Weed Science, 45:288–295. 1997

Economic evaluation of field bindweed (*Convolvulus arvensis*) control

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This research compared seven field bindweed control treatments to a check in a 3-yr winter wheat–sorghum–fallow rotation. Treatments included 3 wk intervals of sweep tillage combined with one or two annual applications of 2,4-D (tillage and 2,4-D). Two other treatments were the same as tillage and 2,4-D, except dicamba or a mixture of picloram and 2,4-D were applied once in October after wheat harvest. A fourth treatment was identical to tillage and 2,4-D, except imazapyr was sprayed immediately after harvest of wheat. Also, three no-tillage systems using glyphosate and 2,4-D at monthly intervals were supplemented with either dicamba, picloram and 2,4-D, or imazapyr the same as in treatments involving tillage and 2,4-D. The check was sweep tilled every 6 wk. All treatments controlled field bindweed in one rotation of two fallow periods and two crops. After control was accomplished, wheat and sorghum yields were about twice the check. Using 1995 costs and returns, profit for an owner–operator for the two fallow periods and two crops was \$123 ha^{-1} for tillage and 2,4-D, compared to \$19 ha^{-1} for the check. Tillage and 2,4-D supplemented with picloram or imazapyr were almost as profitable as tillage and 2,4-D. Because of high herbicide cost and low yields, no-tillage treatments lost money. Profits with a 33:67 owner–tenant rental agreement were \$105 and \$21 ha^{-1}, respectively, for owner and tenant using tillage and 2,4-D. With no field bindweed control practice, the tenant lost \$33 ha^{-1} and the owner made \$51 ha^{-1}.

Nomenclature: dicamba, 3,6-dichloro-2-methoxybenzoic acid; 2,4-D, (2,4-dichlorophenoxy)acetic acid; glyphosate, *N*-(phosphonomethyl)glycine; imazapyr, (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid; picloram, 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid; field bindweed, *Convolvulus arvensis* L. CONAR; sorghum *Sorghum bicolor* L. Moench 'Jacques 377W,' winter wheat, *Triticum aestivum* L. 'TAM 200.'

Key words: Economic return, sweep tillage, CONAR.

Field bindweed is a creeping, herbaceous, perennial weed native to Europe and western Asia that was introduced to North America along the Atlantic seaboard about 1790 (Phillips 1978). The weed has spread coast to coast and is a serious problem in wheat-growing areas in the western U.S. Field bindweed is very competitive because it has an extensive perennial root system and produces seed that remain viable for 50 yr (Brown and Porter 1942).

Research in the 1930s and 1940s indicated sweep plowing at 2- to 3-wk intervals for 3- to 5-yr controlled large infestations of field bindweed by gradually reducing root reserves (Phillips and Timmons 1954; Wiese and Rea 1959). In the late 1940s, it was demonstrated that 2,4-D was toxic to field bindweed (Hamner and Tukey 1944; Phillips 1950). In humid areas, the greatest control was achieved by applying 2,4-D when plants were budding. However, this did not hold true for dry areas like the southern Great Plains, where drought often limits plant growth and vigor. Under dry conditions, most consistent control with 2,4-D was obtained when runners were 15 to 25 cm long and plants were growing vigorously. By the budding stage, plants usually were out of soil water and growing poorly if at all (Wiese and Rea 1955). Although 2,4-D was very effective, repeated applications alone did not eliminate the weed (Phillips 1961; Swan 1982; Wiese and Lavake 1986). The most effective use of 2,4-D was in conjunction with tillage at 2- to 3-wk intervals during fallow periods between crops that are competitive with field bindweed (Derscheid et al. 1970; Phillips 1961; Russ and Anderson 1960; Stahlman 1978; Schweizer et al. 1978; Swan 1982; Wiese and Rea 1959). Combining 2,4-D applications with tillage reduced control cost by decreasing the number of tillages per year and the number of years required to control the weed. Also, if rain delayed tillage, 2,4-D treatment of large weeds prevented buildup of root reserves (Wiese and Rea 1962). In addition to 2,4-D, dicamba, glyphosate, imazapyr, or picloram, applied alone or in combinations, have been effective in controlling field bindweed (Gooding et al. 1967; Heering and Peeper 1988; Schoenhals et al. 1990; Wiese et al. 1967; Wiese and Lavake 1986) and may be useful when combined with repeated tillage. Recently, fluroxypyr (MacDonald et al. 1993) has proven effective against field bindweed.

Conservation compliance requirements are another dimension that affect field bindweed control programs and may prevent tillage at 2- to 3-wk intervals because of erosion potential (Federal Register 1987). Consequently, no-tillage cropping systems need to be developed that will control field bindweed while retaining crop residues on the soil surface to minimize erosion.

Winter wheat–sorghum–fallow, where two crops are grown in 3 yr, is a possible crop rotation for field bindweed control in dry areas because of ample time for repeated till-

TABLE 1. Tillage and spray treatments used during fallow periods in a winter wheat–sorghum–fallow rotation.

Treatment no.	Fallow treatment designation	Planned tillage and sprays
1	Check	Sweep-tillage at 6-wk intervals.
2	Tillage and 2,4-D	Sweep tillage at 3-wk intervals plus 2,4-D at 1.1 kg ha^{-1} to 5-wk-old field bindweed regrowth that was vigorous because of ample precipitation; 2,4-D at 0.6 kg ha^{-1} to wheat. Atrazine was applied at 1.7 kg ha^{-1} to 15 cm tall sorghum for annual weed control.
3	Tillage and dicamba	Like Treatment 2, plus dicamba at 2.2 kg ha^{-1} applied once to 5-wk-old field bindweed regrowth during October after the 1st wheat harvest.
4	Tillage and picloram	Like Treatment 2, plus picloram + 2,4-D at 0.28 + 0.6 kg ha^{-1} applied once to 5-wk-old field bindweed regrowth during October after the 1st wheat harvest.
5	Tillage and imazapyr	Like Treatment 2, plus imazapyr applied once at 0.26 or 0.13 kg ha^{-1} to stubble immediately after the 1st wheat harvest. (The 0.26 kg ha^{-1} rate was used the first year in the 1985 experiment but caused sorghum injury, after which 0.13 kg ha^{-1} was used.)
6	No-tillage and dicamba	Instead of sweep tillage for control of field bindweed and annual weeds, the basic treatment was 4-wk applications of glyphosate + 2,4-D at 0.4 + 0.6 kg ha^{-1}. Dicamba at 2.2 kg ha^{-1} was applied to 5-wk-old field bindweed regrowth during October after the 1st wheat harvest. Atrazine at 3.3 kg ha^{-1} was applied to wheat stubble immediately after harvest; chlorsulfuron at 0.034 kg ha^{-1} was applied to sorghum stubble in April about 5 mo after harvest. Atrazine was applied at 1.7 kg ha^{-1} to 15 cm tall sorghum for annual weed control.
7	No tillage and picloram	Like Treatment 6, except dicamba was omitted and picloram + 2,4-D at 0.28 + 0.6 kg ha^{-1} was applied once to 5-wk-old field bindweed regrowth during October after the 1st wheat harvest.
8	No-tillage and imazapyr	Like Treatment 6, except dicamba was omitted and imazapyr was sprayed once at either 0.26 or 0.13 kg ha^{-1} to stubble immediately after wheat harvest. Atrazine at 3.3 kg ha^{-1} was not applied to wheat stubble.

age or other control measures during the 11-mo fallow periods. Field bindweed control in this rotation has never been reported. Winter wheat is the most competitive crop to use in a field bindweed control program in the southern Great Plains because it grows during the late fall, winter, and early spring when field bindweed is dormant and cannot compete for limited precipitation and stored soil water. When field bindweed emerges in late spring, winter wheat is 15 cm tall, shading the weed, and has an established root system that is able to compete effectively for soil water. Sorghum, by contrast, is a poor competitor because it has the same growing season and cannot compete with field bindweeds' established root system for soil water (Wiese and Rea 1959).

The profitability or cost of various systems for field bindweed control only has been evaluated in a winter wheat–fallow rotation (Wiese et al. 1996). The objective of this research was to determine the profitability of field bindweed control using either 2,4-D, dicamba, imazapyr, or picloram with either sweep plowing at 3-wk intervals or no-tillage during fallow periods in a winter wheat–sorghum–fallow rotation.

Materials and Methods

This study was conducted on Pullman clay loam (fine, mixed, thermic, Torrertic Paleustoll) having 1.5% organic matter and pH 7.7 near Bushland, TX, in the southern Great Plains on a field uniformly infested with field bindweed. The study areas had not been cropped for several years, but were sweep plowed three or four times annually to control annual weeds and encourage growth of field bindweed. Two identical experiments during fallow periods in a winter wheat–sorghum–fallow rotation were initiated June 1985 and March 1986. In this rotation, a fallow period of about 11 mo occurs from wheat harvest in late June of 1 yr to sorghum planting in early June the following year. After sorghum harvest in October or November, there is a second fallow period of about 11 mo prior to wheat planting in September. Plots were 8 by 18 m. Sorghum was planted in 1-m wide rows at 2.2 kg ha^{-1} (three seed per m of row) with a planter equipped with disk openers. TAM 200 winter wheat was planted in 25-cm rows at 33 kg ha^{-1} (10 seed per m of row) with a drill having 2.5-cm wide chisels. Experiments were continued for one rotation of two crops and two fallow periods. A third fallow period was included on one of the fields where control was not complete after two fallow periods and on two other fields to see if control persisted.

Herbicides used were the butoxyethylester formulation of 2,4-D; atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine]; dimethylamine salt of dicamba; commercial formulation of isopropylamine salts of 2,4-D + glyphosate[1]; chlorsulfuron {2-chloro-*N*-[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide}; imazapyr; and 2,4-D tank mixed with a potassium salt of picloram. Herbicides were applied broadcast with a tractor plot sprayer in 240 L ha^{-1} spray mixture at 210 kPa using flat fan tips. Sweep tillage was 10 cm deep with an implement having five V-shaped blades that were each 0.8 m wide. Details of eight treatments including herbicide rates used during fallow periods and designations used in the paper are outlined in Table 1. The untreated check was sweep tilled at 6-wk intervals (Treatment 1). This controlled annual weeds yet allowed field bindweed to flourish without competition. The basic operations in the next four treatments were sweep tillages at 3-wk intervals. This schedule was changed with application of 2,4-D at 1.1 kg ha^{-1} to 5-wk-old field bindweed regrowth whenever sufficient rain fell during a fallow period to promote vigorous plant growth (Treatment 2). In other words, if soil was too wet to sweep till at the scheduled time, 2,4-D was applied 2 wk later. One of the four treatments was modified with an application of dicamba at 2.2 kg ha^{-1} to 5-wk-old field bindweed regrowth during October after wheat harvest regardless of growing conditions (Treatment 3). Another received picloram + 2,4-D at 0.28 + 0.6 kg ha^{-1} at the same time (Treatment 4). Imazapyr at 0.13 kg ha^{-1} was applied to wheat stubble immediately after harvest (Treatment 5). Only one application of dicamba, imazapyr, or picloram + 2,4-D was made during the two fallow periods. The remaining three treatments were not tilled, and weeds including field bindweed were controlled with applications of a glyphosate–2,4-D formulation at 0.28 + 0.5 kg ha^{-1} every 4 wk. If grass weeds were not present, 2,4-D at 1.1 kg ha^{-1} was used instead of the glyphosate + 2,4-D to reduce cost. Atrazine at 3.3 kg ha^{-1} was applied to stubble immediately after wheat harvest, and chlorsulfuron at 0.034 kg ha^{-1} was applied to sorghum stubble in April about 5 mo after harvest. Dicamba and picloram + 2,4-D were applied to two treatments the same as with sweep tillage (Treatments 6 and 7). Finally, imazapyr was applied the same as in Treatment 5 to Treatment 8.

Winter annuals, primarily flixweed [*Descurainia sophia* (L.) Webb. ex Prantl], were controlled in winter wheat with 2,4-D at 0.5 kg ha^{-1} in late February where sweep tillage was the basic treatment. Chlorsulfuron at 0.034 kg ha^{-1} was used at the same time in wheat with no-tillage treatments. Chlorsulfuron, which persisted in soil, helped control annual weeds in subsequent no-tillage fallow. When sorghum was 15 cm tall, all treatments were sprayed with atrazine at 1.7 kg ha^{-1} postemergence to control annual weeds, primarily Palmer amaranth (*Amaranthus palmeri* S. Wats.).

To harvest sorghum and wheat each year, each phase of the rotation was started the first year of the experiment. Consequently, there were 24 plots to make three replications. The length of fallow periods the first year in both the 1985 and 1986 experiments were less than the normal 11 mo. The parts of the rotation planted to sorghum, planted to wheat, or in fallow the first year of the 1985 experiment were designated as Fields 85S, 85W, and 85F, respectively. In 1986, fallow, sorghum, and wheat plots, respectively, were Fields 86F, 86S, and 86W. Consequently, there are Fields 85S, 85W, 85F, 86F, 86S, and 86W listed in tables. The 1985 experiment was initiated June 19, 1985. Field 85S was planted to sorghum June 19, 1985, without a fallow period, and the first fallow started after sorghum harvest. Field 85W was planted to wheat October 25, 1985, after 4 mo of fallow. The first fallow period on Field 85F was from June 19, 1985, until sorghum planting June 20, 1986. The 1986 experiment was started March 7, and Field 86F was planted to spring wheat that was destroyed July 1 when the first fallow started. After a normal fallow period, sorghum was planted June 12, 1987. Field 86S was planted to sorghum June 20, 1986, after a 3-mo fallow. The 86W field was planted to wheat October 17, 1986, after a 7-mo fallow. The second fallow periods were all the normal 11 or 12 mo. Treatments in each field were continued for one rotation of two fallow periods, one sorghum crop, and one wheat crop. Yields were not obtained as planned because, in 1989, wheat on Fields 85W and 86F was destroyed by hail. Experiments were divided into areas of either wheat, sorghum, or fallow. Seven control treatments and the check were imposed during the fallow periods in each rotation. ANOVA was used to analyze data from each crop or fallow area as a randomized complete block. Means were separated using Duncan's New Multiple Range Test at the 0.05 level of probability. Field bindweed percent control was visually estimated at the end of each fallow period just before crop planting. Gravimetric soil water content at 0.3-m increments to 1.2 m was determined at wheat planting, and crops were harvested with a plot combine from a 1.3-by 18-m area. Grain yield was corrected to 13% moisture.

Short-term economic analyses were calculated for two fallow periods and two crops. The analyses considered crop income and all production costs including herbicides, tillage, spraying, planting, seed, and interest, along with cost of harvesting and hauling grain to the elevator. For simplicity, interest was 10% for 1 yr on all items except harvest and hauling. Costs for management, land, and machinery depreciation were not considered.

Custom charges for spraying and sweep tillage were \$7.50 and \$12.50 ha^{-1}, respectively (Findley and Waldrop 1992). Planting cost was \$12.50 ha^{-1} for sorghum and wheat. Costs of wheat and sorghum seed were \$7.50 and \$2.50 ha^{-1}, respectively. Herbicide costs to farmers in \$ kg^{-1} were obtained from a local cooperative elevator in June 1995 and were atrazine, \$7; glyphosate, \$36; 2,4-D, \$7; dicamba, \$45; chlorsulfuron, \$684; and picloram, \$107. Wheat and sorghum prices used were \$0.18 and \$0.13 kg^{-1}, respectively, or about the average growers received in 1995.

Analyses were made for an owner–operator with average as well as lowest yields from these experiments. A similar analysis of the treatments was made for a 33:67 owner–tenant lease using average yields from the experiments. Crop yields for the analyses were calculated by averaging sorghum or wheat yields following one and two fallow periods. This was done to have representative yields for the 3-yr control program. Where field bindweed had been controlled, yields were higher after the second fallow period. Crop income and expenses were averaged for the 1985 and 1986 experiments.

Results and Discussion

Field bindweed control at the end of the first fallow period increased with length of fallow period (Table 2). Fields 85W and 86S with 3- or 4-mo fallow periods had 60% or less control, except treatments with no-tillage and dicamba and no-tillage and imazapyr on Field 86W. Control on Field 86F also was low and varied from 10 to 73%.

After 2 yr of fallow, average control from six fields was 88% or greater for all treatments, except tillage and 2,4-D (Table 2). Control treatments were carried out for a third fallow period on Fields 85W, 86S, and 86W that had first fallow periods of 7 mo or less (Table 2).

After three fallow periods, there were no differences among treatments, and control ranged from 93 to 100% on Field 85W, where control had been low after one and two fallow periods. The low control on this field after two fallow periods came about because the first fallow period was only 4 mo. Field bindweed was controlled when there were two full 11-mo fallow periods. However, if for some reason the first fallow period was not 11 mo, allowing the maximum number of tillage and herbicide applications, a third fallow

TABLE 2. Field bindweed control after one, two, or three fallow periods.[a]

Fallow treatment	Field bindweed control						
	After one fallow period in fields						
	85S	85W	85F	86F	86S	86W	Avg.
	%						
Check	0 d	0 c	0 c	0 d	0 c	0 e	0 B
Tillage and 2,4-D	56 c	45 ab	66 b	22 bc	20 bc	98 a	51 A
Tillage and dicamba	76 b	43 ab	81 ab	63 a	6 c	88 ab	60 A
Tillage and picloram + 2,4-D	91 a	60 a	86 ab	70 a	26 b	67 bc	67 A
Tillage and imazapyr	73 ab	47 ab	83 ab	33 b	84 a	73 bc	66 A
No-tillage and dicamba	93 a	30 b	100 a	73 a	6 c	53 cd	59 A
No-tillage and picloram + 2,4-D	94 a	40 b	100 a	58 a	6 c	30 d	55 A
No-tillage and imazapyr	66 bc	42 ab	66 b	10 cd	86 a	70 bc	57 A
Preceding crop	Sorghum	None	None	Wheat	None	None	
Fallow period, mo	12	4	12	11	3	7	
Subsequent crop	Wheat	Wheat	Sorghum	Sorghum	Sorghum	Wheat	
Precipitation, fallow period, mm	460	345	574	605	174	414	
Precipitation average, mm[b]	469	258	469	393	163	396	

Fallow treatment	After two fallow periods in fields						
	85S	85W	85F	86F	86S	86W	Avg.
	%						
Check	0 c	0 d	0 b	0 c	0 b	0 b	0 C
Tillage and 2,4-D	75 b	42 c	100 a	77 b	100 a	94 a	81 B
Tillage and dicamba	100 a	99 a	100 a	97 a	100 a	100 a	99 A
Tillage and picloram + 2,4-D	100 a	100 a	100 a	93 ab	100 a	100 a	99 A
Tillage and imazapyr	97 a	77 b	100 a	97 a	100 a	99 a	95 A
No-tillage and dicamba	100 a	85 ab	100 a	100 a	100 a	99 a	95 A
No-tillage and picloram + 2,4-D	100 a	68 bc	100 a	90 ab	100 a	100 a	93 A
No-tillage and imazapyr	82 ab	48 c	100 a	97 a	100 a	99 a	88 AB
Preceding crop	Wheat	Wheat	Sorghum	Sorghum	Sorghum	Wheat	
Fallow period, mo	12	12	11	11	11	11	
Subsequent crop	Sorghum	Sorghum	Wheat	Wheat	Wheat	Sorghum	
Precipitation, fallow period, mm	517	587	560	518	560	517	
Precipitation, average, mm[b]	444	469	430	430	430	444	

Fallow treatment	After three fallow periods in fields			
	85W	86S	86W	Avg.
	%			
Check	0 b	0 b	0 b	0 B
Tillage and 2,4-D	93 a	90 a	99 a	94 A
Tillage and dicamba	100 a	98 a	98 a	99 A
Tillage and picloram + 2,4-D	100 a	95 a	97 a	97 A
Tillage and imazapyr	97 a	99 a	100 a	99 A
No-tillage and dicamba	100 a	93 a	100 a	98 A
No-tillage and picloram + 2,4-D	93 a	93 a	100 a	95 A
No-tillage and imazapyr	100 a	89 a	99 a	96 A
Preceding crop	Sorghum	Wheat	Sorghum	
Fallow period, mo	11	11	10	
Subsequent crop	Wheat	Sorghum	Wheat	
Precipitation, fallow period, mm	505	524	500	
Precipitation, average, mm[b]	430	432	530	

[a] Means within columns followed by the same letter are not different at P = 0.05 using Duncan's New Multiple Range test.
[b] Average precipitation for 40 yr at Bushland, TX, for the months involved in the fallow period.

Table 3. Available water in 1.2 m of soil profile at wheat planting.[a]

Fallow treatment	After one fallow[b]	After two fallows[c]
	mm	
Check	52	50 c
Tillage and 2,4-D	68	98 ab
Tillage and dicamba	69	109 a
Tillage and picloram + 2,4-D	77	107 ab
Tillage and imazapyr	74	104 ab
No-tillage and dicamba	55	84 b
No-tillage and picloram + 2,4-D	49	86 b
No-tillage and imazapyr	53	81 b

[a] Means within columns followed by the same or no letter are not different at P = 0.05 using Duncan's New Multiple Range test.
[b] Average of Fields 85S and 86W.
[c] Average of Fields 85F, 86F, 86S, and 86W.

period was needed, as in Field 85W. This is in agreement with results from a similar experiment with a winter wheat–fallow rotation at the same location (Wiese et al. 1996).

Available soil water content in a 1.2-m soil profile was determined just prior to wheat planting on Fields 85S and 86W after one fallow period and Fields 85F, 86F, 86S, and 86W after two 11- or 12-mo fallow periods (Table 3). Data were analyzed separately for one or two fallow periods. There were no interactions among fields, so data were averaged. After one fallow period, there was no difference among treatments and the check, indicating that controls had not been in place long enough to affect soil water use by field bindweed. After control treatments were in place for two fallow periods, field bindweed was adequately controlled, so that available soil water with sweep tillage treatments was about twice that of the check. Soil water content was less with the three no-tillage treatments than with the best sweep tillage treatment. Because field bindweed control was equal with all treatments, water use by weeds should not have caused the difference. A more logical explanation is that not enough sorghum crop residue was on the soil surface of no-tillage plots to hamper runoff from the 2% slope. Runoff was retarded by the rough soil surface created with sweep tillage. This effect was observed in a dryland cropping systems experiment about 5 km from this research (Jones and Johnson 1993). These nearby experiments indicated runoff was minimized under dryland conditions with no-tillage after wheat and sweep tillage after sorghum in a wheat–sorghum–fallow rotation.

One fallow period was generally not adequate to affect wheat yield (Table 4). There was no difference among treatments and check in the average of the three fields. After two fallow periods, wheat yields with sweep tillage treatments were more than twice the check. Wheat yield with no-tillage was as low or lower than the check. The reason for this is not known but may be due in part to less soil water at planting. Wheat yields of about 2,000 kg ha^{-1} from sweep tillage were high for the area because precipitation during fallow and crop seasons was above long-term averages (Table 4).

Sorghum yields also were high for dryland fields because of above normal precipitation (Table 5). After one fallow period, yields with sweep tillage treatments from three fields

Table 4. Wheat yield after one or two fallow periods.[a]

Fallow treatment	Wheat yield: After one fallow period in fields 85S	85W	86W	Avg.
	kg ha^{-1}			
Check	1,880	340 b	1,210	1,140
Tillage and 2,4-D	1,880	540	1,410	1,280
Tillage and dicamba	2,150	610	1,280	1,340
Tillage and picloram + 2,4-D	1,810	610	1,410	1,280
Tillage and imazapyr	2,220	540	1,280	1,340
No-tillage and dicamba	1,950	670	1,140	1,280
No-tillage and picloram + 2,4-D	1,810	610	1,340	1,280
No-tillage and imazapyr	2,150	540	1,210	1,280
Fallow period, mo	12	4	7	
Precipitation, fallow period, and wheat crop, mm	851	509	767	
Precipitation, average, mm[b]	709	465	657	

Fallow treatment	After two fallow periods in fields 85F	86S	Avg.
Check	940 b	740 b	840 C
Tillage and 2,4-D	1,950 a	1,750 a	1,850 B
Tillage and dicamba	2,020 a	1,950 a	1,980 AB
Tillage and picloram + 2,4-D	1,810 a	1,950 a	1,880 B
Tillage and imazapyr	2,220 a	2,220 a	2,220 A
No-tillage and dicamba	600 b	270 b	440 D
No-tillage and picloram + 2,4-D	470 b	400 b	440 D
No-tillage and imazapyr	940 b	470 b	710 CD
Fallow periods, mo	11	11	
Precipitation, fallow period and wheat crop, mm	873	873	
Precipitation, average, mm	698	698	

[a] Means within columns followed by the same letter or no letters are not different at P = 0.05 using Duncan's New Multiple Range test.
[b] Average precipitation at Bushland, TX, for 40 yr for the months involved with fallow period and wheat crop.

averaged almost 1,600 kg ha^{-1} and checks produced 340 kg ha^{-1}. After two fallow periods, checks from three fields averaged 1,240 kg ha^{-1}. There were no differences in yield among control treatments, which ranged from 1,840 to 2,070 kg ha^{-1}, except for no-tillage and dicamba. The reason for low yield with this treatment is not known.

Short-term economic analyses that did not consider machinery depreciation or returns for management and land for an owner–operator are given in Table 6. Because growers might start a control program at any time in the rotation, wheat and sorghum yields for one and two fallow periods from Tables 4 and 5 were averaged to calculate income. Using these assumptions, income for the check was \$281 ha^{-1}, while sweep tillage treatments produced over \$500 ha^{-1}. Income with no-tillage was much less because of low wheat yield. Tillage and 2,4-D was the most profitable control treatment. Expenses for the check or no treatment were \$262 ha^{-1} and ranged from \$382 ha^{-1} for sweep tillage and 2,4-D to \$486 ha^{-1} for no-tillage and dicamba. Returns

TABLE 5. Sorghum yield after one or two fallow periods.[a]

Fallow treatment	Sorghum yield: After one fallow period in fields 85F	86F	86S	Avg.
	kg ha^{-1}			
Check	200 c	470 b	360 c	340 B
Tillage and 2,4-D	1,760 a	1,510 a	1,460 b	1,580 A
Tillage and dicamba	1,840 a	1,620 a	1,320 b	1,590 A
Tillage and picloram + 2,4-D	1,620 a	1,430 a	1,750 a	1,600 A
Tillage and imazapyr	280 c	1,230 a	200 cd	570 B
No-tillage and dicamba	960 b	1,530 a	90 d	860 AB
No-tillage and picloram + 2,4-D	1,080 b	1,550 a	60 d	900 AB
No-tillage and imazapyr	70 c	1,550 a	30 d	550 B
Fallow period, mo	12	11	3	
Precipitation, fallow period and sorghum crop, mm	872	882	452	
Precipitation, average, mm[b]	732	722	332	

Fallow treatment	After two fallow periods in fields 85S	85W	86F	Avg.
	kg ha^{-1}			
Check	2,490 b	290 b	950 c	1,240 B
Tillage and 2,4-D	2,860 b	550 ab	2,110 a	1,840 A
Tillage and dicamba	3,050 ab	710 a	1,880 ab	1,880 A
Tillage and picloram + 2,4-D	3,050 ab	750 a	2,180 a	1,990 A
Tillage and imazapyr	2,890 b	740 a	2,090 a	1,910 A
No-tillage and dicamba	3,610 a	830 a	1,620 b	2,020 A
No-tillage and picloram + 2,4-D	3,200 ab	720 a	2,090 a	2,000 A
No-tillage and imazapyr	3,350 a	720 a	2,150 a	2,070 A
Fallow period, mo	12	12	11	
Precipitation, fallow period and sorghum crop, mm	811	906	774	
Precipitation, average, mm[b]	725	732	700	

[a] Means within columns followed by the same letter are not different at P = 0.05 using Duncan's New Multiple Range test.
[b] Average precipitation for 40 yr at Bushland, TX, for the months involved in the fallow period and sorghum crop.

were \$19 ha^{-1} for the check and ranged from \$123 ha^{-1} for tillage and 2,4-D to \$56 for tillage and dicamba on sweep tillage treatments. No-tillage treatments lost from \$79 ha^{-1} for no-tillage and imazapyr to \$144 ha^{-1} for no-tillage and dicamba. The losses with no-tillage treatments were caused by a combination of low wheat yield and high herbicide cost.

When returns were calculated using low wheat yields from Field 85W after one fallow period (Table 4) and sorghum yields from Field 85W after two fallow periods (Table 5), the situation changed markedly. Costs exceeded income by \$163 ha^{-1} on the check and from \$198 to \$267 ha^{-1} for control treatments. This indicates cost of control on marginal land with low yield potential would not be justified. Possible alternative use would be winter wheat or summer annual forage crops for grazing, with low inputs to minimize risk. Spraying 2,4-D on summer crops to suppress field bindweed and increase forage yield probably would be justified.

Calculating break-even yields for wheat and sorghum using 1995 prices would be about 1,100 kg ha^{-1} for wheat and 1,400 kg ha^{-1} for sorghum. With these yields, total income and expenses for sweep tillage and 2,4-D would be \$362 and \$382 ha^{-1}, respectively. This is a small loss of \$20 ha^{-1}.

A drop in grain price also would affect profit. Prices for sorghum and wheat in the fall of 1995 were high, \$0.18 and \$0.13 kg^{-1}, respectively with above average yields accounted for high profits. If prices dropped 25% to \$0.135 kg^{-1} for wheat and \$0.10 kg^{-1} for sorghum, returns would be \$381 ha^{-1} or \$1 ha^{-1} less than the \$382 ha^{-1} expenses for tillage and 2,4-D. In contrast, if no controls were initiated, income would be \$213 ha^{-1} to offset expenses of \$262 ha^{-1}. The loss would be \$49 ha^{-1}.

Long-term benefit for controlling field bindweed for an owner–operator could be estimated by calculating income from grain yields after the second fallow period in Tables 4 and 5 for tillage and 2,4-D. Expenses could be modified by reducing herbicide and sprayer cost in half, tillage cost the same as the check, and adjusting interest. Using these assumptions and 1995 grain prices, income would be \$571 ha^{-1} to offset expenses of \$254 ha^{-1}, making a profit of \$317 ha^{-1} for tillage and 2,4-D. If grain prices dropped 25%, income would be \$433 ha^{-1} to offset \$254 ha^{-1} expenses. Reducing grain prices to 50% of 1995 levels would result in \$286 ha^{-1} income and \$32 ha^{-1} profit.

TABLE 6. Short-term economic analyses of field bindweed control treatments for an owner-operator or owner-lease agreement considering two fallow periods and two crops in a wheat–sorghum–fallow rotation. These analyses do not consider machinery depreciation or returns for management and land.[a,b]

	Treatment numbers							
	1	2	3	4	5	6	7	8
	$ ha^{-1}							
Analysis for owner-operator (Average yields from experiment)[c]								
Yields:								
Wheat yield, kg ha^{-1}	990	1,570	1,660	1,580	1,780	860	860	1,000
Sorghum yield, kg ha^{-1}	790	1,710	1,740	1,800	1,240	1,440	1,450	1,310
Income:								
Wheat @ $0.18 kg^{-1}	178	283	299	284	320	155	155	180
Sorghum @ $0.13 kg^{-1}	103	222	226	234	161	187	189	170
Total for rotation	281	505	525	518	481	342	344	350
Expenses:								
Herbicide	19	48	128	71	87	246	199	194
Tillage	102	146	146	146	141	0	0	0
Sprayer	25	49	49	48	53	95	94	96
Planting and seed	35	35	35	35	35	35	35	35
Interest @ 10%[d]	18	29	36	30	32	38	33	33
Harvest and haul:								
Wheat	34	36	36	36	38	34	34	34
Sorghum	29	39	39	40	38	38	37	37
Total variable costs	262	382	469	406	424	486	432	429
Returns:	19	123	56	112	24	(144)	(88)	(79)
(Lowest yields from experiment)[e]								
Yields:								
Wheat yield, kg ha^{-1}	340	540	610	610	540	670	610	540
Sorghum yield, kg ha^{-1}	290	550	710	750	740	830	720	720
Income:								
Wheat @ $0.18 kg^{-1}	61	97	110	110	97	121	110	97
Sorghum @ $0.13 kg^{-1}	38	72	92	98	96	108	94	94
Total for rotation	99	169	202	208	193	229	204	191
Total variable costs	262	382	469	406	424	486	432	429
Returns:	(163)	(213)	(267)	(198)	(231)	(257)	(228)	(238)
Analysis for 33:67 lease agreement[f] (Average yields from experiment)								
Owner Share:								
Income:	93	167	173	171	159	113	114	116
Variable costs	42	62	102	73	82	159	136	133
Returns:	51	105	71	98	77	(46)	(22)	(17)
Tenant share:								
Income:	188	338	352	347	322	229	230	235
Variable costs	221	317	365	331	340	325	294	294
Returns:	(33)	21	(13)	16	(18)	(96)	(64)	(59)

[a] Treatment numbers are detailed in Table 1.
[b] Parentheses indicate negative returns or losses.
[c] Average of yields from one and two fallow periods for 1985 and 1986 experiments.
[d] Interest was 10% of cost of herbicides, tillage, sprayer, planting, and seed—items that must be paid before harvest.
[e] Low wheat yields from Field 85B after one fallow period in Table 4 and low sorghum yield from Field 85B after two fallow periods in Table 5.
[f] Expenses and yields as in owner–operator analysis except owner and tenant share chemical and harvest costs. Tenant applies herbicides and does the tillage. Owner and tenant divide income from yield 33 and 67%.

These analyses give an indication of how much field bindweed-infested land would have to be discounted. To achieve normal production with tillage and 2,4-D for two fallow periods, expenses were \$382 ha^{-1}. This amount would be the minimum the price of infested land should be reduced.

Much of the land in the southern Great Plains is operated by tenants. The most common rental agreement is a 33:67 split of yield for owner and tenant. With this arrangement, the tenant does tillage and spraying and pays 50% of harvest and herbicide costs. Costs and income in the bottom part of Table 6 were split accordingly. With no treatment (check), returns to the owner and tenant were \$51 and −\$33 ha^{-1}, respectively. The owner's profits would range from \$105 for tillage and 2,4-D to \$71 ha^{-1} for tillage and dicamba. The owner would lose from \$17 to \$46 ha^{-1} with no-tillage systems because of high chemical cost. The tenant would make \$21 ha^{-1} with sweep tillage and 2,4-D, but suffer losses with other sweep tillage treatments except sweep tillage and imazapyr. The tenant would suffer losses for no-tillage systems ranging from \$59 to \$96 ha^{-1}.

If grain price dropped 25%, the owner's income would be \$70 ha^{-1} to offset \$42 ha^{-1} expenses, making a profit of \$28 ha^{-1} with no treatment. The tenant's income would be \$142 ha^{-1} and costs \$221, yielding a loss of \$79 ha^{-1}. With tillage and 2,4-D, income for the owner would be \$126 ha^{-1} and expenses \$62 ha^{-1}, giving \$64 ha^{-1} profit. In contrast, income for the tenant would be \$256 ha^{-1} to offset expenses of \$317 ha^{-1}, yielding a \$61 loss.

Considering that grain prices are usually about 25% less than 1995 prices, owners will have to adjust lease agreements to encourage tenants to farm infested fields or to conduct field bindweed control programs. For example, with tillage and 2,4-D, if in addition to half of the herbicide cost, the owner paid one-quarter to one-third of tillage cost, profit for owner and tenant would be about equal at about \$60 to \$70 ha^{-1}. Another alternative would be for the owner to pay all herbicide costs; however, the tenant would still not make as much money as the owner.

In the past, a winter wheat–fallow rotation was considered best for controlling field bindweed (Wiese and Rea 1955, 1959). When similar research with a winter wheat–fallow rotation at the same location and time (Wiese et al. 1996) is compared to this research, the winter wheat–sorghum–fallow is a more profitable rotation for controlling field bindweed. In the wheat–fallow field bindweed experiment (Wiese et al. 1996), the wheat price used was \$0.14 kg^{-1}, or about the same as the 25% reduced price in this experiment. Returns for an owner–operator using tillage and 2,4-D during two fallow periods to control field bindweed with wheat–fallow were \$36 ha^{-1}. Controlling the weed with tillage and 2,4-D in two fallow periods in a wheat–sorghum–fallow rotation resulted in \$110 ha^{-1} profit using equivalent grain prices.

A winter wheat–sorghum–fallow rotation also was much more profitable than winter wheat–fallow in a noninfested field 5 km from these experiments (Jones and Johnson 1993).

Sources of Materials

[1] Landmaster BW, formulated as isopropylamine salt containing (100 g L^{-1} glyphosate and 182 g L^{-1}-1 2,4-D), Monsanto Agricultural Co., 800 North Lindberg Boulevard, St. Louis, MO 63167.

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Received July 9, 1996, and approved October 22, 1996.