Downy Brome (*Bromus tectorum*), Jointed Goatgrass (*Aegilops cylindrica*) and Horseweed (*Conyza canadensis*) Control in Fallow[1]

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Abstract. Jointed goatgrass, downy brome, and horseweed are increasingly troublesome winter annual weeds during fallow periods in conservation-tillage systems in the southern Great Plains. These experiments determined the optimum weed size, vigor, and minimum herbicide rate required for 95% or better control of these weeds on fallow land. Jointed goatgrass and downy brome were controlled best when plants were 10 cm or less tall and growing vigorously at time of treatment. Horseweed was controlled best when plants were 30 cm tall and growing vigorously. Based on local retail and application costs and assuming optimum conditions for control, the two most economical herbicide treatments that controlled each weed 95% or better were: jointed goatgrass, clethodim at 250 g ai/ha and glyphosate + 2,4-D at 249 + 479 g ae/ha; downy brome, quizalofop at 18 g ai/ha and glyphosate + 2,4-D at 582 + 950 g ae/ha; and horseweed, 2,4-D at 560 g ae/ha and metsulfuron at 5 g ai/ha. **Nomenclature:** Clethodim, (*E,E*)-(±)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one; glyphosate, *N*-(phosphonomethyl)glycine; metsulfuron, 2-[[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid; quizalofop, (±)-2-[4-[(6-chloro-2-quinoxalinyl)oxy]phenoxy]propanoic acid; 2,4-D, (2,4-dichlorophenoxy)acetic acid; downy brome, *Bromus tectorum* L. #[3] BROTE; horseweed, *Conyza canadensis* (L.) Croq. # ERICA; jointed goatgrass, *Aegilops cylindrica* Host # AEGCY.

Additional index words: Glyphosate, metsulfuron, quizalofop, 2,4-D.

INTRODUCTION

Jointed goatgrass, downy brome, and horseweed are increasingly troublesome winter annual weeds in the southern Great Plains during fallow periods of winter wheat (*Triticum aestivum* L.) fallow or winter wheat-fallow-sorghum [*Sorghum bicolor* (L.) Moench] fallow crop rotations. If not controlled in fallow periods, these weeds, especially jointed goatgrass and downy brome, have the potential of becoming serious problems in subsequent winter wheat crops (7, 10).

Jointed goatgrass is a rapidly increasing threat to winter wheat production especially in the western United States and central and northern Great Plains (7). Observations by the authors indicate jointed goatgrass is increasing in the southern Great Plains. In replacement series experiments using growth chambers, vegetative winter wheat was more competitive than jointed goatgrass, which in turn was more competitive than downy brome (8). Winter wheat was most competitive when conditions were wet and warm, while jointed goatgrass was most competitive in cool, wet conditions that occur after winter wheat planting in the fall. There are no selective chemical controls for this weed in wheat (7). Rotating to summer annual crops is the best method of control, but this is difficult in areas where continuous winter wheat or winter wheat-fallow are the only practical cropping systems.

Downy brome has been a problem since the 1960's when early no-tillage research was reported (3, 15). The competitiveness and economic threshold of downy brome growing in winter wheat has been determined. In Oregon, 108 to 160 plants per m^2 reduced winter wheat yield 6% when removed by March and 40% when left until maturity (11). Winter wheat yields in the central Great Plains were reduced 10, 15, and 20% by 20, 40, and 65 downy brome plants per m^2, respectively (13). Moderate levels of downy brome control in winter wheat have been reported for chlorsulfuron {(2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]-benzenesulfonamide]} (1), diclofop {±)-2-[4-(2,4-dichlo-

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[3]Letters followed by this symbol are a WSSA-approved computer code from composite List of Weeds, Revised 1989. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

rophenoxy)phenoxy]propanoic acid} (12), metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] (14), and the ethylthio analog of metribuzin (10). Downy brome control in conservation-fallow systems in western Canada was 80 to 90% with glyphosate, paraquat (1,1′dimethyl-4,4′-bipyridinium ion), quizalofop, sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one}, and a glyphosate + 2,4-D mixture (2).

Horseweed has been a problem in Southwestern range land for many years, and recently has proven troublesome in conservation-tillage systems for cotton (*Gossypium hirsutum* L.) (9). Horseweed behaves as a summer annual in the northern United States and a winter annual in the south and southwest, control in no-tillage and reduced-tillage systems is difficult (4). Attempts at herbicidal control of horseweed have been made in conservation-tillage systems throughout North America in corn (*Zea mays* L.) (6, 17), soybean [*Glycine max* (L.) Merr.] (5, 16), and cotton (9). Little information is available for controlling jointed goatgrass, downy brome, and horseweed in conservation-tillage systems in the southern Great Plains. The purpose of this research was to find effective and economical herbicide controls for these weeds growing in fallow fields.

MATERIALS AND METHODS

From 1986 through 1989, herbicide effectiveness was determined on different sized jointed goatgrass, downy brome, and horseweed plants growing on fallow land on or near the USDA Research Laboratory near Amarillo, TX. Soil was Pullman clay loam (fine, mixed, thermic family of Torrertic Paleustolls) having about pH 7.5 and 1.5% organic matter content. The three weed species were usually located in farmers fields that had been in sorghum the previous year. Jointed goatgrass and downy brome were mixed together in the same fields and horseweed was usually growing alone in other fields. The two grass weeds also were found growing together on roadsides. Herbicides tested included atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine], clethodim, dicamba (3,6-dichloro-2-methoxybenzoic acid), fenoxaprop {(±)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]-propanoic acid}, fluazifop-P {(*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid}, glyphosate, metsulfuron, paraquat, quizalofop, sethoxydim, thifensulfuron {3-[[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid}, triasulfuron {2-(2-chloroethoxy)-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide], tribenuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoic acid}, isooctyl ester and diethylamine salts of 2,4-D, and a prepackaged mixture[4] of glyphosate and 2,4-D plus surfactant. Rates of glyphosate, glyphosate + 2,4-D, 2,4-D, and dicamba are given as acid equivalent; others are active ingredient. Adjuvants used were a surfactant[5] at 0.5% v/v or 0.33 L/ha and a crop oil concentrate[6] at 2.4 L/ha. Ammonium sulfate at 70 g/L was added to the spray solution when glyphosate was used alone on horseweed.

Herbicides were applied in 66 L/ha of water at 206 kPa through flat fan tips using a tractor-mounted plot sprayer. Plots were from 2 to 5 m wide and 10 m long. Herbicide treatments at each time of application were replicated three times in a randomized complete block design. There were six treatment times for jointed goatgrass and downy brome, and three for horseweed. At time of treatment, plant vigor or condition, which was primarily determined by availability of soil water, was rated visually as either excellent, good, fair, or poor. "Excellent" indicated lush plant growth; "good," somewhat restricted plant growth; "fair," very little active plant growth; and "poor," plant growth stopped and leaves starting to wilt. Also, plant height and growth stage were recorded. Percent control on a 0 to 100 scale was estimated visually 3 to 6 wk after treatment. Means were separated using a combination of ANOVA and LSD at $P = 0.05$.

An attempt was made to assess the practical significance of the results by comparing costs of treatments, including application, that resulted in 95% or better control. The control level of 95% was selected because this is the minimum acceptable control in no-tillage systems in the southern Great Plains where a few weeds can seriously deplete soil water during fallow periods. Application cost used was $7.50/ha[7]. Herbicide and adjuvant costs were obtained from a local cooperative elevator and farm supply.

[4]Landmaster BW, a mixture of 100 g/L glyphosate and 182 g/L 2,4-D, Monsanto Agricultural Co., 800 N. Lindbergh Blvd., St. Louis, MO 63167.

[5]X-77, 100% alkylaryl polyoxyethylene glycols, free fatty acids and isopropanol from Valent U.S.A. Corp., P.O. Box 8025, Walnut Creek, CA 94596-8025.

[6]Prime Oil, paraffin based crop oil polyol fatty acid esters, 83%, Terra International Inc., Box 20606, Waco, TX 76702-0606.

[7]Personal communication. 1994. Steven Amazzon, Texas Agric. Ext. Ser., 6500 Amarillo Blvd. West, Amarillo, TX 79106.

Table 1. Control of jointed goatgrass 3 to 6 wk after treating at various growth stages and plant vigor.[a]

Treatment[b]	Herbicide[c] rate	Application date: Apr. 8, 1987	May 11, 1987	Apr. 4, 1986	Apr. 20, 1988	May 4, 1988	Apr. 28, 1986
	g/ha	%					
Glyphosate + X-77	310	—	—	—	87	85	—
	430	—	—	—	98	98	—
Glyphosate + 2,4-D	294 + 479	96	95	93	—	—	23
	440 + 718	99	99	100	97	89	51
	582 + 950	100	99	98	—	—	76
Paraquat + X-77	560	45	75	80	13	77	61
Quizalofop + COC	18	0	10	13	28	30	10
	36	97	18	86	58	28	16
Fenoxaprop + COC	68	3	0	26	—	—	0
	280	7	0	33	7	23	0
Fluzifop-P + COC	68	57	7	100	—	—	0
	134	55	7	100	55	27	0
	280	99	3	100	87	30	6
Sethoxydim + COC	340	50	7	100	32	55	16
Clethodim + COC	68	50	3	100	—	—	6
	280	99	13	100	99	85	33
LSD 0.05		13	19	24	10	11	11
Weed height, cm		8	25	8	5	20	30
Weed vigor		Excellent	Excellent	Good	Fair	Fair	Poor
Weed stage		Tiller	Boot	Tiller	Tiller	Boot	Headed

[a]A dash indicates herbicide treatment not applied at this date.

[b]COC = Crop Oil Concentrate used at 2.4 L/ha and X-77 surfactant at 0.33 L/ha.

[c]Rates of glyphosate and glyphosate + 2,4-D are given in acid equivalent. Others are in active ingredient.

RESULTS AND DISCUSSION

Jointed goatgrass. In general, best control of jointed goatgrass with low herbicide rates was obtained when plants were 8 cm or less tall, in the tiller stage, and in good or excellent condition (Table 1). Quizalofop, fluazifop-P, sethoxydim, and clethodim controlled nonstressed jointed goatgrass better when plants were in the tiller stage prior to the boot stage. For example, in two experiments quizalofop at 36 g/ha controlled 86 and 97% of jointed goatgrass in the tiller stage compared to 18 and 28% control of jointed goatgrass plants in the boot stage. Glyphosate + 2,4-D was equally effective on plants in the tiller or boot stages. Control of jointed goatgrass in excellent or good condition with glyphosate + 2,4-D at 294 + 479 g/ha was 93% or better regardless of plant size. Medium rates of glyphosate, and glyphosate + 2,4-D controlled 5-cm tall plants in fair condition by 87% or better. Herbicides and minimum application rates providing 95% or better control of 8-cm tall weeds in either good or excellent condition were glyphosate + 2,4-D at 294 + 479 g/ha and fluazifop-P, 280 g/ha. Glyphosate + 2,4-D at 440 + 718 g/ha provided 89% or better control of 5- to 25-cm tall jointed goatgrass as long as plants were not in poor condition from moisture stress. When plants were in poor condition, the highest application rate of glyphosate + 2,4-D (582 + 950 g/ha) controlled only 76% of 30-cm tall jointed goatgrass that was headed and growing in dry soil. This indicates that even the best herbicide treatment could not control large, moisture-stressed jointed goatgrass. Fenoxyprop was ineffective regardless of rate, plant size, or vigor. Paraquat at 560 g/ha controlled jointed goatgrass no better than 80%.

Downy brome. Glyphosate + 2,4-D at 440 + 718 g/ha provided 90% or better control of plants in the tiller or boot stages and in fair to excellent condition (Table 2). However, control of severely stressed (poor vigor) plants in the boot stage was 71% compared with 90% control of nonstressed plants in the boot stage. This indicates plant vigor probably was more important than growth stage in determining herbicide effectiveness. Herbicide treatments that controlled 90% or more of 5-cm tall plants in good condition were: glyphosate at 310 g/ha; glyphosate + 2,4-D at 229 + 374 g/ha; quizalofop at 18 g/ha; fluazifop-P at 280 g/ha; and clethodim at 280 g/ha. Least control was obtained of 20- or 25-cm tall plants in fair or poor condition.

Table 2. Control of downy brome 3 to 6 wk after treating at various growth stages and plant vigor.[a]

Treatment[b]	Herbicide[c] rate	Application date					
		Apr. 8, 1987	May 11, 1987	Apr. 4, 1986	Apr. 28, 1988	May 4, 1988	Apr. 28, 1986
	g/ha	%					
Glyphosate + X-77	310	—	93	—	—	75	—
	430	—	93	—	—	97	—
Glyphosate + 2,4-D	229 + 374	—	92	—	—	72	—
	294 + 479	83	—	78	75	—	58
	440 + 710	90	93	93	93	94	71
	582 + 950	95	—	97	96	—	76
Paraquat + X-77	560	73	80	15	0	57	23
Quizalofop + COC	18	77	97	36	82	13	6
	36	80	92	93	96	17	40
Fenoxaprop + COC	68	0	—	0	13	—	0
	280	7	0	0	10	0	0
Fluazifop-P + COC	68	50	—	21	47	—	45
	134	60	48	23	70	32	58
	280	67	98	30	88	38	65
Sethoxydim + COC	340	70	58	13	47	38	66
Clethodim + COC	68	20	—	11	28	—	56
	280	82	90	30	88	58	73
LSD 0.05		17	13	8	12	25	7
Weed height, cm		28	5	10	10	20	25
Weed vigor		Excellent	Good	Good	Good	Fair	Poor
Weed stage		Boot	Tiller	Tiller	Tiller	Tiller	Boot

[a]A dash indicates herbicide treatment not applied at this date.

[b]COC = Crop Oil Concentrate used at 2.4 L/ha and X-77 surfactant at 0.33 L/ha.

[c]Rates of glyphosate and glyphosate + 2,4-D are given in acid equivalent. Others are in active ingredient.

Fenoxaprop at 68 or 280 g/ha controlled downy brome less than 13% regardless of plant vigor or size. Paraquat at 560 g/ha provided no better than 80% control.

Horseweed. Horseweed plants were treated when either 5, 10, or 30 cm tall. Best control was obtained when 30-cm tall plants in good condition were sprayed in July, and least control was obtained when moisture-stressed, 5-cm tall rosettes were treated in March (Table 3). The poor vigor of small horseweed occurred because plants emerged in the fall and very little precipitation fell during the winter. For example, 2,4-D ester at 560 g/ha controlled 100% of 30-cm tall horseweed, but only 47% of plants in the rosette stage. Metsulfuron, triasulfuron, thifensulfuron, and tribenuron were much less effective on smaller than larger plants. Atrazine + 2,4-D ester at 1120 + 1120 g/ha controlled horseweed by 89% or better regardless of growth stage. Herbicide treatments providing 95% or better control of large, vigorously growing horseweed were: 2,4-D ester at 560 g/ha; dicamba at 280 g/ha; atrazine + 2,4-D at 3360 + 1120 g/ha; chlorsulfuron at 13 g/ha; metsulfuron at 5 g/ha; metsulfuron + 2,4-D at 5 + 560 g/ha; triasulfuron at 13 g/ha; and thifensulfuron at 13 g/ha. For plants in poor condition, 95% or better control of 5-cm tall weeds was obtained with the following treatments: 2,4-D ester at 2240 g/ha; atrazine + 2,4-D at 1120 + 1120 g/ha; chlorsulfuron at 13 g/ha; and metsulfuron + 2,4-D at 5 + 560 g/ha. These results are contrary to those obtained by Keeling et al. (9) who reported best control in the rosette stage.

In these experiments, the most effective and consistent herbicidal control of jointed goatgrass and downy brome growing in fallow fields was obtained when weeds were 10 cm or less tall and growing vigorously at time of treatment. Best control of horseweed was obtained when 30-cm tall, vigorously growing plants were treated. However, horseweed plants that were 5-cm tall rosettes also were controlled well by atrazine + 2,4-D ester. This study suggests that plant vigor is equally as important as growth stage for effective jointed goatgrass and downy brome control with several of the herbicides evaluated. Precipitation in the southern Great Plains usually is not adequate to maintain vigorous growth throughout the life of the plant. Therefore, best control most likely would be obtained by treating weeds when they are young and growing vigorously. In contrast, horseweed was difficult to control in the

Table 3. Control of horseweed 3 to 6 wk after treating at various growth stages and plant vigor.[a]

Treatment[b]	Herbicide[c] rate	Application date: Apr. 25, 1988	July 13, 1988	Mar. 15, 1989
	g/ha		%	
2,4-D ester	560	58	100	47
	1120	68	99	80
	2240	80	97	96
2,4-D amine	1120	57	92	63
Dicamba	280	57	98	83
	560	75	100	88
Atrazine + 2,4-D ester + COC	1120 + 1120	95	89	98
	3360 + 1120	90	99	99
Chlorsulfuron + X-77	13	23	100	97
	26	42	100	100
Metsulfuron + X-77	5	38	97	67
Metsulfuron + 2,4-D ester + X-77	5 + 560	32	100	95
Triasulfuron + X-77	13	47	97	50
	26	32	98	50
Thifensulfuron + X-77	13	3	97	13
	26	7	90	7
Tribenuron + X-77	13	47	93	38
	36	58	92	27
Paraquat + X-77	560	17	0	35
Glyphosate + ammonium sulfate + X-77	212	15	—	23
	314	42	—	43
Glyphosate + 2,4-D + ammonium sulfate	229 + 374	35	—	50
	324 + 529	88	—	67
	440 + 718	95	—	83
LSD 0.05		12	10	23
Weed height, cm		10	30	5
Weed vigor		Good	Good	Poor
Weed stage		5 leaf	14 leaf	Rosette

[a]A dash indicates herbicide treatment not applied at this date.

[b]COC = Crop Oil Concentrate used at 2.4 L/ha and X-77 surfactant at 0.33 L/ha.

[c]Rates of 2,4-D, dicamba, glyphosate, and glyphosate + 2,4-D are given in acid equivalent. Others are in active ingredient.

rosette stage regardless of plant vigor. Unfortunately, horseweed that had bolted and was moisture stressed was not treated, so the effect of vigor at this stage was not determined.

Herbicide treatments that provided 95% or more weed control under optimum conditions are shown in Table 4 along with approximate cost to farmers in the southern Great Plains. The two most economical herbicide treatments for each weed species were: jointed goatgrass, glyphosate + 2,4-D at 294 + 479 g/ha and clethodim at 280 g/ha; downy brome, quizalofop at 18 g/ha and glyphosate + 2,4-D at 582 + 950 g/ha; horseweed, 2,4-D ester at 560 g/ha and metsulfuron, 5 g/ha.

It is likely that more than one weed would be present in a fallow field, so selection of the herbicide treatment would depend on the weeds present. Our results indicate glyphosate + 2,4-D at 582 + 950 g/ha was the most economical herbicide treatment for controlling jointed goatgrass and downy brome. This rate was not evaluated on 30-cm tall horseweed, but considering 95% control of 10-cm tall horseweed was obtained with glyphosate + 2,4-D at 440 + 718 g/ha, the higher rate needed to control downy brome also would control 30-cm tall horseweed. Sweep tillage in March or early April is another practical alternative for controlling the three weed species in a conservation-tillage system where some tillage is used (4).

Table 4. Herbicide rates of application and cost to local farmers that would result in 95% or more control of jointed goatgrass and downy brome not over 10-cm tall and 30-cm tall horseweed when plants had excellent or good vigor.

Species and treatment	Herbicide rate	Cost[a]
	g/ha	$/ha
Jointed goatgrass		
Fluazifop-P + COC	280	49.70
Glyphosate + 2,4-D	294 + 479	19.20
Clethodim + COC	280	45.93
Downy brome		
Fluazifop-P + COC	280	49.70
Glyphosate + 2,4-D	582 + 950	33.40
Quizalofop + COC	36	33.60
Horseweed		
Atrazine + 2,4-D + COC	3360 + 1120	31.36
Chlorsulfuron + X-77	13	17.90
Dicamba	280	20.10
Metsulfuron + X-77	5	17.20
Metsulfuron + 2,4-D + X-77	5 + 560	21.90
Thifensulfuron + X-77	13	NA
Triasulfuron + X-77	13	17.90
2,4-D ester	560	11.40

[a]Cost includes herbicide cost from local cooperative elevator; plus, cost of application at $7.50, COC at $2.75, and X-77 at $1.50 per ha.

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