing weed species presence as well as maturity of these weeds. Due to the size of weeds present (10 cm or smaller), it was assumed and expected that the weeds present would be controlled by paraquat at the time of CC planting. Paraquat was also selected because it is fast-acting relative to other burndown herbicides (i.e., glyphosate and glufosinate), which would eliminate the potential for competitive effects on emerging CC plants. Currently, paraquat is more widely used in fall preplant burndown applications in the region and offers diversity as another mode of action for herbicide programs.

Visible weed control and suppression for each weed species present was collected on a 0% to 100% scale with 0% being no control and 100% being complete control in mid-April relative to the nontreated check (no CC and no preplant paraquat). Here, and throughout the document, weed control is used to describe the effects observed as a result of the paraquat application; the term weed suppression describes the effects observed as a result of the CC alone. Aboveground CC and weed biomass were collected in late April prior to termination using a 0.25-m^2 quadrat, randomly placed in each plot. The late-April data collection timing represents a typical timeframe when a grower would be likely to terminate their CC to prepare for cash crop planting. Weed and CC biomass were collected from the same quadrat but were later separated to obtain individual biomass. In each quadrat, plants were chopped at the base by hand using shears. Weed species were combined into a composite sample. All samples were dried in an oven at 60 C for 4 d prior to being weighed and recorded for statistical analysis.

Data were analyzed subjected to ANOVA using JMP Pro 16 (JMP®, Version 16; SAS Institute Inc., Cary, NC), and Fisher's protected LSD ($\alpha = 0.05$) was utilized for means separation. Site-year and replication were considered random effects, whereas preceding crop, herbicide treatment, and CC species were main effects. The model included main effects as well as two- and three-way interactions.

Results and Discussion

Cover Crop Biomass

Cover crop biomass varied by species, preceding crop, and site-year. Contrary to the hypothesis of this study, the main effect

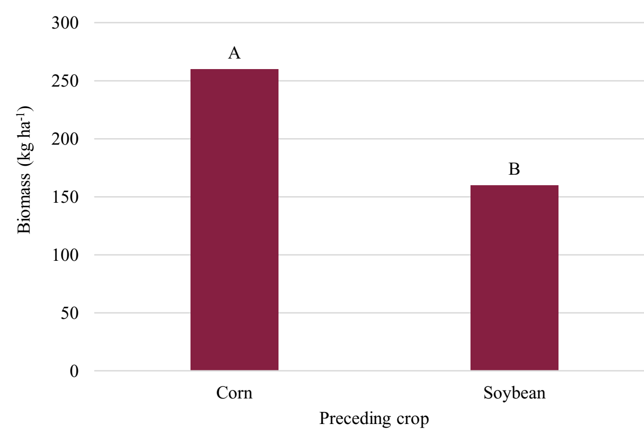

Figure 2. Difference of total cover crop biomass across cover crop species following either a corn or soybean crop from field experiments in Virginia in 2019–2021. Letters indicate significant differences according to Fisher's Protected LSD (P < 0.05) in cover crop biomass as a result of the preceding crop.

of presence or absence of paraquat application did not significantly affect CC biomass (P > 0.090) or interact with other main effects. Although this hypothesis was rejected, preplant herbicide applications in fall-established crops such as wheat (*Triticum aestivum* L.) have resulted in no difference in grain yield, similar to the results of CC biomass in our study (Ogg and Young 1991).

The main effect of CC species was significant (P < 0.001). Of the four CC species observed, cereal rye and cereal rye + hairy vetch generated more biomass than the hairy vetch alone or crimson clover treatments (Figure 1). These results are congruent with previous research indicating that cereal rye generates more aboveground biomass than leguminous CCs such as hairy vetch or crimson clover (Ruis et al. 2019). Cereal rye can actively grow in temperatures as low as 0 C, whereas hairy vetch does not actively grow until temperatures reach > 4 C (Teasdale et al. 2008). Within the leguminous CC species evaluated, however, no difference in biomass production was determined.

The main effect of preceding crop was also significant (P < 0.001), as greater CC biomass accumulation was achieved when a CC followed a corn crop compared to a soybean crop (Figure 2). These results were expected due to the difference in total GDDs accumulated prior to CC termination when established earlier following a corn crop as opposed to later after

Table 2. Weed control estimates in mid-April following establishment of the cover crop treatments for seven weed species, as influenced by preplant paraquat application, preceding cash crop, and their interaction from field experiments in Virginia in 2019–2021. Data were pooled across sites.

	Control															
	Paraquat rate[a]				Preceding crop				Soybean				Corn			
Weed species	0.85		0		Soybean		Corn		Paraquat		No paraquat		Paraquat		No paraquat	
	%															
Cutleaf evening primrose	–[c]	–	–	–		–	–	–	74	A[b]	42	B	37	B	40	B
Hairy bittercress	63	A	26	B	57	A	32	B	–	–	–	–	–	–	–	
Henbit	–	–	–	–	55	A	35	B								
Mouse-ear chickweed	45	A	19	B	35	A	29	B	–	–	–	–	–	–	–	
Persian speedwell	49	A	20	B	–	–	–	–	–	–	–	–	–	–	–	
Purple deadnettle	66	A	20	B	–	–	–	–	–	–	–	–	–	–	–	
Purslane speedwell	–	–	–	–	–	–	–	–	64	A	21	BC	28	B	16	C

[a]Paraquat rate expressed as kg ai ha^{-1}. Nonionic surfactant was included in all paraquat treatments at 0.25% v/v.
[b]Letters indicate significant differences ($P < 0.05$) in weed control within a row.
[c]Dashes indicate that the factor was not significant or the interaction was presented rather than the main effect.

a soybean crop (Table 1). Similar results were observed by Farsad et al. (2011), in which earlier planted CC established more successfully than CC planted later in the season. Ultimately, the biomass accumulation of a CC will be affected by the total GDDs (Farsad et al. 2011). This information is practical in application, as growers in regions with insufficient GDDs may find it difficult to achieve biomass goals, and therefore may have to select CC species based on this obstacle.

Weed Suppression

Seven main weed species were evaluated at the sites observed: hairy bittercress (*Cardamine hirsute* L.), mouse-ear chickweed [*Cerastium fontanum* Baumg. ssp. *vulgare* (Hartm.) Greuter & Burdet], henbit (*Lamium amplexicaule* L.), purple deadnettle (*Lamium purpureum* L.), cutleaf evening primrose (*Oenothera laciniata* Hill), purslane speedwell (*Veronica peregrina* L.), and Persian speedwell (*Veronica persica* Poir.). The main effects evaluated for weed control were the presence or absence of the preplant herbicide, the preceding crop, weed species, and the CC.

The three-way interaction of preceding crop/preplant herbicide/weed species was significant ($P = 0.003$). Accordingly, data were analyzed by weed species, and main effects were only presented when significant and in the absence of a significant interaction (Table 2). In general, preplant paraquat was more likely to increase weed control when compared to no-preplant paraquat, and overall weed suppression was greater following soybean than corn. When paraquat was applied at CC planting, weeds emerged with or after the CC, resulting in better weed suppression compared to no paraquat. Preplant paraquat increased hairy bittercress, mouse-ear chickweed, Persian speedwell, and purple deadnettle control 37%, 26%, 29%, and 46%, respectively compared to no paraquat. The main effect of preceding crop was also significant for some weed species; weed suppression of hairy bittercress, henbit, and mouse-ear chickweed were all greater following soybean than in fields following corn by 25%, 20%, and 6%, respectively. Finally, the two weed species that showed a significant two-way interaction were cutleaf evening primrose and purslane speedwell, which both displayed greater control following soybean and with preplant paraquat.

Cover crop species was also a significant main effect for weed suppression ($P < 0.001$) and was analyzed separately to show key differences. Previous research has shown cereal rye consistently providing greater weed suppression when compared to legume CCs alone (Rector 2019; Ruis et al. 2019; Weston 1990). The results from this study support these previous findings, as the weed suppression observed from the cereal rye and cereal rye + hairy vetch treatments was greater than the hairy vetch alone or crimson clover treatments for six of the seven species evaluated, with the only exception being cutleaf evening primrose (Table 3). We attribute greater fall competition and spring biomass amounts from cereal rye as likely the reason for the greater weed suppression compared to legume CCs alone.

Some weed species were consistently among the lesser controlled weed species evaluated; these included: mouse-ear chickweed, purslane speedwell, and Persian speedwell (Tables 2 and 3). Additionally, the no-CC treatment consistently had less weed suppression regardless of weed species when compared to the treatments seeded with a CC, because of a lack of competition.

Themain effects of CC species ($P < 0.001$) and preplant herbicide ($P < 0.001$) application were the only significant factors for weed biomass. Weed biomass data followed the weed suppression results closely, as greater weed biomass was present in the no-CC treatments followed by the treatments using crimson clover alone and hairy vetch alone (Figure 3). The cereal rye–alone and cereal rye + hairy vetch treatments contained the least total weed biomass, which is congruent with the greater control observed in the visible ratings. Weed biomass was also significantly different as a result of the preplant application. Total weed biomass was greater when the preplant application of paraquat was not applied at the time of CC planting (Figure 3).

These observed weed control and weed biomass results could be attributed to many factors such as emergence patterns of winter weeds related to soil temperature (Baskin and Baskin 1988; Werle et al. 2014). Different emergence patterns of weed species could result in variable efficiency of a preplant herbicide such as paraquat. Weeds present at the time of paraquat application would have been likely controlled and given the CC a weed-free start, but those weeds emerging after the application would not be controlled, because paraquat has no residual activity (Sagar 1987). It is also important to mention that the emergence of winter weeds is likely to vary as a result of geography and weather patterns, which is site-specific. Therefore, more sampling dates including prior to paraquat application could be helpful in further demonstrating the effect of a preplant herbicide at the time of CC planting.

Table 3. Visible weed suppression by species achieved as a result of cover crop (CC) species from field experiments in Virginia in 2019–2021.

	Suppression				
	CC				
Weed species	No CC	Cereal rye	Hairy vetch	Cereal rye + hairy vetch	Crimson clover
	%				
Cutleaf evening primrose	18 B[a]	51 A	52 A	60 A	53 A
Hairy bittercress	30 B	56 A	39 AB	53 A	45 AB
Henbit	11 C	63 A	43 B	62 A	39 B
Mouse-ear chickweed	21 B	42 A	25 B	42 A	29 B
Persian speedwell	18 C	39 AB	38 AB	48 A	29 BC
Purple deadnettle	34 A	50 A	40 A	45 A	43 A
Purslane speedwell	13 C	41 AB	25 BC	45 A	35 AB

[a]Letters indicate significant differences according to Fisher's protected LSD ($P < 0.05$) in weed suppression within CC.

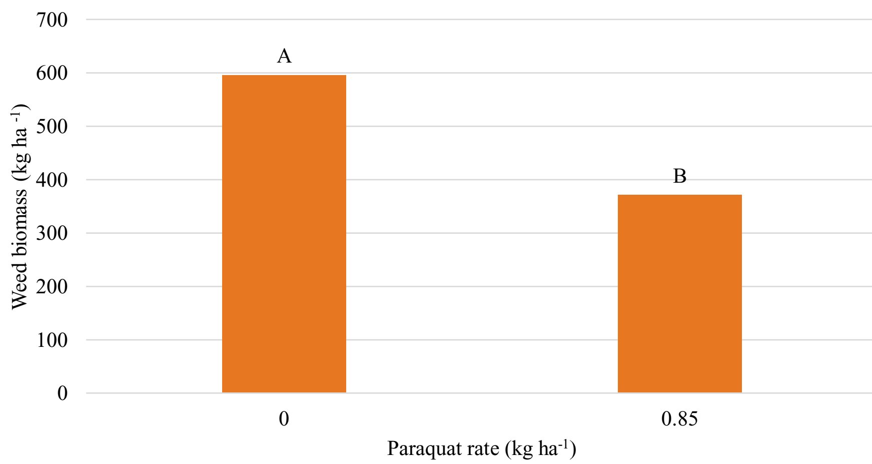

Figure 3. Difference of total weed biomass as a result of a preplant paraquat application at the time of cover crop planting from field experiments in Virginia in 2019–2021. Letters indicate significant differences according to Fisher's Protected LSD ($P < 0.05$) in total weed biomass as a result of preplant paraquat application.

Practical Implications

The focus of this study was to determine if a preplant herbicide would make a difference in CC biomass as well as weed control. Although, the preplant herbicide did not significantly influence CC biomass accumulation, it may serve a purpose in controlling specific weeds of interest. Such applications in the fall could be recommended if there are large populations of troublesome weeds outcompeting the CC or if a weed is difficult to control at the time of cash crop preplant herbicide application, but not as a general practice. To our knowledge, there is no previous literature that has evaluated the effect of the presence or absence of a preplant herbicide such as paraquat on a CC prior to the time of CC planting, making this information valuable for growers interested in CCs. Overall, the major outcomes of this study include the following: although observed weed control varied by weed species, in general, weed control was (i) greater when paraquat was applied at CC planting, (ii) when cereal rye or cereal rye + hairy vetch was the CC selected, (iii) when the CC followed soybean as compared to corn, and (iv) the application of a preplant herbicide did not affect CC biomass production. This information is practical and directly affects growers who are interested in using CCs or are trying to optimize their agricultural programs. More research concerning CC management is still needed to further provide recommendations to growers—specifically, examining problematic weed species such as horseweed (*Erigeron canadensis* L.) and common ragweed (*Ambrosia artemisiifolia* L.), given these weeds emerge during the CC growing seasons and are hard to control at the time of preplant burndown due to resistant to multiple herbicide sites of action. Other potential research includes examining changes in emergence patters of weeds starting late in the cash crop season and throughout active CC growth as well as studying the influence of residual herbicides on CC biomass and weed control.

Acknowledgments. Partial funding was provided by the Virginia Agricultural Experiment Station, the Virginia Soybean Board, and the Virginia Corn Board for this research. The authors specifically acknowledge Wykle Green, Eli Russell, Matthew Spoth, and all the undergraduate assistants for field help on this project. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement. No conflicts of interest have been declared.

References

Baraibar B, Mortensen DA, Hunter MC, Barbercheck ME, Kaye JP, Finney DM, Curran WS, Bunchek J, White CM (2018) Growing degree days and cover crop type explain weed biomass in winter cover crops. Agron Sustain Dev 38:65

Baskin CC, Baskin JM (1988) Germination ecophysiology of herbaceous plant species in a temperate region. Amer J Bot 75:286–305

https://doi.org/10.1017/wet.2023.59 Published online by Cambridge University Press

Buhler DD (2004) Weed-crop competition: a review. Crop Sci 44: 2284–2285
Cardina J, Regnier E, Sparrow D (1995) Velvetleaf (*Abutilon theophrasti*) competition and economic thresholds in conventional- and no-tillage corn (*Zea mays*). Weed Sci 43:81–87
Dieleman A, Hamill AS, Fox GC, Swanton CJ (1996) Decision rules for postemergence control of pigweed (*Amaranthus* spp.) in soybean (*Glycine max*). Weed Sci 44:126–132
Fageria NK, Baligar VC, Bailey BA (2005) Role of cover crops in improving soil and row crop productivity. Comm Soil Sci Plant Analysis 36: 2733–2757
Farsad A, Randhir TO, Herbert SJ, Hashemi M (2011) Spatial modeling of critical planting date for winter rye cover crop to enhance nutrient recovery. Agron J 103:1252–1257
MacLaren C, Swanepoel P, Bennett J, Wright J, Dehnen-Schmutz K (2019) Cover crop biomass production is more important than diversity for weed suppression. Crop Sci 59:733–748
Mirsky SB, Curran WS, Mortensen DA, Ryan MR, Shumway DL (2009) Control of cereal rye with a roller/crimper as influenced by cover crop phenology. Agron J 101:1589–1596
Mirsky SB, Ryan MR, Teasdale JR, Curran WS, Reberg-Horton CS, Spargo JT, Wells MS, Keene CL, Moyer JW (2013) Overcoming weed management challenges in cover crop–based organic rotational no-till soybean production in the eastern United States. Weed Technol 27:193–203
Myers R, Watts C (2015) Progress and perspectives with cover crops: interpreting three years of farmer surveys on cover crops. J Soil and Water Conserv 70:125A–129A
Ogg AG, Young FL (1991) Effects of preplant treatment interval and tillages on herbicide toxicity to winter wheat (*Triticum aestivum*). Weed Technol 5:291–296
Osipitan OA, Dille JA, Assefa Y, Knezevic SZ (2018) Cover crop for early season weed suppression in crops: systematic review and meta-analysis. Agron J 110:2211–2221
Rector LS (2019) Herbicide carryover to cover crops and evaluation of cover crops for annual weed control in corn and soybeans. M.S. thesis. Blacksburg, VA: Virginia Polytechnic Institute and State University. 26 p
Ruis SJ, Blanco-Canqui H, Creech CF, Koehler-Cole K, Elmore RW, Francis CA (2019) Cover crop biomass production in temperate agroecozones. Agron J 111:1535–1551
Sagar GR (1987) Uses and usefulness of paraquat. Human Toxicol 6:7–11
Teasdale JR (1996) Contribution of cover crops to weed management in sustainable agricultural systems. J Prod Agric 9:475–479
Teasdale JR, Devine TE, Mosjidis JA, Bellinder RR, Beste CE (2008) Growth and development of hairy vetch cultivars in the northeastern United States as influenced by planting and harvesting date. Agron J 96: 1266–1271
Werle R, Bernards ML, Arkebauer TJ, Linquist JL (2014) Environmental triggers of winter annual weed emergence in the midwestern United States. Weed Sci 62:83–96
Weston LA (1990) Cover crop and herbicide influence on row crop seedling establishment in no-tillage culture. Weed Sci 38:166–171