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Live and Killed Hairy Vetch Cover Crop Effects on Weeds and Yield in Glyphosate-Resistant Corn[1]

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Abstract: A 2-yr field study was conducted from 2002 to 2003 on a Dundee silt loam soil at the Southern Weed Science Research Unit Farm, Stoneville, MS (33°26′N latitude), to examine the effects of hairy vetch cover crop (hairy vetch killed at corn planting [HV-K], hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting [HV-B], hairy vetch left alive [HV-L], and no hairy vetch [NHV]) and glyphosate postemergence (broadcast, banded, and no herbicide) application on weed control and yield in glyphosate-resistant corn. Two applications of glyphosate at 0.84 kg ae/ha were applied 3 and 5 wk after planting (WAP) corn. Hairy vetch dry biomass was higher in HV-L (4,420 kg/ha) and HV-B (4,180 kg/ha) than in HV-K (1,960 kg/ha) plots at 7 WAP. Hairy vetch reduced densities of pitted morningglory, prickly sida, and yellow nutsedge in HV-B and HV-L compared with NHV plots, but hairy vetch had no effect on densities of barnyardgrass, johnsongrass, and large crabgrass at 7 WAP regardless of desiccation. Total weed dry biomass at 7 WAP was lower in HV-B and HV-L than in HV-K and NHV plots. Corn yield was higher in HV-K (10,280 kg/ha) than in HV-B (9,440 kg/ha) and HV-L (9,100 kg/ha), and yields were similar between HV-K and NHV (9,960 kg/ha). Glyphosate applied broadcast resulted in the highest corn yield (11,300 kg/ha) compared with a banded application (10,160 kg/ha). These findings indicate that hairy vetch cover crop has the potential for reducing the density of certain weed species in glyphosate-resistant corn production systems; however, optimum weed control and higher yield were obtained when glyphosate was used.

Nomenclature: Glyphosate; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. #[3] ECHCG; hairy vetch, *Vicia villosa* Roth # VICVI; johnsongrass, *Sorghum halepense* (L.) Pers. # SORHA; large crabgrass, *Digitaria sanguinalis* (L.) Scop # DIGSA; pitted morningglory, *Ipomoea lacunosa* L. # IPOLA; prickly sida, *Sida spinosa* L. # SIDSP; yellow nutsedge, *Cyperus esculentus* L. # CYPES; corn, *Zea mays* L. 'AG RX 738RR', 'DKC 69-72RR'.

Additional index words: Cover crop, glyphosate, integrated weed management, mulch, transgenic corn, weed biomass, weed density.

Abbreviations: HV-B, hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting; HV-K, hairy vetch killed at corn planting; HV-L, hairy vetch left alive; NHV, no hairy vetch; POST, postemergence; WAP, weeks after planting.

INTRODUCTION

Warm winter and spring temperatures, relatively high rainfall, and fertile soils of the lower Mississippi River Delta region provide a conducive environment for establishment of a wide array of annual and perennial weed species (Heatherly and Elmore 1983; Reddy 2001). Control of emerged weeds at planting is critical to corn stand establishment, which necessitates the use of nonselective herbicides. Winter annual cover crops can be a useful tool to suppress or replace winter annual weed species (Locke et al. 2002; Teasdale 1996). Cover crops are planted in the fall and desiccated with herbicides the following spring before no-till planting of the summer crop (Koger et al. 2002; Reddy et al. 2003). Cover crops have long been used to reduce soil erosion and water runoff, improve soil physical and chemical properties, sequester atmospheric CO_2 into soil, and conserve leachable plant nutrients (Clark et al. 1995; Decker et al. 1994; Locke and Bryson 1997; Mallory et al. 1998; Sainju and Singh 1997; Yenish et al. 1996). In addition

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

to these benefits, legume cover crops biologically fix atmospheric nitrogen, which subsequently becomes available to a crop during residue decomposition (Ebelhar et al. 1984; Sainju and Singh 1997; Teasdale and Shirley 1998; Wagger 1989). Although natural winter vegetation provides soil cover in certain fields, it may not provide sufficient mulch for longer periods, as is the case with planted cover crop residues (Reddy 2001).

Hairy vetch is a succulent winter annual legume that produces relatively large amounts of biomass that contains high nitrogen (Decker et al. 1994; Ebelhar et al. 1984; Sainju and Singh 1997; Wagger 1989). Although hairy vetch provides early-season weed suppression, herbicides generally are required to achieve full-season weed control and optimum corn yields (Curran et al. 1994; Johnson et al. 1993; Teasdale and Shirley 1998). Weed suppression effects of cover crop residue decrease with time after cover crop residue decomposition. Live hairy vetch cover crop provided effective weed suppression longer than desiccated hairy vetch residue (Teasdale and Daughtry 1993). Therefore, planting corn into live hairy vetch could potentially improve weed suppression and reduce herbicide use. This approach could permit maximum production of hairy vetch biomass and sequestration of atmospheric nitrogen. Furthermore, this system could eliminate the need for preemergence herbicides and allow management of late-season weeds with postemergence (POST) herbicides on an as-needed basis.

In Mississippi, most spring growth of hairy vetch occurs between March and May. Corn is usually planted between February 25 and April 10 in southern Mississippi and between March 15 and April 25 in northern Mississippi (Anonymous 2003). Thus, the period of maximum cover crop growth and normal corn planting dates overlap. Generally, cover crops are killed at or before corn planting. If left alive, hairy vetch will continue to grow until natural senescence occurs, or it is killed by POST herbicide applications. Live hairy vetch at corn planting can adversely affect corn stand establishment mainly because of poor seedling emergence in dense hairy vetch biomass (Curran et al. 1994; Johnson et al. 1993; Teasdale and Shirley 1998). One way to overcome the poor stand establishment is to kill the hairy vetch in a band over the crop row. The desiccated band will provide a favorable environment for corn seedlings to emerge, and live hairy vetch between the rows will continue to suppress weeds.

Transgenic corn resistant to glyphosate provides the flexibility to control a broad spectrum of weeds with one or two POST applications of glyphosate. Several studies have shown that glyphosate POST-only programs were as effective as preemergence followed by POST programs in controlling a wide spectrum of weeds. Corn yields with glyphosate POST-only programs were equal to or greater than yields with preemergence followed by POST programs (Hellwig et al. 2003; Johnson et al. 2000; Nolte and Young 2002; Tharp and Kells 2002).

Numerous studies have shown that weed management tactics in addition to a cover crop are needed because cover crops that are desiccated at planting of the summer crop do not provide complete weed control. Hairy vetch left alive (HV-L) at corn planting has the potential to extend the period of weed suppression. Information is lacking on integration of live hairy vetch and glyphosate POST applications in glyphosate-resistant corn in the lower Mississippi River Delta region. The specific objectives of this research were (1) to determine the effect of killed, live, and band-killed hairy vetch cover crop on weeds and corn yield and (2) to determine the efficacy of glyphosate POST applied broadcast vs. in a band over the crop row on weeds and corn yield.

MATERIALS AND METHODS

Field studies were conducted during 2002 and 2003 at the USDA-ARS, Southern Weed Science Research Unit Farm, Stoneville, MS (33°26′N latitude). The soil was a Dundee silt loam (fine-silty, mixed, thermic Aeric Ochraqualf) with 26% sand, 56% silt, and 18% clay. Before initiation of the study, the experimental area was cropped to soybean [*Glycine max* (L.) Merr.] for 5 yr. The experiment was conducted in a split-plot arrangement of treatments in a randomized complete block design with cover crop systems as the main plot and glyphosate applications as the subplot, with four replications. Each subplot consisted of eight rows spaced 102 cm apart and 15.2 m long. The same treatment was assigned to the same plot each year. Field preparation consisted of disking and bedding in the fall of 2001. In 2002, after corn harvest, old seedbeds were raised without disking. Hairy vetch was drill seeded in 19-cm-wide rows using a no-till grain drill[4] in mid-October of 2001 and 2002 at a seeding rate of 30 kg/ha in all plots except no hairy vetch (NHV) plots.

Cover crop systems were hairy vetch killed at corn planting (HV-K), hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting (HV-B), HV-L, and NHV. The hairy vetch cover crop was

[4] John Deere 750 series grain drill, Deere and Co., 501 River Drive, Moline, IL 61265.

killed in HV-K and HV-B plots with paraquat at 1.1 kg ai/ha 1 d before planting corn. At desiccation, hairy vetch was 25 to 30 cm tall. The NHV plots also were treated with paraquat at 1.1 kg ai/ha to kill existing vegetation. Corn was planted without tillage directly into killed or live hairy vetch residue. Glyphosate-resistant corn cultivars and planting dates were 'AG RX 738RR' on April 5, 2002, and 'DKC 69-72RR' on April 1, 2003. Corn was planted in 102-cm-wide rows using a Max-Emerge 2 planter[5] at 80,000 seeds/ha. Fertilizer application and insect control programs were standard for corn production (Anonymous 2003). Rainfall during April through July was 34.3 and 40.9 cm in 2002 and 2003, respectively. The 30-yr average rainfall for the corresponding period is 45 cm. Corn was flood irrigated on June 3 and 24 in 2002 and June 2 and 27 in 2003.

POST herbicide treatments were glyphosate (0.84 kg ae/ha) applied broadcast and in a 38-cm-wide band centered over the crop row at 3 and 5 wk after planting (WAP) corn and no-herbicide treatment. The commercial formulation of isopropylamine salt of glyphosate[6] with no adjuvant was used. No preemergence herbicides were used in the study. Herbicide treatments were applied with a tractor-mounted sprayer delivering 187 L/ha water. Glyphosate at 3 WAP was applied broadcast using 8004 standard flat spray tips[7] and in a 38-cm-wide band centered over the crop row using 65015 standard flat spray tips. Glyphosate at 5 WAP was applied broadcast using a hooded sprayer equipped with off-center nozzles (OC-01 flat spray tips) for postdirect spraying and sprayer hoods with three nozzles (95002 even flat spray tips) for spraying between the rows. Glyphosate was applied in a band by postdirected spray with off-center nozzles. Band application used 63% less glyphosate than the broadcast application.

Hairy vetch cover crop biomass was determined at corn planting and at 3 and 7 WAP. Hairy vetch plant residue was clipped at the soil surface from one randomly selected 0.09-m^2 quadrat in each plot, oven-dried, and weighed. The cover crop biomass includes both live and killed hairy vetch present within each quadrat. A different area was used for each sampling time. Weeds were counted by species in one 1.0-m^2 area in each plot at 7 WAP. Dry weight of all weeds present was recorded from one randomly selected 1.0-m^2 area at 7 WAP. Hairy vetch biomass, weed count, and weed biomass data were recorded between the second and third rows of an eight-row plot. Corn population was determined by counting plants in two 1.0-m-long row lengths in each plot at 6 WAP. Corn plant height from the soil surface to the tip of the youngest leaf was measured on five randomly selected plants at 6 WAP. Corn population and corn plant height data were recorded from the second and third rows of an eight-row plot. Corn was harvested on August 22, 2002, and August 18, 2003, from four (second, third, sixth, and seventh) rows of an eight-row plot using a combine, and grain yield was adjusted to 15% moisture.

Data were subjected to analysis of variance using PROC MIXED to determine significance of main effects and interactions (SAS 1998). Treatment means were separated at the 5% level of significance using Fisher's protected LSD test. Data were averaged across years (as main effect means) if interactions were not significant and are presented for interactions where appropriate.

RESULTS AND DISCUSSION

Hairy Vetch Dry Biomass. Hairy vetch established uniformly and produced a complete ground cover at corn planting in both years. Hairy vetch dry biomass at the time of corn planting was 2,340 kg/ha (data not shown). Planting and fertilization operations killed about 40% of the vetch and reduced vigor of plants in tire tracks in all treatments.

At 3 and 7 WAP, HV-B and HV-L plots had more dry biomass than HV-K plots despite their 40% stand loss due to planting and fertilization operations (Table 1). Hairy vetch in HV-L plots and between the rows in HV-B plots continued to grow until senescence or treatment with glyphosate POST. Similarly, Clark et al. (1995) observed increased hairy vetch biomass from 2,800 kg/ha in early April to 4,630 kg/ha in mid-May in Maryland. However, in another Maryland study, killing hairy vetch with POST herbicides resulted in little or no additional hairy vetch biomass accumulation compared with biomass present at corn planting (Teasdale and Shirley 1998). Plant biomass in NHV plots was from winter annuals, which were predominantly annual bluegrass (*Poa annua* L.), Carolina foxtail (*Alopecurus carolinianus* Walt.), hairy buttercup (*Ranunculus sardous* Crantz), henbit (*Lamium amplexicaule* L.), shepherd's-purse [*Capsella bursa-pastoris* (L.) Medicus], sibara [*Sibara virginica* (L.) Rollins], and swinecress [*Coronopus didymus* (L.) Sm.].

There were no differences in hairy vetch dry biomass among glyphosate POST treatments regardless of the

[5] MaxEmerge 2 planter, Deere and Co., 501 River Drive, Moline, IL 61265.

[6] Roundup Ultramax®, isopropylamine salt of glyphosate, Monsanto Agricultural Company, St. Louis, MO 63167.

[7] TeeJet standard flat spray tips, Spraying Systems Co., North Avenue and Schmale Road, Wheaton, IL 60189.

Table 1. Hairy vetch residue at 3 and 7 WAP as affected by cover crop systems and glyphosate POST programs in 2002 and 2003 at Stoneville, MS.[a]

Main effect	Hairy vetch dry biomass[b]	
	3 WAP	7 WAP
	kg/ha	
Cover crop		
NHV[c]	650	100
HV-K	2,230	1,960
HV-B	3,750	4,180
HV-L	4,250	4,420
LSD (0.05)	520	790
Glyphosate POST[d]		
No herbicide	2,610	2,750
Band applied	2,850	2,770
Broadcast applied	2,690	2,470
LSD (0.05)	NS	NS

[a] Abbreviations: HV-K, hairy vetch killed at corn planting; HV-B, hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting; HV-L, hairy vetch left alive; NHV, no hairy vetch; POST, postemergence; WAP, weeks after planting; NS, not significant.

[b] Data represent an average of 2 yr.

[c] Biomass in NHV plots was from winter annuals.

[d] Glyphosate at 0.84 kg/ha was applied POST twice in a 38-cm-wide band centered over the corn row and as broadcast.

method of application at 3 and 7 WAP. This response was expected for 3 WAP sampling because first application of glyphosate POST was made at 3 WAP. No reduction in hairy vetch biomass in glyphosate POST broadcast and band treatments at 7 WAP sampling may have been due to regrowth of escaped hairy vetch under a dense mat of ground cover and slow decomposition of freshly desiccated residue during a narrow window of time between glyphosate treatment and sampling date.

Weed Density and Biomass. Sixteen weed species were present in the no-herbicide treatment at 7 WAP. Barnyardgrass, johnsongrass, large crabgrass, pitted morningglory, prickly sida, and yellow nutsedge each ranged from 3 to 53% of the total weed density. Densities of other weed species were too low (<0.5%) to justify reporting. Hairy vetch in HV-B and HV-L plots suppressed pitted morningglory, prickly sida, and yellow nutsedge compared with NHV at 7 WAP (Table 2). Densities of barnyardgrass, johnsongrass, and large crabgrass were not affected by hairy vetch residue regardless of desiccation. Glyphosate POST applied broadcast effectively controlled barnyardgrass, johnsongrass, large crabgrass, pitted morningglory, prickly sida, and yellow nutsedge. Glyphosate POST applied in a band reduced densities of barnyardgrass and large crabgrass compared with the no-herbicide treatment.

Total weed dry biomass was highest in NHV plot at 7 WAP (Table 3). Total weed dry biomass was lower in HV-L and HV-B plots compared with NHV plot. However, there were no differences in total weed dry biomass between HV-K and NHV plots. Overall, hairy vetch decreased total weed dry biomass by 39% in HV-K, by 83% in HV-L, and by 86% in HV-B compared with the NHV system. Glyphosate applications greatly decreased total weed dry biomass, and glyphosate broadcast application resulted in no biomass because of complete control of weeds. Overall, weed dry biomass in glyphosate applied broadcast and in a band were 50 and 100%, respectively, less than that with the no-herbicide treatment. Glyphosate POST-only program provided a similar level of weed control in rye cover crop–based glyphosate-resistant soybean in other research (Reddy 2003).

Corn Population, Height, and Yield. Corn stand was similar among hairy vetch systems regardless of desic-

Table 2. Weed density at 7 WAP as affected by hairy vetch cover crop and glyphosate in 2002 and 2003 at Stoneville, MS.[a,b]

Main effect	Barnyardgrass	Johnsongrass	Large crabgrass	Pitted morningglory	Prickly sida	Yellow nutsedge
	plants/m^2					
Cover crop						
NHV	16.4	10.1	11.3	1.9	4.1	59.5
HV-K	13.3	6.6	5.7	1.3	0.5	27.7
HV-B	10.4	2.0	4.2	0.3	0.5	13.4
HV-L	2.4	0.3	1.1	0.2	0.5	7.6
LSD (0.05)	NS	NS	NS	1.3	1.9	37.7
Glyphosate POST[c]						
No herbicide	25.5	9.2	14.3	1.8	2.5	53.9
Band applied	6.4	5.2	2.3	1.1	1.8	27.3
Broadcast applied	0	0	0	0	0	0
LSD (0.05)	11.1	7.5	6.8	1.1	1.7	32.6

[a] Abbreviations: HV-K, hairy vetch killed at corn planting; HV-B, hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting; HV-L, hairy vetch left alive; NHV, no hairy vetch; POST, postemergence; WAP, weeks after planting; NS, not significant.

[b] Data represent an average of 2 yr.

[c] Glyphosate at 0.84 kg/ha was applied POST twice in a 38-cm-wide band centered over the corn row and as broadcast.

Table 3. Effect of hairy vetch cover crop and glyphosate on total weed dry biomass at 7 WAP and corn yield in studies conducted at Stoneville, MS, in 2002 and 2003.[a,b]

Cover crop	Glyphosate POST[c]	Total weed dry biomass[d]	Corn yield
		kg/ha	
NHV	No herbicide	1,350	7,040
	Band applied	700	10,700
	Broadcast applied	0	12,140
	Mean	690	9,960
HV-K	No herbicide	760	7,790
	Band applied	490	11,260
	Broadcast applied	0	11,790
	Mean	420	10,280
HV-B	No herbicide	260	8,130
	Band applied	40	9,620
	Broadcast applied	0	10,560
	Mean	100	9,440
HV-L	No herbicide	290	7,530
	Band applied	70	9,070
	Broadcast applied	0	10,710
	Mean	120	9,100
Mean	No herbicide	670	7,620
	Band applied	330	10,160
	Broadcast applied	0	11,300
LSD (0.05)	Cover crop	280	740
	Glyphosate POST	240	640
	Interaction	480	1,280

[a] Abbreviations: HV-K, hairy vetch killed at corn planting; HV-B, hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting; HV-L, hairy vetch left alive; NHV, no hairy vetch; POST, postemergence; WAP, weeks after planting.

[b] Data represent an average of 2 yr.

[c] Glyphosate at 0.84 kg/ha was applied POST twice in a 38-cm-wide band centered over the corn row and as broadcast.

[d] Predominant weeds were barnyardgrass, johnsongrass, large crabgrass, pitted morningglory, prickly sida, and yellow nutsedge.

Table 4. Corn population and plant height at 6 WAP as affected by hairy vetch cover crop and glyphosate at Stoneville, MS, in 2002 and 2003.[a,b]

Main effect	Corn population	Corn plant height
	plants/ha	cm
Cover crop		
NHV	74,800	64.9
HV-K	74,230	62.2
HV-B	76,240	55.0
HV-L	73,200	56.2
LSD (0.05)	NS	3.6
Glyphosate POST[c]		
No herbicide	72,740	57.9
Band applied	74,740	59.2
Broadcast applied	76,400	61.5
LSD (0.05)	NS	NS

[a] Abbreviations: HV-K, hairy vetch killed at corn planting; HV-B, hairy vetch killed in a 38-cm-wide band centered over the crop row at corn planting; HV-L, hairy vetch left alive; NHV, no hairy vetch; POST, postemergence; WAP, weeks after planting corn; NS, not significant.

[b] Data represent an average of 2 yr.

[c] Glyphosate at 0.84 kg/ha was applied POST twice in a 38-cm-wide band centered over the corn row and as broadcast.

cation (Table 4). Others have observed reduced corn population after planting into live hairy vetch (Curran et al. 1994; Johnson et al. 1993; Teasdale and Shirley 1998). Paraquat was applied 1 d before corn planting; as a result, there was a dense mat of succulent hairy vetch plants in all hairy vetch plots at corn planting. Despite the dense hairy vetch ground cover, the corn planter was able to cut through the biomass and place corn seeds in contact with soil. Furthermore, rainfall of $>$5 cm occurred within 6 d of corn planting in both years. These conditions may have favored uniform corn stand establishment. Corn plant height was higher in NHV and HV-K systems compared with HV-B and HV-L systems (Table 4). Soil moisture depletion by live hairy vetch may have increased stress on corn during the early season. Total rainfall amounts received during April and May of 2002 and 2003 were 41 and 39%, respectively, less than the normal monthly rainfall. Other studies have shown that allowing a hairy vetch cover crop to grow into May has resulted in soil water depletion, especially when spring rainfall was below normal (Clark et al. 1995). There were no differences in corn population and plant height among glyphosate POST treatments.

Among hairy vetch cover crop systems, corn yield was highest in the HV-K (10,280 kg/ha) system and lowest in the HV-L (9,100 kg/ha) system (Table 3). Corn yields were not different between HV-K and NHV, HV-B and NHV, and HV-B and HV-L systems. Live hairy vetch in HV-L and HV-B systems reduced corn yields compared with desiccated hairy vetch (HV-K). Differences in corn yields were partly due to the effect of live hairy vetch on corn growth. Although hairy vetch had no effect on corn stand establishment, it reduced corn plant height in the HV-L and HV-B systems. This reduced corn growth, and yield could be attributed to greater competition from hairy vetch. Glyphosate POST applied broadcast or banded gave 33 to 48% higher corn yields than did the no-herbicide control. Between glyphosate POST treatments, glyphosate applied broadcast resulted in higher corn yield than glyphosate applied in a band partly because of the effective control of weeds in the broadcast treatment.

Analysis of variance indicated significant interaction between hairy vetch and glyphosate POST treatments for corn yield. Glyphosate POST applied broadcast in the NHV system had higher corn yields than did glyphosate POST applied broadcast in the HV-B or HV-L system. However, corn yields were similar among glyphosate POST broadcast in HV-K, HV-B, and HV-L systems. Corn yield from glyphosate POST applied in a band in the HV-K system was similar to that from glyphosate

POST applied in a band in the NHV system but was greater than that from glyphosate POST applied in a band in the HV-B or HV-L systems. However, corn yields were similar among hairy vetch systems in the absence of glyphosate POST (no-herbicide control). Because hairy vetch cover crop (HV-K, HV-B, and HV-L) residue did not result in higher corn yield than did the NHV system in the absence of glyphosate POST, hairy vetch did not eliminate the need for herbicides under the conditions of this study. Therefore, glyphosate POST applications are critical to complement early-season weed suppression by hairy vetch to exploit hairy vetch's potential for improving soil fertility and crop productivity.

In this study, leaving hairy vetch alive up to 3 WAP increased hairy vetch biomass by 1,520 to 2,020 kg/ha compared with a kill at corn planting. This additional hairy vetch biomass did suppress certain weed species and reduce total weed dry biomass. However, these benefits did not translate into increased corn yield because corn grown in desiccated hairy vetch (HV-K) yielded more than corn grown in live hairy vetch (HV-B and HV-L). Hairy vetch dead or alive did not totally eliminate the need for herbicides. These findings indicate that HV-K has the potential for reducing weed density in glyphosate-resistant corn production systems; however, optimum weed control and higher yield were obtained when glyphosate POST was used. In a hairy vetch–based corn production system, weeds can be managed with a glyphosate POST-only program and potentially eliminate the need for prophylactic preemergence herbicides. Because corn yields were similar between band and broadcast applications, corn production in the HV-K system can reduce glyphosate use by 63% in a band application compared with a broadcast application.

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