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Early Season Weed Suppression in Buckwheat Using Clopyralid

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Currently there are no herbicides registered for direct application to buckwheat for broadleaf weed control. This 4-yr Lithuanian study examined weed control using several rates of clopyralid alone or combined with a single rate of desmedipham. Most applications were applied at the 1-leaf stage of crop growth, however, one rate of clopyralid was applied pre-emergence (PRE) in 2 of the 4 yr. Buckwheat injury was evident within a few days after application (or emergence) with all treatments, but by harvest, no symptoms were evident. In the 2 yr with greatest weed densities, densities were reduced with increasing clopyralid rates alone or with desmediphan. However, weed biomass and density were similar to the nontreated control at harvest. Common lambsquarters, scentless mayweed, wild buckwheat, and narrowleaf hawksbeard were species that were best (> 40% density reduction) controlled with clopyralid. With few exceptions, buckwheat yield in all herbicide-treated plots was similar to the nontreated control. Because yield was not increased with these herbicides, other weed control benefits, such as reduced interference with harvesting equipment or less dockage due to weed seed contamination, must be carefully weighed against the costs of herbicide and application and crop injury that reduced early-season vigor.

Nomenclature: Clopyralid; desmedipham; common lambsquarters, *Chenopodium album* L.; narrowleaf hawksbeard, *Crepis tectorum* L.; scentless mayweed, *Tripleurospermum inordorum* (L.) Schultz-Bip.; wild buckwheat, *Polygonum convolvulus* L.; buckwheat, *Fagopyrum esculentum* Moench.
Key words: Weed management.

Buckwheat is a broadleaf ''pseudocereal'' short-season crop that can be planted later into the summer than almost all other crops in cool climates. Although buckwheat can flower until the occurrence of a killing fall frost due to an indeterminate flowering pattern, yields can be low. Worldwide, about 2 million ha of buckwheat were planted in 1993 (Myers and Meinke 1994) with the United States, China, Russia, Ukraine, and France the world production leaders (Ag Canada Outlook 2007; Alberta Agriculture and Food, 2001). Buckwheat production has increased in recent years, due in part to the demand in the health food market for flour, groats, and buckwheat honey (Myers and Meinke 1994). Net return for buckwheat over variable costs in the midwestern United States market was reported to be about $40/ha in 2002 (Myers 2002).

The importance of buckwheat throughout the world is evidenced by the international nature of research reports in the literature. Studies using both cultural tactics as well as limited herbicide trials for weed management have been reported from India (Rana et al. 2003), eastern Europe and Russia (Jakubiak and Adamczewski 2006; Kavoliunaite and Salna 2003a,b; Novikov 1994; Salna et al. 1998), Chile (Parodi and Nebreda 1998), Nepal (Yoshida et al. 1997), Korea (Choi et al. 1992), Canada (Wall and Smith 1999, 2000), and the United States (Myers 2002; Myers and Mienke 1994). During the Soviet period, buckwheat was not grown in Lithuania. However, buckwheat hectarage increased by a factor of 16 from 1995 to 2003 (Lithuania Department of Statistics 2003) due to high demand and good monetary returns. In fact, buckwheat went from an unranked food commodity in 1995 to ranking 10th in 2003.

Many producers that use low input or organic systems include buckwheat in crop rotations. Once established, buckwheat grows rapidly and its thick canopy is an ideal cover crop, protecting the soil surface from erosion; and a smother crop, limiting late weed emergence and growth (Batish et al. 2002; Choudhury and Prem 2007). In addition, the aerial plant portions of buckwheat contain fagomine, 4-piperidone, and 2-piperidinemethanol, three natural phytotoxins that suppress plant growth (Iqbal et al. 2002; Khanh et al. 2005; Xuan and Tsuzuki 2004).

Although buckwheat is used for weed suppression after establishment, weed control during establishment is challenging (Jakubiak 2005; Podolska 2006; Rana et al. 2003; Sakaliene and Salna 2000) in all production systems. When the field trials reported here began in 1998, there was almost no available literature on postemergence (POST) herbicides and doses in buckwheat that gave acceptable broadleaf weed control, as well as crop tolerance. In fact, there are no registered POST herbicides for use on buckwheat in the United States (Myers 2002), Russia, or the eastern European States (Jakubiak 2005; Sakaliene and Salna 2000). The objectives of this 4-yr research project conducted in Lithuania were to determine the influence of clopyralid and clopyralid + desmedipham at several rates on (1) control of common broadleaf weeds observed in buckwheat fields, and (2) buckwheat growth and yield.

Sixteen different herbicides were used in a prescreening trial on buckwheat prior to conducting this study. Clopyralid and clopyralid + desmedipham, broadleaf herbicides used in sugarbeets (*Beta vulgaris* L.) (Senseman 2007), were selected from this group for more detailed study due to weed efficacy and apparent crop safety. Clopyralid is an auxin-type herbicide that results in poor to excellent control of wild

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buckwheat (*Polygonum convolvulus* L.), depending on application rate and timing. In sugarbeet, clopyralid is often mixed with desmedipham, a photosynthetic inhibitor-type herbicide (Senseman 2007). It was thought that these herbicides, based on early application and low doses, would provide some early-season broadleaf weed control with limited crop injury, and ultimately, increase yield when compared with a nontreated weedy crop.

Materials and Methods

A study was conducted from 1998 to 2001, at Traku Voke Branch of the Lithuanian Institute of Agriculture in southeast Lithuania. The soil type was a haplic luvisol sandy loam with a pH of about 5.8 and soil organic carbon content of about 11 g/kg. Winter rye was the crop prior to buckwheat in 1998, 2000, 2001, whereas in 1999, buckwheat followed buckwheat. The soil was plowed to an 18 to 20 cm depth in the fall and cultivated once in the spring prior to seeding. Based on soil samples, nutrient status each year was about 1.3 g total N/kg; 66 mg P_2O_5/kg, and 320 mg K_2O/kg. Fertilizer was applied at a rate of 30/60/60 kg/ha, N, P_2O_5, K_2O after spring cultivation. The cultivar 'Smuglianka' was planted at a rate of 80 kg/ha on May 19, May 21, May 19, and May 18, 1998 to 2001, respectively.

Treatments evaluated each year included clopyralid[1] applied at 50, 75, 90, or 180 g ai/ha POST, and desmedipham[2] at 360 g/ha alone or at this rate with clopyralid at 50, 90, or 180 g/ha POST. In 2000 and 2001, clopyralid alone at 180 g/ha applied PRE also was included. Clopyralid at the lowest rate was 50% lower and, at the highest rate, was 64% lower, than the lowest and highest labeled rates in sugarbeets (100 to 280 g/ha), respectively (Zollinger 2008). The desmedipham rate represented a midrange labeled rate for sugarbeets (144 to 1,344 g/ha) (Zollinger 2008).

All treatments, except the PRE treatment of clopyralid, were applied when buckwheat was at the 1–true-leaf stage. POST application dates were June 9, 1998; June 6, 1999 and 2000; and June 21, 2001. PRE application dates were May 25, 2000 and May 23, 2001. Herbicide applications were applied with a backpack or bicycle sprayer having nozzles 50 cm on center and calibrated to deliver 200 L/ha of spray solution at 276 kPa. The individual treatment areas were about 50 m^2. The experimental design was a randomized complete block with four replicates each year.

Weed assessments by species were conducted twice each season, 1 mo after herbicide application and just before buckwheat harvest. Weeds were clipped at ground level in four 0.25 m^2 areas of each plot, counted and separated by species, air dried, and weighed. At buckwheat harvest, number of plants/m^2, plant height, grain/plant (weight and seed number), and 1,000 grain mass of buckwheat were determined.

Due to yearly variation of weed densities and biomass, regression analyses based on clopyralid rate were conducted on yearly means of these parameters with differences in slopes and intercepts reported when $P \leq 0.10$. Least significant differences of weed species data were pooled among years due to similarity in relative ranking by species among years.

Table 1. Temperature and precipitation during the 4-yr study period and 30-yr averages at Voke, Lithuania.

	Average temperature				
Year	May	June	July	August	September
	C				
1998	13.0	17.0	16.3	14.6	12.4
1999	10.2	19.6	20.5	16.5	13.9
2000	13.1	15.2	15.8	16.0	10.2
2001	12.3	14.3	21.0	17.9	11.9
30-yr average	12.5	15.7	16.9	16.3	11.6
	Total precipitation				
	mm				
1998	48	68	131	105	54
1999	15	54	29	53	60
2000	55	59	209	65	11
2001	61	39	94	35	82
30-yr average	60	77	78	68	65

Buckwheat yield parameters by treatment within a year were calculated using PROC GLM in SAS with least significant differences reported at $P \leq 0.10$.

Results and Discussion

Climatic Data. Annual monthly average temperatures, total monthly rainfall, and 30-yr averages of these parameters are presented in Table 1. The monthly temperatures and precipitation amounts during the 4 yr ranged from much cooler and drier than average to much wetter and warmer than average, with each year presenting unique climatic conditions. For example, May average temperatures for 1998, 2000, and 2001 were similar to the long-term average, but the average temperature in 1999 was 20% below the long-term average. Average temperature for June 1998 was about 10% above average, whereas average temperature for June and July, 1999 and July 2001 were 20 to 25% above average.

Precipitation amounts during the trial period also were highly variable. May precipitation, during buckwheat planting and emergence, was 20 and 75% below the 30-yr average in 1998 and 1999, respectively. June and July, 1999 remained dry with precipitation amounts 30 and 60%, below average, respectively. In 1998, 2000, and 2001, precipitation amounts in July were almost double, triple, and 20% more than average, respectively.

Weed Data—1 Mo after Application. Weed densities in 1999 (the very dry year) and 2001 were relatively low (< 90 plants/m^2) and were not influenced by clopyralid rate 1 mo after application (Figure 1a–d). Dicot and total weed densities were greatest in 2000 with over 300 and 350 weeds/m^2, respectively, whereas in 1998, densities were 150 and 225 weeds/m^2, respectively. Desmedipham alone reduced dicot and total weed densities by about 20% only in 1998 compared with the nontreated control (Table 2). In 1998 and 2000, dicot and total weed densities decreased as clopyralid rate increased with or without desmedipham (Figure 1a–d and Table 2). In 2000, the slopes of the linear regressions for both the clopyralid and clopyralid + desmedipham treatments were much greater than the slopes

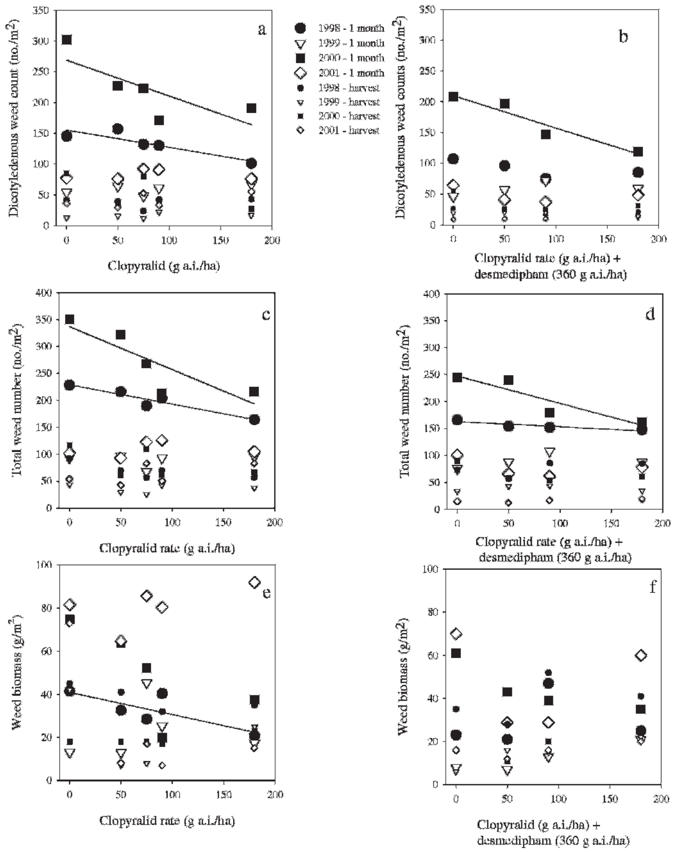

Figure 1. The influence of the rate of clopyralid alone or with desmedipham on dicotyledenous weed density (a, b), total weed density (c, d), and total weed biomass (e, f) during 1998 to 2001 growing seasons. The larger symbols represent the 1-mo sampling time and the smaller symbols represent samples taken at harvest. Regression lines that have a slope < 0 (significant at P ≤ 0.10) are presented on this figure. Parameters for intercepts and slopes are given in Table 2.

calculated for the 1998 data, indicating that greater response was observed under the highest weed densities.

Weed biomass was similar among almost all treatments and years and averaged 55 g/m^2 (Table 2). The one exception was in 1998 when an increasing clopyralid rate decreased biomass.

Over 40 species of weeds were observed in the nontreated control during the study. Perennial dicot weeds made up < 1% of the weed density and included Canada thistle [*Cirsium arvense* (L.) Scop.], perennial sowthistle (*Sonchus arvensis* L.), and common sheepsorrel (*Rumex acetosella* L.). These perennials were reduced in all treatments from 60 to 90% (Table 3). Annual dicot weeds made up about 70% of the total weed density, irrespective of treatment. The two most prevalent annual dicot weeds were common lambsquarters and European field pansy (*Viola arvensis* Murr.), that accounted for 44 and 26% of the total weed density in the nontreated control treatment, respectively (Table 3). Individual species were differentially controlled by the treatments. Common lambsquarters averaged about 40% control in the desmedipham and desmedipham + clopyralid (any rate) treatments, whereas European field pansy had densities similar to the nontreated control, regardless of treatment. Species with > 60% control in the 50 and 75 g/ha clopyralid treatment included scentless mayweed, wild buckwheat, and narrowleaf hawksbeard. Only field pennycress (*Thlaspi arvense* L.) had > 80% control with desmedipham and was the only species that was controlled by desmedipham alone (Table 3).

Annual and perennial grass species accounted for the remaining weed density. The most numerous grass species were quackgrass [*Elytrigia repens* (L.) Desv. ex B. D. Jackson] (80%), and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] (12%), with the remaining grasses a mixture of annual bluegrass (*Poa annua* L.), green foxtail [*Setaria viridis* (L.) Beauv.], and smooth crabgrass [*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.] (Table 3). Grass weed density and the relative abundance of each grass species were not influenced by herbicide treatment (Table 3).

Weed Control Data—Harvest Sampling. Total weed density at harvest in the nontreated control averaged 62% fewer counts than at the 1-mo sampling date with the largest reduction in dicot weed counts in 1998 (76% reduction) and 2000 (72% reduction) (Table 2).

All densities and biomass measurements were similar among years and within treatments when compared within the respective parameter at harvest. These data indicate that neither clopyralid nor desmedipham influenced these parameters (Figure 1 a–f and Table 2).

When evaluated by species, common lambsquarters and European field pansy remained the two most abundant weeds and accounted for 63 and 16% of the annual dicot weeds, respectively (Table 3). Grass density was unaffected by buckwheat when the early and late measurements were compared, although, due to the decrease in annual dicot weeds, grasses at the late sampling made up about 40% of the total weed density. The biomass per weed averaged about 0.33 g/plant in herbicide-treated plots, whereas in the nontreated control individual weed biomass averaged 0.73 g/plant.

The PRE application of clopyralid had very similar results in terms of weed density and weed species at both 1-mo and harvest-sampling times as the POST application (data not shown). Weed biomass at the 1-mo sampling time was 23% greater in the PRE than POST treatment however at harvest no differences in biomass were observed (data not shown).

Buckwheat Response. The two highest rates of clopyralid, with or without desmedipham, and the PRE application of clopyralid, injured buckwheat (data not shown). The injury symptoms were observed within 2 d after POST treatment, or at emergence in the PRE treatment. Injured buckwheat was dark green and wilted. Three to 5 d later, the plants began to curl and became light green with obvious injury seen for 2 to 3 wk after application. The symptoms were outgrown as the plants matured, so that by harvest, all plants appeared normal.

At harvest, buckwheat plant density was greatest in the nontreated control with densities in the herbicide treatments from 4 to 13% lower (data not shown). Plant height was not influenced by herbicide treatment and averaged 87 cm across treatments and years (data not shown).

Buckwheat yield in the nontreated control ranged from 2.27 t/ha in 1998 to 1.40 t/ha in 2001 (Table 4). The very wet weather in July, 2001 (Table 1) resulted in lodged

Table 2. Intercepts and significant slopes of regression lines (shown in Figure 1) based on clopyralid rate for dicotyledonous weed density, total weed density, and weed biomass 1 mo after clopyralid application and at buckwheat harvest for 4 yr in Voke, Lithuania.

Sampling time	Parameter	Year	Control Intercept			clopyralid Slope[a]	clopyralid P[b]	Desmedipham Intercept			+ clopyralid Slope	+ clopyralid P
			Plants/m^2									
1 mo after application	Dicot weed density	1998	155	B[c]	a	−0.28	0.04	101	B	b		
		1999	53	C	a			53	B	a		
		2000	268	A	a	−0.58	0.10	209	A	a	−0.52	0.04
		2001	82	C	a			53	B	a		
	Total weed density	1998	228	B	a	−0.35	0.01	162	B	b	−0.09	0.10
		1999	88	C	a			85	B	a		
		2000	336	A	a	−0.79	0.06	247	A	a	−0.50	0.08
		2001	106	C	a			84	B	a		
			g/m^2									
	Biomass	1998	41			−0.10	0.10	26				
		1999	21					6				
		2000	67					55				
		2001	74					47				
Harvest			Plants/m^2									
	Dicot weed density	1998	36					24				
		1999	14					21				
		2000	75					42				
		2001	32					8				
	Total weed density	1998	82					67				
		1999	36					39				
		2000	101					76				
		2001	48					13				
			g/m^2									
	Biomass	1998	40					34				
		1999	23					8				
		2000	16					17				
		2001	44					14				

[a] Slope of the regression line with increasing clopyralid rates.

[b] Level of significance of the P value of the slope compared to a value of 0. Adjusted r^2 values for regression lines presented > 0.97.

[c] Capital letters compare among years within a parameter. Lower case letters compare within year between weedy control and desmedipham treatment with no clopyralid added. Similar letters within a capitalization case indicate no difference in means at $P \leq 0.10$. No letters indicate means are similar within the parameter by treatment and year.

buckwheat that delayed maturity and resulted in poor yields. With the exception of desmedipham alone and desmedipham + clopyralid at 50 g/ha in 1999, none of the herbicide treatments had greater yield than the weedy control plot. Yield was only lower than the nontreated control in 2001 when clopyralid at 180 g/ha alone or with desmedipham was applied.

Grain numbers and grain mass per plant from plants treated with clopyralid at 180 g/ha treatment alone, or with desmedipham were lower than the nontreated control in 1998 and 2001 (Table 4). These treatments also had lower grain mass per plant in 2000. Desmedipham + clopyralid at 90 g/ha reduced grain number and grain mass in 1998. The 1,000-grain seed mass in the nontreated control was greatest in 2001 with 26.9 g and lowest in 2000 with 22.1 g but was not influenced by herbicide treatment (data not shown).

Results from herbicide trials published after the conclusion of this study have reported on both grass and broadleaf control in buckwheat. For example, grass herbicides in trials have included the PRE herbicides alachlor (Rana et al. 2004), pendimethalin, acetochlor, metolachlor (Salna and Kavoliunaite 2001), and the POST herbicide fenoxaprop (Jakubiak and Adamczewski 2006). Broadleaf weed control also has been attempted with PRE herbicides such as pyrazon (Kavoliunaite and Salna 2003a), and POST herbicides with varying rates and application timings of desmedipham (Kavoliunaite and Salna 2003b; Wall and Smith 1999), napropamide (Kozaczenko 1988), 2, 4-D, and MCPA (Salna et al. 1998; Wall and Smith 2000). In some cases, mixtures of grass and broadleaf herbicides have been studied (Knezevic and Baketa 1992). Some success has been reported; however, most studies state that phytotoxicity to buckwheat, especially shortly after application, is a major complication in all these systems.

Several research reports recommend that light tillage be used to stimulate weed emergence, and then, either tillage again to desiccate the emerged weeds (Rana et al. 2004), or treatment with contact-type herbicide for control of emerged weed seedlings prior to buckwheat emergence (AgCanada Outlook 2007; Myers 2002). Cultural methods including tillage, heavy seeding rates (about 80 kg/ha vs. 40 kg/ha), drilled sowing (rather than broadcast seeding), and hand weeding also have been reported as methods that give varying degrees of success to limit weed interference during buckwheat establishment (AgCanada Outlook 2007; Choi et al. 1992; Kalinova et al. 1999; Kusiorska et al. 1993; Myers 2002; Podolska 2006; Rana et al. 2004).

Due to the small plant size at emergence, weed control during buckwheat establishment has been (Jakubiak 2005) and continues to be a problem. Clopyralid alone or with

Table 3. Mean weed density averaged over the 4-yr study by species taken 1 mo after herbicide application and before buckwheat harvest at Voke, Lithuania.

			Herbicide treatment							
			Clopyralid				Desmedipham + clopyralid			
			g ai/ha							
Weed species	Time of count	Control	50	75	90	180	360	360 + 50	360 + 90	360 + 180
			Annual dicot							
			no./m²							
Common lambsquarters	1 mo	65	60	52	42	35	37	34	24	16
(*Chenopodium album* L.)	harvest	28	18	28	19	16	15	10	7	5
European field pansy	1 mo	38	46	34	33	40	31	34	33	33
(*Viola arvensis* Murr.)	harvest	7	6	8	7	7	7	8	6	7
Shepardspurse	1 mo	6	7	7	9	8	5	6	6	6
[*Capsella bursa-pastoris* (L.) Medic.]	harvest	2	2	2	2	2	1	1	1	2
Common whitlow grass	1 mo	5	6	9	5	7	5	2	2	3
[*Erophila verna* (L.) Bess.]	harvest	0	0	0	0	0	0	0	0	0
Red sandspurry	1 mo	4	2	3	2	2	4	1	2	2
[*Spergularia rubra* (L.) J. & K. Prels.]	harvest	0	0	0	0	0	0	0	0	0
Narrowleaf hawksbeard	1 mo	4	0	0	0	0	2	0	0	0
(*Crepis tectorum* L.)	harvest	1	0	0	0	0	0	0	0	0
Common chickweed	1 mo	5	5	4	4	4	3	2	2	3
[*Stellaria media* (L.) Vill.]	harvest	1	1	1	0	1	0	0	0	0
Corn speedwell	1 mo	4	4	5	5	3	2	3	3	3
(*Veronica arvensis* L.)	harvest	0	0	0	0	0	0	0	0	0
Corn spurry	1 mo	3	4	4	4	3	3	4	2	3
(*Spergula arvensis* L.)	harvest	0	0	0	0	0	0	0	0	0
Scentless mayweed	1 mo	3	1	0	1	0	4	2	1	1
[*Tripleurospermum inodorum* (L.) Schultz-Bip.]	harvest	1	0	0	0	0	0	0	1	0
Common knotweed	1 mo	2	1	2	2	2	2	3	2	2
(*Polygonum aviculare* L.)	harvest	0	0	0	0	1	0	0	0	0
Redstem filaree	1 mo	2	1	2	2	2	2	3	2	3
[*Erodium cicutarium* (L.) L'Hér. ex Ait.]	harvest	1	0	0	1	0	1	1	0	1
			Perennial dicots							
Canada thistle	1 mo	2	1	1	0	0	1	1	0	0
[*Cirsium arvense* (L.) Scop.]	harvest	2	1	1	0	0	1	1	0	0
Perenial sowthistle	1 mo	2	1	1	0	0	1	0	0	0
(*Sonchus arvensis* L.)	harvest	2	1	1	0	0	1	1	0	0
Common sheepsorrel	1 mo	2	1	0	1	0	1	1	0	0
(*Rumex acetosella* L.)	harvest	0	0	0	0	0	0	1	0	0
			Annual monocots							
Barnyardgrass	1 mo	5	4	4	5	5	4	3	4	2
[*Echinochloa crus-galli* (L.) Beauv.)	harvest	5	3	3	3	5	3	3	3	3
Annual bluegrass	1 mo	2	3	2	1	2	4	3	3	2
(*Poa annua* L.)	harvest	2	4	2	1	2	2	0	0	1
			Perennial monocots							
Quackgrass	1 mo	35	28	28	35	28	30	31	34	32
[*Elytrigia repens* (L.) Desv. ex B. D. Jackson]	harvest	21	15	20	1622	23	17	30	30	22

Table 4. Influence of nontreated control, clopyralid rate, desmedipham alone, and desmedipham + clopryalid on buckwheat yield, grain number per plant, and grain mass per plant in Voke, Lithuania, 1998 to 2001.

		1998			1999			2000			2001		
Treatment	Rate	Yield	Grain number	Grain mass	Yield	Grain number	Grain mass	Yield	Grain number	Grain mass	Yield	Grain number	Grain mass
	g ai/ha	t/ha	no./plant	g/plant	t/ha	no./plant	g/plant	t/ha	no./plant	g/plant	t/ha	no./plant	g/plant
Nontreated	0	2.27ab[a]	63a	1.59a	1.72bc	37b	0.98b	2.21a	35ab	0.78a	1.40ab	39a	0.98a
Clopyralid	50	2.50a	60ab	1.52a	1.86ab	39ab	1.05b	2.29a	29b	0.64ab	1.42a	37a	0.88a
	75	2.43a	56ab	1.44a	1.77b	38ab	1.00b	2.16a	33ab	0.71ab	1.09c	36ab	0.95a
	90	2.30a	54ab	1.36ab	1.75b	39ab	1.03b	2.21a	30ab	0.64ab	1.11c	40a	0.94a
	180	2.10b	50ab	1.31ab	1.61c	40ab	1.05b	2.18a	28b	0.59b	0.89d	21b	0.52b
Desmedipham	360	2.57a	57ab	1.46a	1.94a	44a	1.22a	2.26a	36a	0.75a	1.41ab	45a	1.11a
+ clopyralid	50	2.46a	52ab	1.30ab	1.88a	43ab	1.19a	2.19a	36a	0.77a	1.26bc	38a	0.96a
+ clopyralid	90	2.18b	47b	1.17b	1.75bc	45a	1.19a	2.20a	34ab	0.75a	1.26bc	39a	0.99a
+ clopyralid	180	2.10b	40b	0.99b	1.69c	42ab	1.12ab	2.17a	25ab	0.5b	0.93d	26b	0.61b
Clopyralid PRE	180							2.18a	35ab	0.73ab	1.20bc	40a	0.97a

[a] Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

desmedipham in this study had limited weed control success. Weed density was reduced only at very high weed densities, and then only a few broadleaf species were affected. Weed biomass was slightly reduced at 1 mo after application sampling in only 1 yr. At harvest, weed density and biomass in the nontreated control areas were similar to those measured in any treatment. In addition, injury to buckwheat was observed soon after application with higher treatment rates that were the most efficacious to the weed species present. Symptoms of injury were not observed by about 5 wk after application. However, it is unclear if the early season setback hindered buckwheat's yield potential, because none of the treatments consistently outyielded the weedy control. Therefore, the benefit and value of the limited amount of weed control with these herbicide applications must be carefully weighed against the herbicide and application costs. The greatest benefit from these herbicides might be in fields with high densities of specific species, such as field pennycress, wild buckwheat, narrowleaf hawksbeard, or scentless mayweed, which were best controlled by the applications. In addition, reducing these weeds early in the season might reduce combine plugging at harvest or might result in cleaner seed and less dockage due to impure seed.

Sources of Materials

[1] Lontrel 300 (clopyralid), Dow Agrosciences Polska, Warsaw, Poland.

[2] Betanal AM (desmedipham), Bayer Crop Sciences, Warsaw, Poland.

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