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CONTROL OF YELLOW FOXTAIL POSTHARVEST IN SMALL GRAIN

BY

REED EUGENE FROSETH

A thesis submitted in partial fulfillment
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1988

CONTROL OF YELLOW FOXTAIL POSTHARVEST IN SMALL GRAIN

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

W. Eugene. Arnold Major Adviser	Date
Maurice L. Horton Head, Plant Science Dept.	Date

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INTRODUCTION

The use of conservation tillage to preserve soil moisture, decrease soil erosion, and reduce energy and time requirements for crop production often makes weed control more difficult. Controlling weeds between cropping sequences becomes even more important in conservation tillage so as to conserve soil moisture and nutrients in addition to reducing or eliminating weed seed production. Reduced mechanical means of controlling weeds in conservation farming must be supplemented with a means of control which will still allow for soil and water conservation and yet use less time, fuel, labor, and capital while maintaining yields equal to or superior to conventional methods.

The use of postemergence herbicides may reduce the number of seeds produced by weeds which are not controlled by residual herbicides or by mechanical means. The postharvest treatment of weeds with low rates of such postemergence herbicides as fluazifop-butyl {(±)-2-[4-[[5-triflouromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid}, glyphosate [*N*-(phosphonomethyl)glycine], HOE-00661 [ammonium (3-amino-3-carboxypropyl) methylphosphinate], paraquat [1,1'-dimethyl-4,4'-bipyridinium ion], or SC-0224 [trimethylsulfonium carboxymethylaminomethyl phosphonate] may be more justifiable if the number of weed seeds produced can be decreased and cultivation delayed or eliminated. The use of low rates of these postemergence herbicides may be possible by using appropiate carrier volumes which best enhance the performance of each herbicide.

This research was conducted to determine: a) if the control of yellow foxtail [Setaria lutescens (Weigel) Hubb.] by mechanical or chemical means post-harvest in small grain would affect the weed infestation potential of the subsequent crop, b) whether or not tillage influenced corn yield, c) the effect of carrier volume and addition of ammonium sulfate on the above herbicides, and d) the relative toxicities of the above herbicides for control of yellow foxtail.

LITERATURE REVIEW

General. Emphasis on reducing wind and water erosion, conserving moisture, and reducing energy, time, and capital requirements in crop production have led to farming practices involving less tillage, commonly known as conservation tillage. Conservation tillage includes such methods as no till, ridge till, strip till, mulch till, and reduced till. The U. S. Conservation Tillage Information Center defines conservation tillage as "those methods of farming which maintain adequate plant cover on the land to conserve our vital national resources of soil and water, while reducing the labor, energy, and capital needed to maintain economic vitality of American agriculture". The Soil Conservation Service interpets "adequate" cover to mean a minimum of 30% ground cover after planting (26).

In a 1983 United States Department of Agriculture survey of over 11,000 farmers nationwide, more than one-fifth of the nation's farmers used conservation tillage practices. Conservation tillage potentially provides two major benefits to farmers: soil and water conservation and cost and time savings (25).

Weed Infestation. As tillage practices are reduced, weed problems tend to increase (27, 32, 42, 53). Weeds growing between cropping sequences may not be destroyed without tillage, which may result in increased herbicide requirements. Annual weeds allowed to grow either post-harvest or during a fallow period reduce soil moisture, deplete valuable soil nutrients, and if allowed to produce seed, replenish the resevoir of seeds in the soil, increasing potential weed infestation in the subsequent crop. Most annual weeds produce a large number of seeds each year. Stevens (49) reported that a single large developed green foxtail plant [_Setaria viridis_ (L.) Beauv.] can produce 34,000 seeds. In studies where the production of weed seeds was minimal or prevented completely, a drastic reduction in the number of viable weed seeds in the soil occurred within 1 to 6 years (5, 6, 7, 12, 15, 16, 17, 18, 35, 36, 37, 38, 39, 40, 41, 44, 45, 46, 54). In nonirrigated areas, Roberts (38) and Dunham et al. (16) failed to appreciably reduce the number of weed seeds in soil where they employed only different tillage practices to control annual weeds in crop rotations. Roberts (38), however, reported that the number of weed seeds in soil could be maintained at a level of 25 million seeds or less per hectare when herbicides and tillage were employed in conjunction with crop rotations.

Yields under conservation tillage systems are generally higher than conventional tillage systems in years of low rainfall but are only slightly different in years of adequate rainfall (2, 52). Triplett et al. (51) reported that maximum tillage systems did not affect yield to the same extent under dry conditions as systems leaving 75 to 100% soil cover. However, with sufficient rainfall, tillage had no affect on yield.

Herbicide Activity. The addition of adjuvants and other additives such as inorganic salts (3, 8, 9, 10, 11, 20, 21, 22, 23, 24, 30, 31, 33, 50), and carrier volume influence the performance of a herbicide (1, 4, 8, 9, 10, 11, 14, 17, 19, 24, 28, 29, 30, 33, 34, 43, 48). According to McKinlay et al. (29), the volume of carrier affects plant coverage and potentially the phytotoxicity of the spray solution. They state that spray volume and droplet size "inevitably interact with one another". The amount of active ingredient applied per unit area also has a marked affect on the performance of herbicides and might be expected to interact with the carrier volume and droplet size. Therefore, if the same amount of active ingredient is applied in a greater carrier volume the spray solution must be less concentrated and vice versa. McKinlay et al. suggest that the active ingredient may penetrate more rapidly when samller droplets and a more concentrated spray solution are used, which may make it possible to use less active ingredient per application (29).

MATERIALS AND METHODS

Tillage Experiments

Two field experiments were established in the fall of 1982. One location was near Sioux Falls, South Dakota on a Moody-Nora silty clay loam (Udic Haplustolls, mixed, mesic) with 2.5% organic matter and a pH of 6.3. The other location was near Crooks, South Dakota on a Maddock loamy fine sand (Uorothentic Haploborolls, sandy, mixed) with 3.8% organic matter and pH of 5.9. An oat stubble field with a uniform and dense population (800-1000 plants/m^2) of yellow foxtail was selected at each location. Foxtail plants were heading at time of herbicide and initial tillage treatments at both locations. Individual plots measured 15 by 107 m designed as a randomized complete block with four replications. Each experiment was a 4 X 3 factorial consisting of fall tillage, spring tillage, fall and spring tillage, and no tillage in combination with glyphosate plus dicamba at 0.00 and 0.00 kg/ha, 0.10 and 0.14 kg/ha, or 0.16 and 0.14 kg/ha, respectively (Table 1 and Table 2). A nonionic surfactant was added to each treatment at 0.50% (v/v). The herbicide mixture was applied in 28 L/ha of water with a self-propelled sprayer equipped with 730154 flat fan nozzles at 227 kPa and 13 km/h. Fall tillage was done with a chisel plow set to cut

Table 1. Herbicide and tillage treatments at Sioux Falls, South Dakota.

Chemical and Tillage Treatments				
	glyphosate[a]	Tillage		alachlor[b]
(#)	(kg/ha)	(Fall)	(Spring)	(kg/ha)
1.	0.10	8/26/82	NONE	2.91
2.	0.10	NONE	5/29/83	2.91
3.	0.10	8/26/82	5/29/83	2.91
4.	0.10	NONE	NONE	2.91
5.	0.16	8/26/82	NONE	2.91
6.	0.16	NONE	5/29/83	2.91
7.	0.16	8/26/82	5/29/83	2.91
8.	0.16	NONE	NONE	2.91
9.	0.00	8/10/82	NONE	0.00
10.	0.00	NONE	5/29/83	0.00
11.	0.00	8/10/82	5/29/83	0.00
12.	0.00	NONE	NONE	0.00

[a] Dicamba was applied with glyphosate at 0.14 kg/ha plus 0.50% (v/v) nonionic surfactant on 8/10/82.

[b] Alachlor was applied with 0.84 kg/ha of glyphosate on 6/3/83.

Table 2. Herbicide and tillage treatments at Crooks, South Dakota.

Chemical and Tillage Treatments				
	glyphosate[a]	Tillage		alachlor[b]
(#)	(kg/ha)	(Fall)	(Spring)	(kg/ha)
1.	0.10	8/31/82	NONE	3.36
2.	0.10	NONE	5/20/83	3.36
3.	0.10	8/31/82	5/20/83	3.36
4.	0.10	NONE	NONE	3.36
5.	0.16	8/31/82	NONE	3.36
6.	0.16	NONE	5/20/83	3.36
7.	0.16	8/31/82	5/20/83	3.36
8.	0.16	NONE	NONE	3.36
9.	0.00	8/16/82	NONE	0.00
10.	0.00	NONE	5/20/82	0.00
11.	0.00	8/16/82	5/20/82	0.00
12.	0.00	NONE	NONE	0.00

[a] Dicamba was applied with glyphosate at 0.14 kg/ha plus 0.50% (v/v) nonionic surfactant on 8/16/82.

[b] Alachlor was applied alone on 5/21/83.

20-23 cm deep. Spring tillage was done with a tandem disk set to a depth of 15-18 cm. Foxtail plants were visually evaluated for degree of control based on a scale of 0 to 100 with 0=no control and 100=complete control on dates shown in Table 3. In the spring of 1983 `Pioneer 3747` corn seed was planted with a `Hiniker` ridge till planter equipped with disc openers and flouted coulters in rows spaced 96.5 cm apart at both locations on dates shown in Table 3. Alachlor at 3.36 kg/ha was applied with a planter mounted spray system equipped with `TK-10' floodjet nozzles calibrated at 187 L/ha at 248 kPa and 8 km/h at Crooks. Alachlor at 2.91 kg/ha plus glyphosate at 0.84 kg ae/ha was applied with a tractor mounted sprayer equipped with 8003 flat fan nozzles calibrated to apply 117 L/ha at 152 kPa and 6.4 km/h at Sioux Falls. Foxtail plants in the two leaf stage were present at the time of herbicide application at the Sioux Falls location only. Degree of foxtail control was visually assessed two weeks after treatment using a scale as described earlier. Plots were cultivated twice. Corn was either harvested by hand or with a combine in the fall of 1983.

Soil sampling. A total of 12 soil samples per plot were taken in the spring of 1983 before tillage with a 1.9 cm ID soil probe to a depth of 15 cm. Samples were

Table 3. Location and dates of herbicide application, planting, tillage, and visual evaluations.

-----------------------Fall 1982-----------------------

Location	Spray Dates	Tillage Dates	Visual Evaluations
Crooks	8/16/82	8/16/82 8/31/82	8/29/82 9/11/82
Sioux Falls	8/10/82	8/10/82 8/26/82	8/23/82 9/11/82

----------------------Spring 1983----------------------

Location	Tillage Dates	Planting Dates	Spray Dates	Visual Evaluations
Crooks	5/20/83	5/21/83	5/21/83	6/4/83
Sioux Falls	5/29/83	5/31/83	6/3/83	6/16/83

composited for each plot and frozen in plastic bags until analyzed for weed seed content.

Weed seed separation. Soil samples taken from the field were air dried and large clods were crushed with a hand held roller. Each sample was passed through a funneling device and separated into equal halves. A 250 g subsample from each half was conditioned by soaking in 500 ml of a 50 g/l sodium hexametaphosphate solution for 2 h. The soil slurry was then placed into one of the eight elutriation chambers of the hydroelute system (47) (Figure 1).

Weed seeds and other biological material were separated from soil on a 437 m teflon screen by washing for 3 min at 274 kPa inlet water pressure and 69 kPa inlet air pressure, followed by a 3 min wash at inlet water and air pressures of 343 and 69 kPa, respectively. Material on the sieve was rinsed into sand sample bags with a fine stream of water.

Sediment remaining in the elutriation chamber was retrieved on another 437 m sieve and transferred to a sand sample bag. Sediment and sieve retained material were left to dry overnight at 21°C. Weed seeds were identified and counted under a dissecting microscope set at 0.7 magnification.

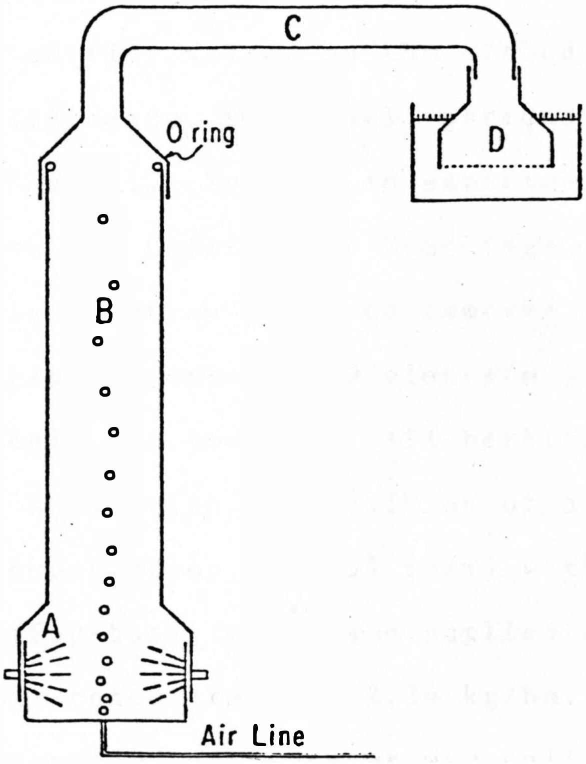

Figure 1. Schematic representation of the hydroelute separation system. The system is composed of five areas: (A) High kintic energy washing chamber, (B) Elutriation tube, (C) Transfer tube, and (D) Low kinetic energy sieve. The transfer tube (C) lifts off the elutriation chamber (B) to remove coarse mineral fraction from the former sample and add the new soil sample. Seeds are transferred from the low energy sieve (D) by inverting and washing seeds into a sand sample bag. Sediment remaining in the washing chamber (A) is transferred to sand sample bags by rotating the elutriation tube (B) and washing seed into bag.

Effect of Carrier Volume

Field experiments were conducted in 1982 and 1983 in small grain stubble fields in South Dakota to determine the effect of carrier volume on the efficacy of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 to yellow foxtail. In 1982 an experiment was established in Brookings County near Brookings, SD in oat stubble where loose straw had been removed and a uniform and dense (approximately 900 plants/m^2) population of yellow foxtail was present. All herbicides were applied at 0.14 kg ae/ha with the addition of a nonionic surfactant at a concentration of 0.5% (v/v) with the exception of fluazifop-butyl which was applied with the addition of crop oil concentrate at 2.34 kg/ha. A tractor mounted compressed air sprayer was calibrated to apply 23, 47, 94, 187, and 374 L/ha at 275 kPa pressure and 4.83 km/h with the exception of 374 L/ha which was obtained at a speed of 2.42 km/h. Hollow cone nozzles, orifice numbers 2.0-80 or 20-M or flat fan nozzles, orifice numbers 73007 or 8002 were used. Visual ratings for degree of control based on a scale of 0 to 100 (0=no injury and 100=complete kill) were taken on dates indicated in Table 4. Foxtail dry weight for each plot was determined two weeks after treatment by clipping plants

Table 4. Location and dates of herbicide application, visual evaluations, and dry weight clippings.

Location & Experiment	Application Dates	Visual Evaluations	Dry Weight Clippings
Brookings County			
Carrier Volume	9/2/82	9/18/82	9/18/82
Phytotoxicity Experiment	9/2/82	9/20/82	9/20/82
Moody County			
Carrier Volume	8/9/83	8/23/83	9/3/83
Phytotoxicity Experiment	8/10/83	8/26/83	9/5/83
Deuel County			
Carrier Volume	8/15/83	8/30/83	9/10/83
Phytotoxicity Experiment	8/15/83	8/30/83	9/17/83

at ground level within 625 cm^2 areas per plot and drying at 35 ^oC.

Experiments were conducted twice in 1983. One location was in Deuel County near Castlewood, SD and the other location was in Moody County near Flandreau, SD. Experiments were conducted in oat stubble where loose straw had been removed and a uniform and dense (800-1000 plants/m^2) population of yellow foxtail was present. Carrier volumes used in 1983 were the same as used in 1982. Herbicides used in the 1983 experiments were the same as in 1982 and were applied at the same rate plus the same surfactant as described for 1982. A tractor mounted CO_2 sprayer equipped with 6 nozzles was calibrated to apply the various delivery volumes at 138 kPa and 4.83 km/h with the exception of the highest delivery volume which was obtained at a speed of 3.22 km/h. Flat-fan nozzles with orifice numbers 730039, 730077, 730154, 730308, or 730462 were used. Treatments were applied to yellow foxtail plants which were 10-45 cm with 25 and 60% of the total population in the milk stage at Moody and Deuel county locations, respectively. Plots measured 3 by 12 m. Visual ratings for degree of control were taken 2 weeks after treatment at both locations. Yellow foxtail dry weights were determined for each plot by cutting foxtail plants at ground level within a 60 cm strip, 6 m long out of each plot with a forage harvester. Total weight for each fresh sample was measured in the field and a 150 g subsample was retained and dried at 50-60 $^{\circ}$C to determine dry weight for each sample. Clippings were taken on dates indicated in Table 4.

Phytotoxicity comparison and effect of ammonium sulfate on phytotoxicity

Field experiments were conducted in 1982 and 1983 in small grain stubble fields in South Dakota to compare the relative phytotoxicities and effect of ammonium sulfate on the efficacy of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 to yellow foxtail. In 1982 an experiment was established in Brookings County near Brookings, SD in oat stubble as described for the 1982 carrier volume study. Experimental design was a randomized complete block with four replications. Individual plots measured 3 by 12 m. Treatments were applied when yellow foxtail plants were 15-30 cm tall with 50% of the population in the milk stage. Herbicides were applied at 0.00, 0.03, 0.07, 0.14, 0.28, 0.56, and 1.12 kg ae/ha plus a nonionic surfactant at a concentration of 0.5% (v/v) with the exception of fluazifop-butyl which was applied with crop oil concentrate at 2.34 L/ha. Each herbicide was also applied at 0.07

kg ae/ha plus 2.80 kg/ha of ammonium sulfate. Excluding glyphosate, all herbicides were applied in 187 L/ha of carrier using a tractor mounted compressed air sprayer equipped with six 8002 flat-fan nozzles at 275 kPa pressure and 4.83 km/h. Glyphosate was applied in 47 L/ha of carrier by using six 20-M hollow cone nozzles with the same pressure and tractor speed as above.

Visual ratings for degree of control based on a scale of 0 to 100 (0=no injury and 100=complete kill) were taken on dates shown in Table 4. Foxtail dry weight for each plot was determined by using the same method as described for the 1982 carrier volume study.

Experiments were conducted twice in 1983 at two locations as described for the 1983 carrier volume studies. Herbicide dosage and experiment design was the same as in 1982. Herbicides were applied in 187 L/ha of carrier volume using a tractor mounted compressed air sprayer equipped with six 730308 nozzles at 138 kPa pressure and 4.83 km/h, with the exception of glyphosate which was applied in 47 L/ha of carrier using 730077 nozzles at the same pressure and speed as above. Treatments were applied to yellow foxtail plants which were 10-45 cm tall with 25 and 60% of the total population in the milk stage at the Moody and Deuel county locations, respectively. Visual ratings for degree of control were determined based on the scale as described earlier on dates shown in Table 4. Yellow foxtail dry weights were determined for each plot as described for the 1983 carrier volume studies. Clippings were taken on dates indicated in Table 4. Data for 1982 and 1983 were subjected to analysis of variance and treatment means were compared with the Waller-Duncan k-ratio T test (P=0.05 and k-ratio=100).

RESULTS AND DISCUSSION

Tillage Experiments

Control of yellow foxtail 14 days after treatment was generally better when glyphosate was applied at 0.16 kg/ha than at 0.14 kg/ha at the Sioux Falls location (Table 5). Mechanical rather than chemical treatment of yellow foxtail resulted in slightly better control of yellow foxtail 14 days after treatment. Control of yellow foxtail 4 weeks after treatment was significantly better when glyphosate applied at 0.14 or 0.16 kg/ha was followed two weeks later by tillage than when glyphosate at the same rate was applied without any follow-up tillage. Tillage alone controlled yellow foxtail as well as any combination of glyphosate followed by tillage. Control of yellow foxtail in the spring of 1983 was equal among equal rates of alachlor. Yellow foxtail plants infested plots where alachlor was not used for a period of two and one half weeks when plots were cultivated.

No significant difference in yield was detected among any treatment containing equal rates of alachlor at the Sioux Falls location (Table 5). All treatments containing an application of alachlor resulted in yields significantly better than any treatments without alachlor. Fall tillage and fall plus spring tillage

Table 5. Comparison of herbicide and tillage treatments on control of yellow foxtail and effect on corn yield at Sioux Falls, South Dakota[a].

	Herbicide treatment		Yellow foxtail control[b]			
	Fall	Spring	Fall		Spring	
Tillage	glyphosate[c]	alachlor[d]	2 WAT	4 WAT	2 WAT	yield
	(kg/ha)	(kg/ha)	-------(%)-------			(hl/ha)
None	0.14	2.90	84 e	84 d	100 b	58 a
Fall tillage	0.14	2.90	85 de	92 bc	100 b	63 a
Spring tillage	0.14	2.90	84 e	85 d	100 ab	64 a
Fall + Spring tillage	0.14	2.90	84 e	95 ab	100 a	60 a
None	0.16	2.90	88 cd	90 c	100 b	59 a
Fall tillage	0.16	2.90	90 bc	94 ab	100 a	59 a
Spring tillage	0.16	2.90	89 c	90 c	100 ab	58 a
Fall + Spring tillage	0.16	2.90	89 c	96 a	100 ab	63 a
None	0.00	0.00	0 f	0 e	0 c	6 d
Fall tillage	0.00	0.00	92 ab	95 ab	0 c	45 b
Spring tillage	0.00	0.00	0 f	0 e	0 c	34 c
Fall + Spring tillage	0.00	0.00	94 a	94 ab	0 c	37 bc

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[a] Means within columns followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[b] WAT=Weeks after initial treatments.

[c] Dicamba at 0.14 kg/ha plus a nonionic surfactant (X-77) at 0.50% (v/v) was added to each glyphosate treatment.

[d] Glyphosate at 0.84 kg/ha was added to each alachlor treatment.

resulted in significantly better yield than no tillage. The lack of tillage and herbicide treatment resulted in significantly lower yield than any other treatment.

No significant difference in control of yellow foxtail was detected among equal rates of 0.14 or 0.16 kg/ha of glyphosate in August 1982 two weeks after application at the Crooks location (Table 6). Best foxtail control two weeks after application was attained with tillage. Tillage two weeks after application of 0.14 kg/ha of glyphosate increased control of yellow foxtail compared to glyphosate applied alone at the same rate. Control at 4 weeks after treatment was comparable whether glyphosate at 0.16 kg/ha was applied with or without follow-up tillage. Tillage alone provided control equal to an application of glyphosate followed by tillage. Control was comparable 4 weeks after treatment between glyphosate applied alone at 0.16 kg/ha and the same followed by tillage. Control in the spring of 1983 was equal among equal rates of alachlor. All alachlor treatments resulted in control of yellow foxtail significantly better than non-alachlor treatments. No significant difference in yield was detected among any tillage treatments with equal alachlor rates. All alachlor treatments resulted in significantly higher yields than any non-alachlor treatment.

Table 6. Comparison of herbicide and tillage treatments on control of yellow foxtail and effect on corn yield at Crooks, South Dakota[a].

	Herbicide treatment		Yellow foxtail control[b]			
	Fall	Spring	Fall		Spring	
Tillage	glyphosate[c]	alachlor	2 WAT	4 WAT	2 WAT	yield
	(kg/ha)	(kg/ha)	-------(%)-------			(hl/ha)
None	0.14	2.90	78 c	82 c	97 a	68 ab
Fall tillage	0.14	2.90	80 c	93 ab	96 a	71 a
Spring tillage	0.14	2.90	78 c	79 c	93 a	59 ab
Fall + Spring tillage	0.14	2.90	79 c	93 ab	97 a	70 a
None	0.16	2.90	91 b	90 b	96 a	53 abc
Fall tillage	0.16	2.90	90 b	94 ab	98 a	65 ab
Spring tillage	0.16	2.90	89 b	90 b	96 a	64 ab
Fall + Spring tillage	0.16	2.90	90 b	93 ab	97 a	66 ab
None	0.00	0.00	0 d	0 d	0 b	34 c
Fall tillage	0.00	0.00	95 a	96 a	0 b	49 c
Spring tillage	0.00	0.00	0 d	0 d	0 b	37 c
Fall + Spring tillage	0.00	0.00	95 a	95 a	0 b	37 c

---

[a] Means within columns followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[b] WAT=Weeks after initial treatments.

[c] Dicamba at 0.14 kg/ha plus a nonionic surfactant (X-77) at 0.50% (v/v) was added to each glyphosate treatment.

The lack of significant difference in yields at both locations among the various tillage practices which had equal amounts of alachlor applied can be due in part to the adequate rainfall received throughout the 1983 growing season (Table 7). This lack of yield response to tillage due to adequate precipitation agrees with the results of Anemiya (2), Triplett et al. (51), and VanDoren (52) who found in their studies that with sufficient rainfall, tillage had no affect on yield.

Yellow foxtail seed stock was significantly higher where neither tillage nor herbicide treatments were performed than all other treatments at both locations (Table 8). No significant difference in seed stock was apparent between treatment of foxtail with herbicide plus tillage compared to the average of herbicide alone and tillage alone at both locations. Comparison of herbicide alone versus tillage alone revealed no significant difference in yellow foxtail seed population at both locations. Whether tillage alone, herbicide alone, or a combination of both was employed, yellow foxtail seed stock was significantly less than allowing foxtail plants to mature until killed by frost.

Table 7. Total precipitation at Crooks and Sioux Falls, South Dakota for 6 month period (April-September), 1983.

Month	Precipitation Crooks	 Sioux Falls
	---(cm)---	
April	5.66	7.32
May	6.43	7.42
June	11.00	17.14
July	4.14	4.62
August	6.55	5.08
September	4.44	4.88
Total	38.22	46.46

Table 8. Orthogonal contrasts of herbicide and tillage treatments for prevention of yellow foxtail seed production postharvest in small grain. Sioux Falls and Crooks, South Dakota, 1982.

Contrast	Seeds/ha 0-15 cm
(Sioux Falls)	
No tillage nor herbicide treatment vs average of herbicide alone, herbicide plus tillage and tillage alone.	3.03×10^{8} vs 1.80×10^{8} **
Herbicide plus tillage vs average of herbicide alone and tillage alone.	1.32×10^{8} vs 2.03×10^{8}
Herbicide alone vs tillage alone.	1.82×10^{8} vs 2.24×10^{8}
(Crooks)	
No tillage nor herbicide treatment vs herbicide alone, herbicide plus tillage and tillage alone.	3.05×10^{8} vs 8.98×10^{7} **
Herbicide plus tillage vs herbicide alone and tillage alone.	1.10×10^{8} vs 7.96×10^{7}
Herbicide alone vs tillage alone.	1.10×10^{8} vs 5.83×10^{7}

** Significant F-test at 0.01 level.

Effect of Carrier Volume on Phytotoxicity to Yellow Foxtail

Data was combined for all experiments for percent foxtail control two weeks after treatment for all herbicides. A curve and equation produced by curvlinear regression depicting the relationship between carrier volume and percent of maximum control of yellow foxtail for each herbicide is presented in figures 2, 3, 4, 5, and 6. Yellow foxtail dry weights are presented in Tables 9 and 10.

A curvlinear relationship (R^2 =.55) was observed between carrier volume and yellow foxtail control for fluazifop-butyl (Figure 2). Yellow foxtail control was greater when fluazifop-butyl was applied in 23 L/ha than in 374 L/ha. Differences were minimal among all other carrier volumes. These results are similar to those of Buhler and Burnside (10) who found decreased phytotoxicity to forage sorghum [*Sorghum* *bicolor* (L.) Moench 'Rox Orange'] and yellow foxtail when fluazifop-butyl was applied in increasing carrier volumes.

Percent of maximum yellow foxtail control decreased as carrier volume was increased from 23 to 374 L/ha for glyphosate (R^2 =.76) (Figure 3). Significantly higher yellow foxtail dry weights were obtained when glyphosate was applied in 374 L/ha than in 23, 47, or 94 L/ha in

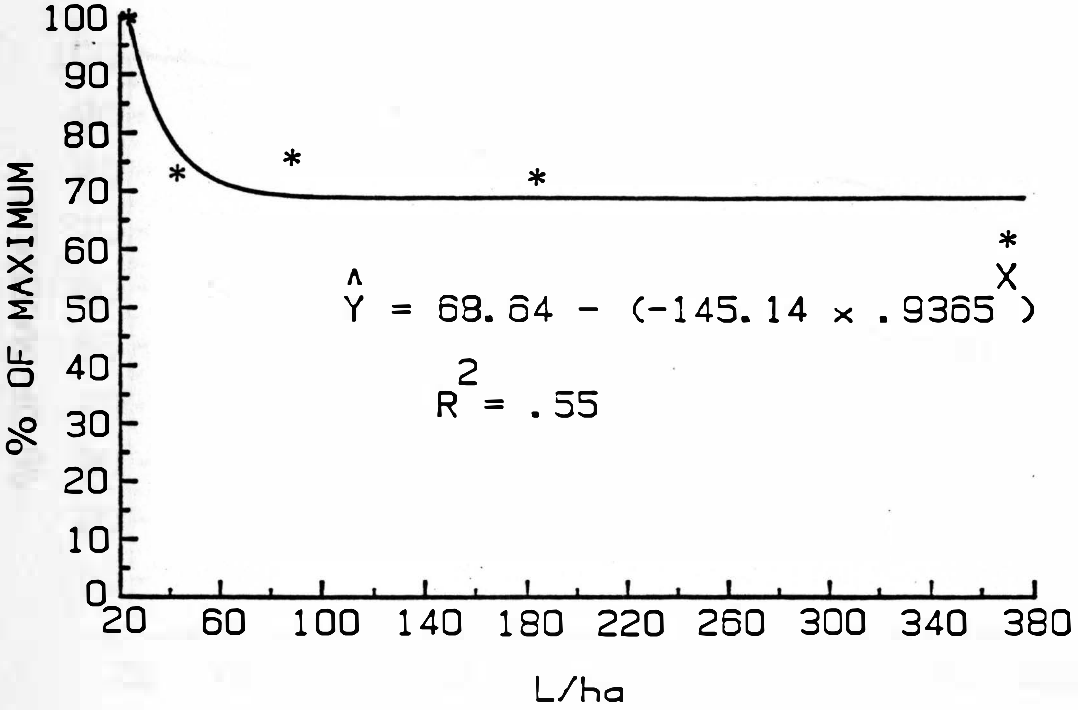

Figure 2. Effect of carrier volume on phytotoxicity of fluazifop-butyl to yellow foxtail 2 weeks after treatment in 1982 and 1983 field studies. Plotted points (*) are the means of percent of maximum control of four replications of three studies.

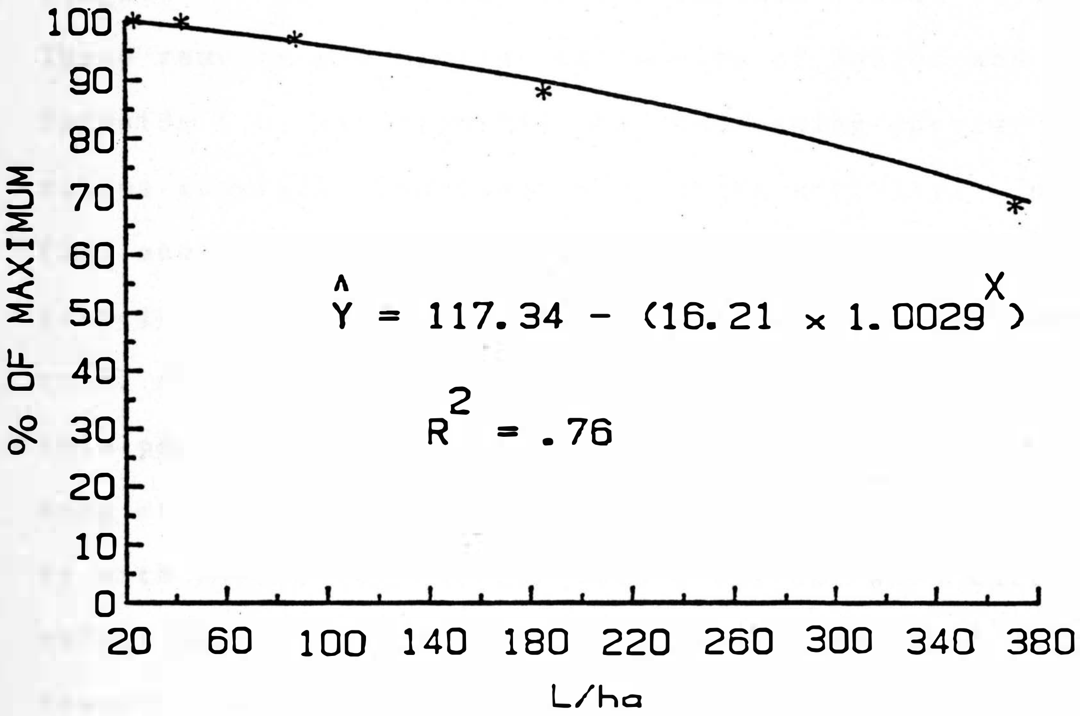

Figure 3. Effect of carrier volume on phytotoxicity of glyphosate to yellow foxtail 2 weeks after treatment in 1982 and 1983 field studies. Plotted points (*) are the means of percent of maximum control of four replications of three studies.

1982 (Table 9). Results were similar in 1983, although no significant differences were detected among dry weights for the various carrier volumes (Table 10). These results are similar to results of Buhler and Burnside (10) who reported that decreasing carrier volume generally increased glyphosate activity. Jordon (24) and Stahlam and Philips (48) reported that phytotoxicity increased when carrier volumes were decreased to 47 and 93 L/ha, respectively. The data presented in this paper are in partial agreement with those of Sanberg et al. (43), who observed increases in phytotoxicity with decreasing carrier volume but not when carrier volume was decreased below 190 L/ha. Results of this research were not consistent with those of Fernandez and Bayer (19) who observed increased glyphosate toxicity to bermudagrass [Cyndon dactylon (L.) Pers.] when applied in 373 L/ha of carrier as compared to 94 L/ha. This was explained by the fact that bermudagrass is difficult to wet and therefore responds to higher volumes of carrier.

Increased glyphosate phytotoxicity as carrier volume is decreased may be explained in part by increased surfactant concentration in the spray solution with lower carrier volumes (Table 11). Although the surfactant added to glyphosate treatments was constant at 0.5% (v/v), commercially formulated glyphosate as used in

Table 9. Effect of carrier volume on the efficacy of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 to yellow foxtail in oat stubble in Brookings County in 1982 16 DAT[a b].

	Chemical[c]				
Carrier volume	fluazifop-butyl	glyphosate	HOE-00661	paraquat	SC-0224
(L/ha)	(Dry weight in g)				
23	11.1 a	10.6 b	11.8 a	11.3 ab	11.2 a
47	11.6 a	12.0 b	9.2 a	11.2 ab	13.1 a
94	9.2 a	11.3 b	12.4 a	12.4 a	11.4 a
187	10.9 a	12.6 ab	10.2 a	9.1 b	10.4 a
374	13.0 a	15.0 a	9.7 a	8.9 b	12.1 a

[a] Data are averages of four replications.

[b] Means within a column followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[c] Surfactant (X-77) was added to each treatment at 0.50% (v/v), with the exception of fluazifop-butyl which was mixed with 2.34 L/ha of crop oil concentrate.

Table 10. Effect of carrier volume on the efficacy of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 to yellow foxtail in oats stubble in 1983[ab].

	Chemical[c]				
Carrier volume	fluazifop-butyl	glyphosate	HOE-00661	paraquat	SC-0224
(L/ha)	(Dry weight in g)				
23	393 a	376 a	363 a	404 a	358 b
47	384 a	414 a	345 a	435 a	361 b
94	380 a	393 a	382 a	349 a	362 b
187	374 a	418 a	361 a	360 a	439 a
374	393 a	429 a	359 a	342 a	408 ab

[a] Data are averages of four replications and two locations.

[b] Means within a column followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[c] Surfactant (X-77) was added to each treatment at 0.50% (v/v), with the exception of fluazifop-butyl which was mixed with 2.34 L/ha of crop oil concentrate.

Table 11. Surfactant concentration in spray solution for glyphosate treatments as affected by carrier volume.

glyphosate rate	carrier volume	surfactant concentration[a]
(kg/ha)	(L/ha)	(% v/v)
0.14	23	0.035
0.14	46	0.0175
0.14	94	0.00875
0.14	187	0.004375
0.14	374	0.0021875

[a] Surfactant was MON-0818 cationic surfactant.

this research contains a cationic surfactant (MON-0818) which increased in concentration as carrier volume was decreased. Jordon (24) reported that increased surfactant concentration contributes to the increase in toxicity obtained with lower carrier volumes when using commercially formulated glyphosate. Buhler and Burnside (8) observed that increasing surfactant concentration can help overcome some of the inhibition of glyphosate phytotoxicity caused by increased carrier volume.

A curvlinear relationship (R^2 =.80) was observed between yellow foxtail control and carrier volume for HOE-00661 (Figure 4). Decreasing carrier volume from 374 to 23 L/ha increased the percent of maximum control attained. Maximum control of yellow foxtail with 0.14 kg/ha of HOE-00661 was attained by applying the herbicide in 23 L/ha of carrier. These results are in partial agreement with Carlson and Burnside (11) who reported increased control when carrier volume was decreased from 190 to 96 L/ha but observed no improvement in toxicity when carrier volumes were less than 96 L/ha. The dose used in their study was 0.40 kg/ha, which appeared to mask improved phytotoxicity resulting from reduced carrier volumes. Carlson and Burnside observed complete control for all carrier volumes when HOE-00661 was applied at 1.60 kg/ha.

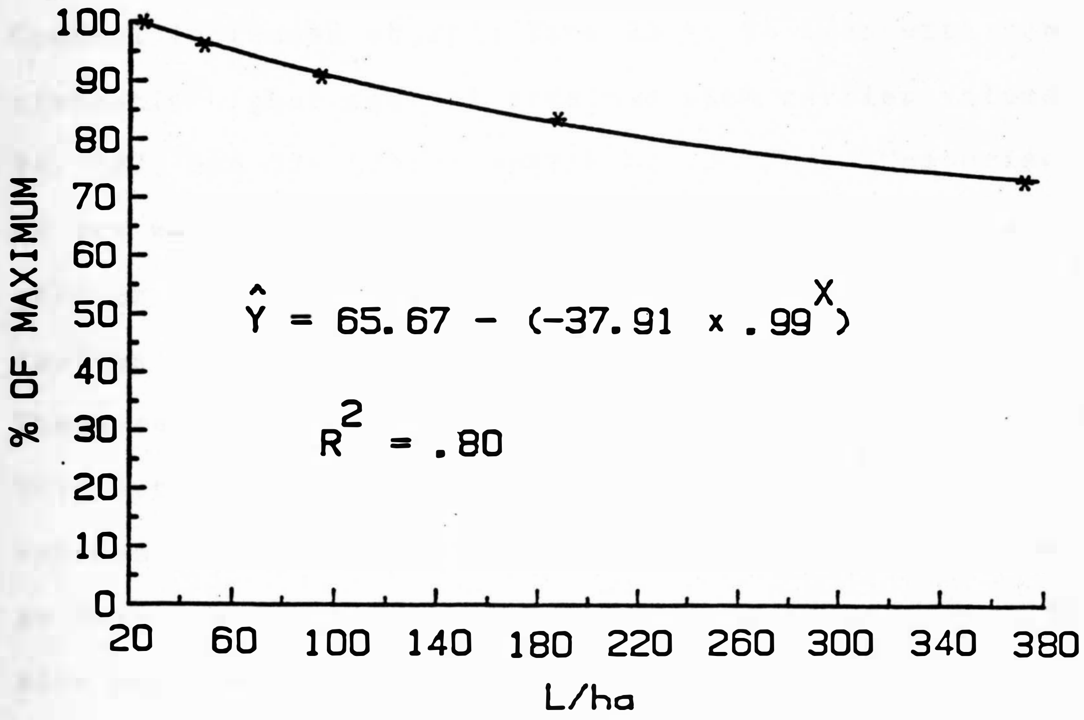

Figure 4. Effect of carrier volume on phytotoxicity of HOE-00661 to yellow foxtail 2 weeks after treatment in 1982 and 1983 field studies. Plotted points (*) are the means of percent of maximum control of four replications of three studies.

Yellow foxtail control increased as carrier volume was increased when applying paraquat at 0.14 kg/ha as depicted by the curvlinear regression model in Figure 5. Control increased sharply from 23 to 94 L/ha with consistently higher control attained with carrier volumes 94, 187, and 374 L/ha compared to 23 L/ha. Comparison of dry weights from 1982 and 1983 seems to indicate greater efficacy of paraquat to yellow foxtail when applied in greater carrier volumes (Tables 9 and 10). These results are in partial agreement with Reichard and Triplett (34) who found that paraquat applied in reduced volumes did not consistently control vegetation as well as when applied in the 190 to 560 L/ha range. Droplet size may have affected the toxicity of paraquat to yellow foxtail. When considering the size of spray droplet with each droplet containing an equal concentration of paraquat, Douglas (14) found that within a range of 250-1000μ, optimum effeciency was recorded for droplets of 400-500 μ. Towards each end of the spectrum the droplets became considerably less efficient. Herbicide activity was measured as the area of visible leaf lesion. It was evident from the results that droplets at the lower end of the spectrum produced very small lesions. Douglas (14) reported that there is a minimal concentration of paraquat, in a given size droplet, at

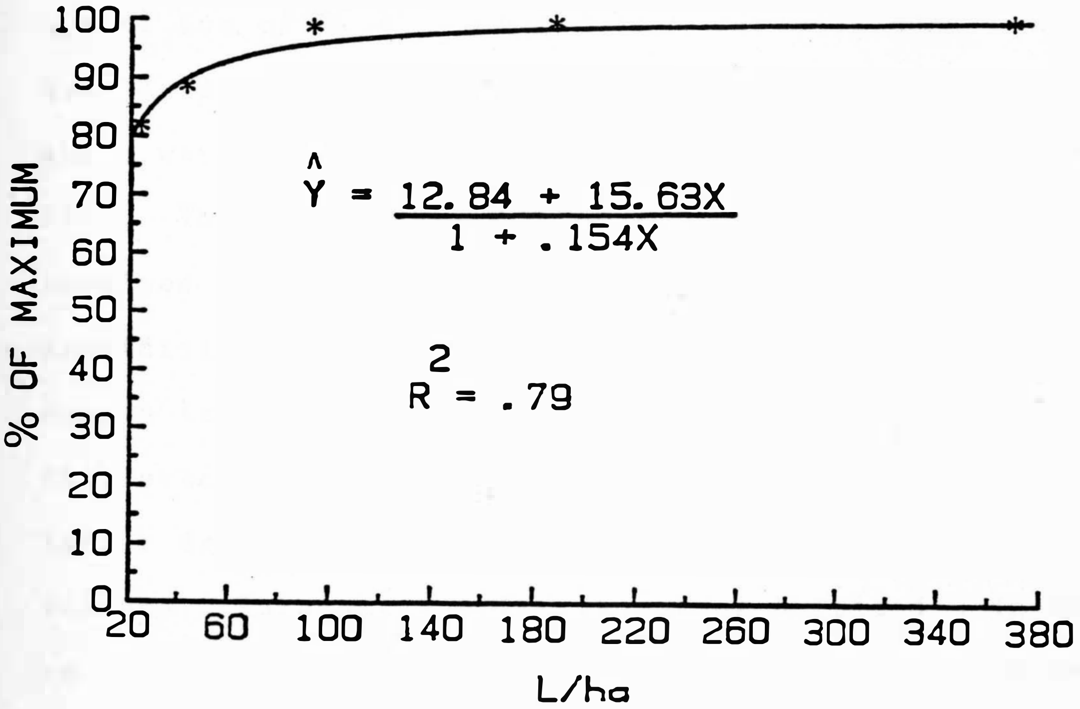

Figure 5. Effect of carrier volume on phytotoxicity of paraquat to yellow foxtail 2 weeks after treatment in 1982 and 1983 field studies. Plotted points (*) are the means of percent of maximum control of four replications of three studies.

which no visible lesion is produced. This was evident when droplet diameters of 1,000, 850, 650, and 400μ containing 0.0156% paraquat produced lesion areas per μg of ion of 6, 2, 1, and 0 cm^2, respectively. Paraquat in solution in each droplet is absorbed by the leaf and a water bridge appears to be essential for uptake (14). The evaporation of the 400μ droplet may have resulted in a water bridge of such limited duration that insufficient paraquat was taken up by the leaf to produce a lesion. This is in agreement with results of this study, considering that a greater percentage of larger droplets can be expected with increased carrier volumes. Paraquat, unlike the other herbicides in this research, acts rapidly and exhibits little or no movement within the plant. Therefore, for maximum effectiveness, paraquat must be well distributed over the plant foliage. The author agrees with Reichard and Triplett (34) who stated that increasing spray volume tends to increase paraquat penetration into the canopy, which provides better contact with the plant foliage and provides for greater toxicity of paraquat to the plant.

The curvlinear relationship between percent control of yellow foxtail and carrier volume for SC-0224 depicts a sharp decline in control when carrier volume was increased from 23 to 46 L/ha (Figure 6). Control was

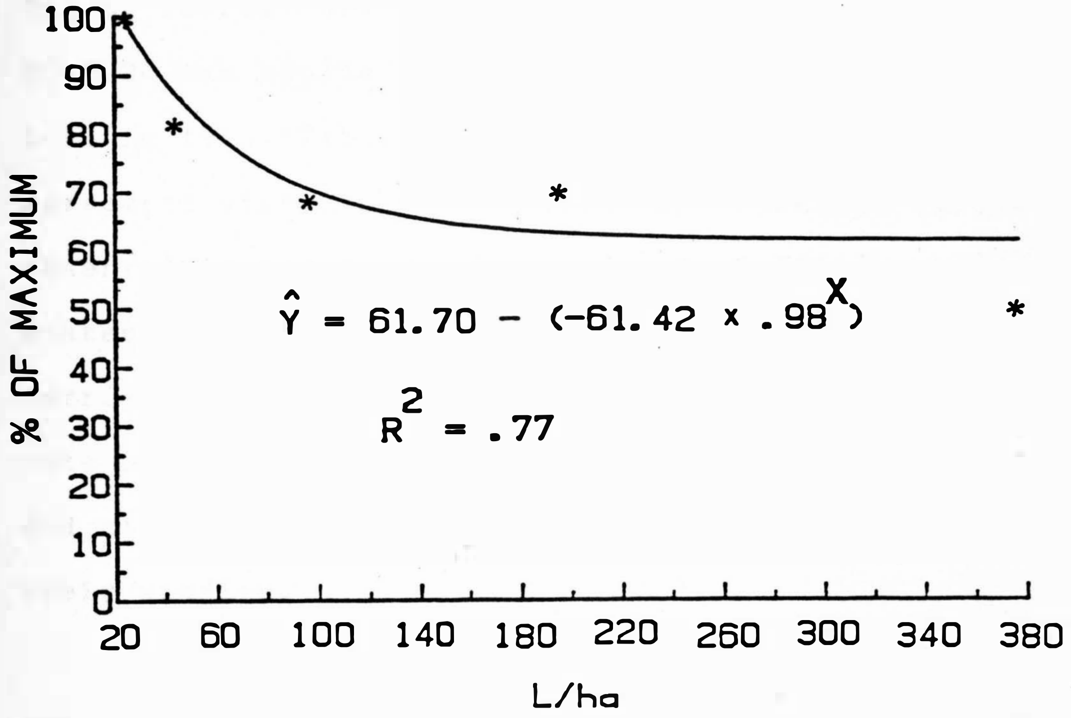

Figure 6. Effect of carrier volume on phytotoxicity of SC-0224 to yellow foxtail 2 weeks after treatment in 1982 and 1983 field studies. Plotted points (*) are the means of percent of maximum control of four replications of three studies.

greatest at 23 L/ha and least at 374 L/ha. Little difference was detected among 46, 94, or 187 L/ha. Yellow foxtail dry weights were significantly lower when SC-0224 was applied in 23, 47, or 94 L/ha than in 187 L/ha in 1983 (Table 10). These results are in partial agreement with those of Carlson and Burnside (11) who observed improved phytotoxicity of SC-0224 to hard red winter wheat [*Triticum aestivum* (L.) `Centurk 78'] when carrier volume was decreased from 190 to 96 L/ha at a rate of 0.10 kg/ha. Carrier volumes less than 96 L/ha did not provide improved phytotoxicity of SC-0224 in their studies.

There are several possible explanations for increased herbicide activity when carrier volume is decreased. Small orifice nozzles generally produce a higher percentage of small droplets (8). These smaller droplets may contribute to increased phytotoxicity due to increased absorption into the leaf for translocated herbicides. The herbicide concentration in the spray droplets that are deposited on the foliage of plants can influence the toxicity of translocated herbicides to the plant (17, 24, 29, 30). It is possible that larger droplets result in decreased absorption because they become physiologically isolated by killing the cells below the droplet (24). Higher concentration of chemical in the spray solution may increase phytotoxicity because more chemical would be absorbed per unit volume of solution that penetrates into the leaf. Ambach and Ashford observed that applying equal amounts of glyhposate in higher concentrated droplets increased its phytotoxic effects (1). Buhler and Burnside (10) reported increased control of forage sorghum with fluazifop-butyl when an equal quantity of the herbicide was applied in smaller, more concentrated droplets, than in larger dilute droplets. Smaller droplets may also result in better distribution over the leaf surface, thus resulting in more absorption per unit area because of greater surface contact.

Impurities in well water, such as divalent cations, have been shown to decrease glyphosate phytotoxicity at higher carrier volumes (9, 43). Decreasing carrier volume reduces the amount of impurities that are present to interact with glyphosate and often eliminates phytotoxicity inhibition from hard water as reported by Buhler and Burnside (9). With fluazifop-butyl the presence of impurities in well water does not appear to be a factor since no difference in phytotoxicity was observed when the herbicide was applied at 190 L/ha of well or distilled water (10).

Effect of Ammonium Sulfate and Relative Toxicities

Foxtail control varied with the herbicide and dosage applied. Glyphosate, paraquat, and SC-0224 at 1.12 kg/ha all controlled yellow foxtail better than fluazifop-butyl at the Brookings County location (Table 12). Control of yellow foxtail was comparable among equal rates of HOE-00661, paraquat, and SC-0224 when applied at 0.56 and 1.12 kg/ha. Fluazifop-butyl, glyphosate, paraquat, and SC-0224 applied at 0.28 kg/ha all gave significantly better control than HOE-00661 applied at an equal dose. Paraquat at 0.14 and 0.28 kg/ha gave superior control when comparing equal rates of fluazifop-butyl, HOE-00661, and SC-0224. Control was significantly better with paraquat than glyphosate when comparing between equal rates of 0.07 and 0.14 kg/ha. Yellow foxtail control was comparable between 0.14 kg/ha of paraquat and 0.07 kg/ha of glyphosate with 2.80 kg/ha of ammonium sulfate. Enhancement of glyphosate with ammonium sulfate has also been documented for barley [*Hordeum vulgare* (L.) 'Galt'] (33), quackgrass [*Agropyron repens* (L.) Beauv.] (3,22), and Canada thistle [*Cirsium arvense* (L.) Scop.] (21). The ammonium sulfate enhancement of glyphosate phytotoxicity is most likely due to increased absorption of glyphosate caused by increased cell membrane permeability from ammonium sulfate (22). The

Table 12. Comparison of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 for control of yellow foxtail in oat stubble in Brookings County in 1982 16 days after treatment[a,b].

	Chemical[c]				
Herbicide dosage	fluazifop-butyl	glyphosate	HOE-00661	paraquat	SC-0224
(kg/ha)	(%)				
1.12	69 d-i	96 ab	84 a-e	99 a	91 a-c
0.56	50 h-l	74 c-g	68 e-i	90 a-e	84 a-e
0.28	50 h-l	75 b-f	22 mn	90 a-d	60 f-j
0.13	25 mn	56 f-k	39 j-n	85 a-e	50 h-l
0.07 + AS[d]	34 l-n	71 c-h	44 j-m	52 g-l	31 l-n
0.07	35 k-n	36 k-n	34 l-n	76 b-f	34 l-n
0.03	24 mn	44 j-m	20 no	49 i-l	20 no
0.00	0 o	0 o	0 o	0 o	0 o

[a] Data are averages of four replications.

[b] Means within columns and rows followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[c] Surfactant (X-77) was added to each treatment at 0.50% (v/v), with the exception of fluazifop butyl which was mixed with 2.34 L/ha of crop oil concentrate.

[d] Treatments with added ammonium sulfate (AS) contained 2.80 kg/ha of water soluble ammonium sulfate.

addition of ammonium sulfate to paraquat reduced percent control. There were no significant differences among foxtail dry weights (data not shown).

Percent foxtail control was similar among glyphosate, HOE 00661, paraquat, and SC-0224 at 0.56 and 1.12 kg/ha at Deuel county in 1983 (Table 13). All three herbicides controlled foxtail better than fluazifop-butyl. Control was superior with HOE-00661 at 0.07, 0.14, and 0.28 kg/ha compared to SCO-0224 at equal rates. Control was comparable among equal rates of glyphosate and HOE-00661 except 0.14 kg/ha which resulted in significantly better control with HOE-00661. Glyphosate compared to SC-0224 at 0.07 kg/ha gave significantly better control. All other rates of the two herbicides resulted in comparable control. Paraquat at dosages as low as 0.07 kg/ha resulted in higher percent control of foxtail than any other herbicide at an equal dosage. Control was less with the highest rate of fluazifop-butyl, 0.14 kg/ha of glyphosate and SC-0224 and 0.56 kg/ha of HOE-00661 plus 2.80 kg/ha of ammonium sulfate. Dry weights were significantly reduced and percent control was significantly higher when ammonium sulfate was added to HOE-00661 (Table 14). Percent control of foxtail was significantly higher when SC-0224 was applied at 0.07 kg/ha plus 2.80 kg/ha of ammonium

Table 13. Comparison of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 for control of yellow foxtail in oat stubble in Deuel County in 1983 16 days after treatment[ab].

	Chemical[c]				
Herbicide dosage	fluazifop-butyl	glyphosate	HOE-00661	paraquat	SC-0224
(kg/ha)	(%)				
1.12	58 c-e	99 a	100 a	100 a	99 a
0.56	51 e-g	95 a	100 a	95 a	94 a
0.28	35 f-i	86 ab	94 a	95 a	74 bc
0.13	32 g-j	39 e-h	71 b-d	95 a	30 h-j
0.07 + AS[d]	19 i-k	52 d-f	56 c-e	89 ab	41 e-h
0.07	0 k	41 e-h	31 h-j	85 ab	6 k
0.03	0 k	8 k	10 k	71 b-d	14 jk
0.00	0 k	0 k	0 k	0 k	0 k

[a] Data are averages of four replications.

[b] Means within columns and rows followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[c] Surfactant (X-77) was added to each treatment at 0.50% (v/v), with the exception of fluazifop-butyl which was mixed with 2.34 L/ha of crop oil concentrate.

[d] Treatments with added ammonium sulfate (AS) contained 2.80 kg/ha of water soluble ammonium sulfate.

Table 14. Comparison of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 for control of yellow foxtail in oat stubble in Deuel County in 1983 33 days after treatment[ab].

Herbicide dosage	Chemical[c] fluazifop-butyl	glyphosate	HOE-00661	paraquat	SC-0224
(kg/ha)	(Dry weight in g)				
1.12	180 f-m	166 j-p	127 o-r	102 rs	160 k-p
0.56	178 g-m	109 q-s	101 rs	79 s	123 p-r
0.28	206 b-i	149 m-q	152 l-q	129 n-r	192 d-l
0.13	246 ab	172 h-n	167 j-o	150 l-q	162 k-p
0.07 + AS[d]	216 a-g	201 c-k	184 e-m	162 l-p	217 a-g
0.07	226 a-e	199 d-k	229 a-d	169 i-o	234 a-d
0.03	243 a-c	209 b-j	212 b-i	199 d-k	258 a
0.00	223 a-f	211 b-i	214 b-h	211 b-i	230 a-d

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[a] Data are averages of four replications.

[b] Means within columns and rows followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[c] Surfactant (X-77) was added to each treatment at 0.50% (v/v), with the exception of fluazifop butyl which was mixed with 2.34 L/ha of crop oil concentrate.

[d] Treatments with added ammonium sulfate (AS) contained 2.80 kg/ha of water soluble ammonium sulfate.

sulfate compared to SC-0224 applied alone at the same dosage. Although the difference was nonsignificant, percent control with glyphosate plus ammonium sulfate was higher than glyphosate alone.

Percent foxtail control was higher with glyphosate, HOE-00661, paraquat, and SC-0224 at 1.12 kg/ha than fluazifop-butyl at the Moody County location in 1983 (Table 15). Comparisons of HOE-00661, paraquat, and SC-0224 reveal that HOE-00661 generally provided comparable or better control of yellow foxtail at equal rates. These results contradict those of Wilson et al. (55), who found control of rye (*Secale cereale* L.) to be significantly better with equal rates of glyphosate, SC-0224, and 0.5X rate of paraquat compared to HOE-00661. They found control of fall panicum (*Panicum dichotomiflorum* Michx.) to be superior to paraquat when compared to HOE-00661 and glyphosate at equal or higher rates. Glyphosate at 0.28 kg/ha gave higher percent foxtail control than any of the other herbicides at an equal dosage. The addition of ammonium sulfate to glyphosate significantly increased the percent control of foxtail. Although few differences were significant among foxtail dry weights, a general trend of decreasing dry weights with increasing dosage was evident for each herbicide (Table 16).

Table 16. Comparison of fluazifop-butyl, glyphosate, HOE-00661, paraquat, and SC-0224 for control of yellow foxtail in oat stubble in Moody County in 1983 26 days after treatment[ab].

	Chemical[c]				
Herbicide dosage	fluazifop-butyl	glyphosate	HOE-00661	paraquat	SC-0224
(kg/ha)	(Dry weight in g)				
1.12	247 e-i	134 hi	116 i	165 g-i	243 e-i
0.56	383 c-i	139 hi	206 e-i	310 d-i	194 f-i
0.28	535 a-i	265 e-i	241 e-i	401 a-i	438 a-i
0.13	568 a-h	299 d-i	514 a-i	480 a-i	599 a-g
0.07 + AS[d]	416 a-i	244 e-i	466 a-i	420 a-i	390 b-i
0.07	830 ab	379 c-i	475 a-i	728 a-d	597 a-g
0.03	731 a-d	479 a-i	530 a-i	556 a-i	621 a-f
0.00	641 a-e	525 a-i	463 a-i	811 a-c	842 a

[a] Data are averages of four replications.

[b] Means within columns and rows followed by the same letter are not significantly different at the 5% level using Waller Duncan k-ratio T test (P=0.05 and k-ratio=100).

[c] Surfactant (X-77) was added to each treatment at 0.50% (v/v), with the exception of fluazifop-butyl which was mixed with 2.34 L/ha of crop oil concentrate.

[d] Treatments with added ammonium sulfate (AS) contained 2.80 kg/ha of water soluble ammonium sulfate.

The highest control of yellow foxtail attained with fluazifop-butyl in these studies was 69% control. This lack of control agrees with results of Derr et al. (13), who reported decreased control of giant foxtail (*Setaria faberi* Herrm.) when treatments were applied in the late tiller stage.

The difference in yellow foxtail control among locations as evidenced by a significant herbicide x rate x location interaction can be explained in part by climatic conditions before and after herbicide application (Table 17). The mean minimum and maximum temperature for the 7 and 14 day periods following treatment was greater at the Deuel County location than the other two locations. This variation may account for the apparent increase in control with paraquat at rates as low as 0.07 kg/ha at the Deuel County location compared to the Brookings and Moody county locations. This hypothesis coincides with the study results of Bovey and Davis (4), who reported that leaf necrosis of yaupon (*Fex voumitoria*) 7 days after treatment was greatest with higher temperatures at the time of application. They suggested that this temperature effect would indicate that higher temperatures favor more rapid paraquat absorption, that paraquat activity is associated with higher metabolic activity in cells, or both.

Table 17. Minimum and maximum temperatures for 14 days after treatment (DAT) for herbicide comparison studies in 1983.

	Brookings Co.		Deuel Co.		Moody Co.	
DAT	MIN	MAX	MIN	MAX	MIN	MAX
	(°C)					
0	10	27	18	34	19	31
1	6	23	21	34	18	30
2	10	26	17	34	13	30
3	16	28	19	34	13	28
4	9	21	21	33	16	28
5	10	18	16	32	13	30
6	16	22	22	32	13	31
7	17	23	13	29	21	35
8	13	24	17	32	19	31
9	16	29	19	32	17	31
10	12	24	20	33	18	36
11	9	17	21	37	16	31
12	9	14	18	37	18	32
13	8	12	18	35	14	32
14	4	13	19	36	16	28

The apparent reduced control of yellow foxtail with HOE-00661 at the Brookings County location may be due to lower temperatures relative to the other two locations. This hypothesis coincides with that of Wilson et al. (55), who reported that low temperatures for the 7 days following treatment of horseweed [Conyza canadensis (L.) Cronq.] with HOE-00661 may have reduced control. In their studies, they also attributed the lack of control of fall panicum control with HOE-00661, compared to good control in earlier studies, to lower temperatures.

Moisture levels varied among studies and may have also influenced herbicide activity (Table 18). Significant rainfall was received in the 7-day period preceding and following herbicide application at Brookings County. Rainfall totaling 0.86 cm was received the morning of herbicide application at the Deuel County location, followed by 0.74 cm of rain in the 7 days after application Minimal precipitation was received in the week preceding and following treatment at the Moody County location. Only minimal differences in total rainfall among all locations were present 4 weeks prior to application. The low rainfall amounts for the 7 days preceding and following herbicide applications at the Moody county location may have created a moisture stress on the yellow foxtail plants, resulting in reduced control with

Table 18. Total precipitation received for 30, 21, 14, and 7 days before treatment (DBT) and 7 and 14 days after treatment (DAT) at each experiment location in 1983.

Experiment Location	30 DBT	21 DBT	14 DBT	7 DBT	7 DAT	14 DAT
	-------------------	-------------------	-------------------	(cm)	-------------------	-------------------
Brookings Co.	5.18	4.55	4.50	3.00	1.65	4.06
Deuel Co.	3.61	1.07	0.86	0.86	0.74	0.74
Moody Co.	5.59	0.84	0.61	0.00	0.08	0.94

paraquat. Significant rainfall at the Brookings County location may have aided in providing optimum growing conditions which resulted in generally better paraquat toxicity than that of the Moody County location, even though temperatures were substantially lower at the Brookings County location. The precipitation received at the Deuel County location, coupled with the high temperatures before and after application, may have created the proper conditions for higher metabolic activity in the cells of yellow foxtail plants, further explaining the apparent increase in paraquat toxicity.

SUMMARY

Tillage or tillage plus herbicide treatment with glyphosate and dicamba gave best control of yellow foxtail postharvest in small grain. Yellow foxtail seed population was greatest where neither tillage nor chemical treatment of yellow foxtail was implemented. No significant difference in seed population was detected between chemical control of yellow foxtail and control by tillage. Yields were similar among different tillage treatments where an equal rate of alachlor was used. Yields were significantly lower where no alachlor was used.

Carrier volume affected the efficacy of all herbicides. Control of yellow foxtail with fluazifop-butyl, glyphosate, HOE-00661, and SC-0224 decreased as carrier volume increased. Efficacy of paraquat to yellow foxtail was greater with higher carrier volumes.

Fluazifop-butyl gave poor control of yellow foxtail. Glyphosate, HOE-00661, paraquat, and SC-0224 all gave acceptable control of yellow foxtail at the highest rate. The addition of ammonium sulfate increased the control of glyphosate, HOE-00661, and SC-0224.

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