INFLUENCE OF WHEAT ROW SPACING AND SEEDING RATE ON HERBICIDE EFFICACY

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INFLUENCE OF WHEAT ROW SPACING AND SEEDING RATE ON HERBICIDE EFFICACY

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INTRODUCTION

Each chapter of this thesis is a manuscript to be submitted for publication in Weed Technology, a Weed Science Society of America publication.

CHAPTER I

NET RETURNS FROM CHEAT (<u>Bromus</u> <u>secalinus</u>) CONTROL IN WINTER WHEAT (<u>Triticum</u> <u>aestivum</u>)

Net Returns from Cheat (*Bromus secalinus*) Control in Winter Wheat (*Triticum aestivum*)

Abstract. In field experiments, wheat row spacing, seeding rate, and herbicide treatment affected cheat seed content of harvested wheat, wheat yield, and net returns. No individual practice or combination of practices consistently increased net returns from cheat-infested wheat. Net returns were frequently increased and never decreased by applying metribuzin at 420 g ha^{-1} or chlorsulfuron + metsulfuron at 21.9 + 4.4 g ha^{-1} or by increasing the seeding rate. The data indicate that herbicide rates should not be reduced when row spacing is decreased and/or seeding rates increased.

Nomenclature: Chlorsulfuron, 2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide; metsulfuron, 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl] benzoic acid; metribuzin, 4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one; cheat, *Bromus secalinus* L. BROSE[1]; wheat, *Triticum aestivum* L.

Additional index words: Enterprise budgets, chlorsulfuron plus metsulfuron, metribuzin, BROSE.

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[1]Letters following this symbol are a WSSA-approved computer code from Composite Lists of Weeds, revised 1989. Available from WSSA, 309 W. Clark St., Champaigne, IL 61820.

INTRODUCTION

Cheat is the major grass weed in wheat in Oklahoma. Dockage in harvested grain can exceed 40% in heavily infested fields (17). Because of the limitations of available herbicides there is increased interest in combinations of cultural controls and herbicides. Cultural practices also have limitations. Moldboard plowing and stubble burning often conflict with environmental goals. Other cultural options include decreasing row spacing and increasing seeding rate. Delayed seeding is often not an option because early seeding maximizes forage production.

Decreasing row spacing of wheat increases its competitive ability with weeds (15). Reducing row spacing from 23 to 7.5 cm improved yield of hard red winter wheat 12% in cheat-infested fields (18). In other research reducing row spacing from 23 to 7.5 cm improved wheat yield in two of three experiments with weed-free wheat and six of ten experiments with cheat-infested fields (12).

In Oklahoma, wheat seeding rates vary with residue management practice, tillage system, and personal preference (6). Increasing wheat seeding rates from 67 to 101 kg ha^{-1} or reducing row spacing from 22.5 to 15 cm increased winter wheat yield over a range of cheat infestation levels (0 to 134 kg ha^{-1}) (13).

Chlorsulfuron plus metsulfuron (5:1 w/w)[2] controls several broadleaf weeds and a few grasses in wheat including interrupted windgrass (*Apera interrupta* L.) and Italian ryegrass (*Lolium multiflorum Lam.*) (5, 7, 19). Yield of soft white winter wheat was increased 22% when chlorsulfuron plus metsulfuron was applied POST at 20.9 g ai ha^{-1} to

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[2]Trade name is Finesse, E.I. DuPont de Nemours, Wilmington, DE 19898.

control several broadleaf weeds (19). Chlorsulfuron plus metsulfuron at 34 g ha^{-1} did not injure wheat (14). Chlorsulfuron plus metsulfuron applied PRE at 26 g ha^{-1} controlled cheat 40 to 60% and increased wheat yields at two of three locations (11).

Metribuzin use rates for cheat control in wheat vary from 280 to 510 g ai ha^{-1} depending on soil variables and application timing (2). Metribuzin can control Bromus spp. 80 to 100% , but, crop injury is a concern with metribuzin use (4, 16).

Net economic returns were not increased by applying metribuzin for cheat control in wheat seeded in 25 cm rows in 12 of 13 wheat seeding date, location, foraging situations in Oklahoma (10). In 11 of those situations, metribuzin controlled most of the cheat.

Cost estimates for seeding wheat with a 7.5- versus a 23-cm drill indicate that for a 120-ha farm, wheat grain yields would have to increase 93 kg ha^{-1} for the 7.5-cm system to break even with the 23-cm system (8). This estimate was computed based on an assumption that drill price is a function of number of openers per unit of width and that seeding rate is the same for both systems.

The objectives of this research were to determine whether decreasing row spacing and increase wheat seeding rates would improve cheat control obtained with herbicides and to determine whether application rates of cheat control herbicides could be reduced without reducing cheat control if the wheat was seeded at higher rates in 7.5-cm rows. Enterprise budgets were used to estimate the net returns associated with each combination of practices (9).

MATERIALS AND METHODS

Field experiments were conducted during the 1990-91 growing season near Lahoma, Chickasha, and Orlando, Oklahoma to determine the interaction of wheat row spacing, wheat seeding rates, and herbicide treatments on wheat grain yields and cheat seed content of the harvested grain. The soil at Lahoma, Chickasha, and Orlando was a Pond Creek loam (thermic, Udic Arguistoll), a Dale silt loam (thermic, Pachic Haplustolls), and a Pulaski loam (thermic, Typic Ustifluvent), respectively. The pH varied from 5.4 to 6.8 and organic matter content from 1.2 to 1.9%.

The experimental design at each site was a randomized complete block with a factorial arrangement of treatments and six replicates. Plot size was 2.1 by 7.5 m. Before seeding wheat, 50 kg ha^{-1} of locally harvested cheat seed (approximately 1100 seeds m^{-2}) and, based on soil test recommendations, fertilizer adequate for 4000 kg ha^{-1} grain yield were broadcast and incorporated into the soil approximately 4 to 5 cm deep.

Wheat seeding dates were Oct. 4, 1, 15, 1990 at Lahoma, Chickasha, and Orlando, respectively. At each location, '2157' wheat, a metribuzin-tolerant, hard red winter wheat cultivar was seeded with an experimental seeder with openers spaced 7.5 cm apart (2). Plugs were inserted into seed meter inlets to change row spacing by blocking rows. Each plot contained twenty-four 7.5-cm rows, twelve 15-cm rows, or eight 23-cm rows, all 7.6 m long. The knife opener-press wheel configuration placed the seed about 2.5 cm deep. An infinitely variable drive was adjusted to obtain seeding rates of 84 or 134 kg/ha in each of the row spacings.

The herbicide treatments included chlorsulfuron plus metsulfuron at 16.3 plus 3.3 and 21.9 plus 4.4 g ha^{-1} applied PRE, and metribuzin at 315 and 420 g ha^{-1} applied when wheat had 3 to 4 tillers, and a check. All herbicide treatments were applied with a CO_2-pressurized backpack sprayer in a total volume of 190 L ha^{-1}.

Wheat injury was estimated visually as the wheat matured. Cheat density was estimated in late February by counting the cheat plants in two 23 by 23-cm quadrants in all plots planted at 84 kg ha^{-1} in 23-cm rows.

Grain yield was determined by harvesting the plots with a small plot combine. To determine both wheat grain yield and cheat seed yield, the harvested samples were cleaned with a small seed cleaner to separate cheat seed, wheat seed and other material. Wheat grain yield, adjusted to 13.5% moisture, was determined after cleaning.

The grain was graded according to USDA standards to determine market value (1). Established grades include 1 to 5, where Grade 1 is the highest quality and Grade 5 (sample grade) is the lowest quality wheat. Cheat is removed before grading, thus cheat seed content of harvested grain does not affect grades. The regional average price penalties used for determining the value of inferior quality wheat were 0, 0.11, 0.25, and 0.44 cents per kg for Grades 2 through 5, respectively[3].

Production costs and net returns to land, labor, overhead, risk, and management were computed for each treatment combination at all locations by using an appropriate enterprise budget (Table 1). Total revenues

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[3]Specter, T. 1992. Personal Communication. CO-OP Farmer Exchange, Perry, OK 73077

include income from grain sale and income from participation in federal wheat commodity programs. The revenue from farm programs was estimated assuming that commodity program payment limitations would not be exceeded (3). The appropriate weighted county average wheat yields used by the USDA Agricultural Stabilization and Conservation Service to determine commodity program benefits were used in calculating government payments [4]. The prices used for chlorsulfuron plus metsulfuron and metribuzin, \$609/kg and \$48/kg, respectively, are average retail prices in Oklahoma[5]. Net returns were evaluated assuming a baseline input of 84 kg ha^{-1} of wheat seed, no herbicide, and a conventional 23-cm row spacing grain drill.

RESULTS AND DISCUSSION

Cheat seed content of harvested grain was affected by wheat seeding rate, row spacing, and herbicide treatment at Chickasha. With no herbicide, increasing the wheat seeding rate reduced cheat seed production except when wheat was seeded in 23-cm wide rows (Table 2). Chlorsulfuron plus metsulfuron at the lower rate did not reduce cheat seed when wheat was seeded at 84 kg ha^{-1} in 23-cm rows. However, increasing the herbicide rate, reducing row spacing, or increasing the wheat seeding rate reduced cheat seed. Seeding rate and row spacing did not influence the amount of cheat seed present in metribuzin treated

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[4]Hughes, D. 1992. Personal Communication. Programs assistant USDA-ASCS State Office, Stillwater, OK 74078

[5]Johnson, M.D. 1992. Personal Communication. Sales representative. DuPont Ag Products. Edmond OK 73034.

plots.

Row spacing did not interact with other factors on cheat yield at the other locations. Averaged over wheat seeding rates and herbicide treatments, cheat yield was 139, 150, and 174 kg ha^{-1} (LSD 0.05 = 12) in wheat seeded in 7.5-, 15-, and 23-cm rows, respectively, at Lahoma. Cheat yields were 304, 281, and 321 kg ha^{-1} (LSD 0.05 = 22) with the same respective row spacings at Orlando. These results are similar to those reported by Koscelny et al. (15).

Increasing wheat seeding rate reduced cheat seed content at Lahoma and Orlando. Compared to plots seeded at 84 kg ha^{-1} and treated with the lower rate of either herbicide, cheat yield was reduced as much or more by increasing the seeding rate as by increasing the herbicide rate. Increasing both seeding rate and herbicide rate did not reduce cheat seed more than just increasing the seeding rate, except at Lahoma. At Lahoma cheat seed was the lowest with the higher seeding rate and higher metribuzin rate.

No seeding rate by row width by herbicide treatment interaction or two way interaction was found in the wheat yield data. Averaged over herbicide treatments and row spacings, increasing the seeding rate from 84 to 134 kg ha^{-1} increased (P = 0.05) wheat yield 2480 to 2750 kg ha^{-1} at Orlando, but seeding rate did not affect yield at other locations. Each decrease in row spacing increased (P = 0.05) wheat yield 130 kg ha^{-1} at Lahoma, but row spacing did not affect yield at other locations. Wheat yield was increased by all herbicide treatments at all locations with the exception of the lower rate of chlorsulfuron plus metsulfuron at Chickasha and by both metribuzin treatments at Lahoma (Table 3). At Lahoma, metribuzin visually reduced the wheat stand 8 and 14% at the low and high rates. No other wheat injury occurred at any site.

Practices that increased net returns at Chickasha included reducing row spacing to 7.5 cm with no herbicide or reducing row spacing to 15 cm and applying chlorsulfuron plus metsulfuron at either rate. If 23-cm row spacing was retained, net returns were increased by applying either chlorsulfuron plus metsulfuron at the low rate or metribuzin at 420 g ha^{-1} or by seeding at the higher rate and applying chlorsulfuron plus metsulfuron at the low rate (Table 4).

Net returns at Lahoma were not influenced by seeding rate. Assuming the same baseline input as above, net returns were not increased simply by reducing row spacing unless chlorsulfuron plus metsulfuron at either rate or metribuzin at the low rate was also applied. Chlorsulfuron plus metsulfuron at the low rate increased net returns $37 per ha.

Averaged over seeding rates and herbicide treatments, net returns at Orlando were $43, 55, and 47 per ha for wheat planted in 7.5, 15, and 23-cm rows, respectively. Since there were no interactions with row spacing, the baseline input is assumed to be 84 kg ha^{-1} of wheat seeded and no herbicide. The only input which increased net returns was metribuzin at the low rate. Applying chlorsulfuron plus metsulfuron at the low rate decreased net returns.

The variable net returns indicate that no individual practice or combination of practices can consistently be expected to increase net returns from cheat-infested wheat. However, net returns were frequently increased and never decreased by applying the high rate of either herbicide or by increasing the seeding rate. Thus, to maximize the potential for positive returns, combinations of practices should be used, including seeding at a higher rate.

LITERATURE CITED

1. Anonymous. 1988. Grain Inspection Handbook. Book II, Wheat. U.S. Dep. Agric., Fed. Grain Inspec. Serv.
2. Anonymous. 1991. Lexone Supplemental Labeling. DuPont de Nemours, Wilmington DE 19898.
3. Anderson, K. and L. D. Sanders. 1990. Farm level analysis of budget cutting options in the pending 1990 farm bill. Insert in Agricultural Policy's Economic Issues 5:8. Coop. Ext. Service, Oklahoma State University, Stillwater, OK 74078.
4. Appleby, A. P., and L. A. Morrow. 1990. The Pacific Northwest. Chap. 10 In W.W. Donald ed., Systems of Weed Control in Wheat in North America. Weed Sci. Soc. Amer. Champaign, IL 61820.
5. Belles, W. S. 1989. Control of broadleaf weeds in winter wheat with dicamba-sulfonyl-urea combinations. Res. Prog. Rep., West. Soc. Weed Sci.,p. 356-357.
6. Cuperus, G., R. Thompson, B. Tucker, S. Coppock, E. Williams, J. Stiegler, P. Bloome, H. Greer, J. Pitts, and D. Fain. 1985. Wheat production and pest management in Oklahoma. Cir E-831. Coop. Ext. Service. Oklahoma State University, Stillwater, OK 74078.
7. Dial, M. J., and D. C. Thill. 1989. Postplant preemergence weed control in winter wheat. Res. Prog. Rep., West. Soc. Weed Sci. p. 366-367.

8. Epplin, F. M., V. K. Allread, J. B. Solie, T. F. Peeper, and J. A. Koscelny. 1992. Economics of ultranarrow row planting for hard red winter wheat production in Oklahoma. J. Prod. Agric. 5:(in press).

9. Epplin, F. M., T. F. Tice, S. J. Handke, T. F. Peeper, and E. G. Krenzer, JR. 1983. Cost estimates of alternative wheat production systems for Garfield County. Agric. Exp. Stn. Bull. B-766. Okla. State Univ. Stillwater, OK 74078.

10. Ferreira, K. L., T. F. Peeper, and F. M. Epplin. 1990. Economic returns from cheat (Bromus secalinus) control in winter wheat (Triticum aestivum). Weed Technol. 4:306-313.

11. Justice, G. G., T. F. Peeper, J. E. Driver, and J. A. Koscelny. 1991. Finesse for cheat suppression in Oklahoma wheat. Proc. South. Weed Sci. Soc. 44:113.

12. Koscelny, J. A., T. F. Peeper, J. B. Solie, S. G. Solomon, JR. 1990. Effect of wheat (Triticum aestivum) row spacing, seeding rate, and cultivar on yield loss from cheat (Bromus secalinus). Weed Technol. 4:487-492.

13. Koscelny, J. A., T. F. Peeper, J. B. Solie, and S. G. Solomon, JR. 1991. Seeding date, seeding rate, and row spacing affect wheat (Triticum aestivum) and cheat (Bromus secalinus). Weed Technol. 5:707-712.

14. Miller, S. D., A. W. Dalrymple, and D. A. Ball. 1989. Weed control in winter wheat with fall or spring herbicide treatments. Res. Prog. Rep., West. Weed Sci. Soc.,p.230-231.

15. Nalewaja, J. D., and W. E. Arnold. 1970. Weed control methods, losses and costs due to weeds, and benefits of weed control in wheat and other small grains. 1st FAO Int. Conf. Weed Control, Davis, CA 95616. p.1-16.

16. Peeper, T. F., and L. A. Morrow. 1990. Substituted ureas, triazines, and triazinones. Chap. 20. In W.W. Donald ed., Systems of Weed Control in Wheat in North America. Weed Sci. Soc. Amer. Champaign, IL 61820.

17. Ratliff, R. and T. Peeper. 1987. Bromus control in winter wheat (Triticum aestivum) with the ethylthio analog of metribuzin. Weed Technol. 1:235-241.

18. Solie, J. B., S. G. Solomon, JR., K. P. Self, T. F. Peeper, J. A. Koscelny. 1991. Reduced row spacing for improved wheat yields on weed-free and weed-infested fields. Trans. Am. Soc. Agr. Eng. 34:1654-1660.

19. Thompson, C. R., and D. C. Thill. 1992. Interrupted windgrass and broadleaf weed control in soft white winter wheat. Res. Prog. Rep., West. Weed Sci. Soc., Sec. III- Weeds of Agronomic Crops. p.175-176.

20. U.S. Department of Agriculture. 1990. Agriculture Prices. Agriculture Statistics Board Publications, Washington, DC 20520.

Table 1. Wheat grain budget.

Budget parameter	Unit of measure	Price	Quantity	Value[a]
Receipt sources		$ per unit	units per ha	$ ha^{-1}
Wheat grain	kg	0.092[b]	---	---
USDA wheat program	kg	0.039	---[c]	---
Total receipts				---
Operation inputs				
Wheat seed	kg	0.222	---[d]	---
18-46-0 fertilizer	kg	0.267	58	15.5
Ammonium nitrate	kg	0.227	198	45.0
Ammonium application	ha	4.94	1	4.94
Insecticide	kg	8.89	.42	3.73
Insecticide application	ha	11.12	.50	5.56
Chlorsulfuron + metsulfuron	g	0.609	---[e]	---
Metribuzin	g	0.048	---[f]	---
Fuel, lube, and repairs	ha			---[g]
Annual operating capital	$	0.09	---	---
Custom harvest				
Base charge	ha	29.64	1.0	29.64
Yield above 1334 kg ha^{-1}	kg	0.004	---	---
Hauling	kg	0.004	---	---
Total operating cost				---
Machinery fixed cost	$ ha^{-1}			---[h]
Return above all costs except land, labor, overhead, risk and management	$ ha^{-1}			---[i]

[a] Values obtained by multiplying price by quantity.

[b] Local harvest price ($ kg^{-1}) for USDA No. 1 hard red winter wheat (20) adjusted for price penalties.

Table 1. Continued.

[c] County average wheat yield, i.e. 2321, 2441, and 2227 kg ha^{-1} for Chickasha, Lahoma, and Orlando, respectively.

[d] Wheat seeding rates of 84 and 134 kg ha^{-1}.

[e] Two rates of 19.6 and 26.3 g ha^{-1}.

[f] Two rates of 315 and 420 g ha^{-1}.

[g] Rates vary with row spacing [i.e. $27.86, $27.15, and $26.90 for 7.5, 15, and 23 cm, respectively (8)].

[h] Rates vary with row spacing [i.e. $81.99, $76.75 and $74.99 for 7.5, 15 and 23 cm, respectively (8)].

[i] Net returns are tabulated in Table 4.

Table 2. Interaction of herbicide treatment, seeding rate, and row spacing on cheat seed content of harvested wheat at three locations.

		Chickasha						Lahoma		Orlando	
		Wheat seeded (kg ha^{-1})									
		84			134			84	134	84	134
		Row spacing (cm)									
Treatment	Rate	7.5	15	23	7.5	15	23	Mean[a]	Mean[a]	Mean[a]	Mean[a]
	g ha^{-1}	kg ha^{-1}									
Chlorsulfuron + metsulfuron	16.6 + 3.3	89	100	211	111	111	122	222	122	456	367
Chlorsulfuron + metsulfuron	21.9 + 4.4	111	156	133	89	111	100	167	111	445	345
Metribuzin	315	67	67	78	56	67	78	122	78	156	111
Metribuzin	420	44	67	67	67	56	67	78	56	100	78
Check	---	211	255	200	156	156	189	367	211	556	400
LSD (0.05)		48						20		39	

[a] Mean indicates that the three way interaction was not significant.

Table 3. Effect of herbicide treatments averaged over row width and seeding rate on wheat yield at three locations.

Treatment	Rate	Chickasha	Lahoma	Orlando
	$g\ ha^{-1}$		$kg\ ha^{-1}$	
Chlorsulfuron + metsulfuron	16.6 + 3.3	2300	2000	2500
Chlorsulfuron + metsulfuron	21.9 + 4.4	2400	2100	2600
Metribuzin	315	2600	1900	2800
Metribuzin	420	2600	1700	2800
Check	---	2200	1800	2300
LSD 0.05		110	120	150

Table 4. Net returns above all costs except land, labor, overhead, risk, and management.

Treatment	Rate	Chickasha						Lahoma			Orlando	
		Wheat seeded (kg ha^{-1})										
		84			134			Mean[a]			84	134
		Row spacing (cm)										
		7.5	15	23	7.5	15	23	7.5	15	23	Mean[b]	Mean[b]
	g ha^{-1}	$ per ha										
Chlorsulfuron + metsulfuron	16.3 + 3.3	33	40	40	59	41	49	15	5	25	21	33
Chlorsulfuron + metsulfuron	21.9 + 4.4	41	47	39	41	20	39	16	24	-6	52	53
Metribuzin	315	26	34	16	22	27	33	16	-5	-5	67	60
Metribuzin	420	16	17	44	25	33	48	-11	-24	-19	57	43
Check	---	47	-8	16	19	27	8	-27	-11	-12	47	63
LSD (0.10)		24										
LSD (0.05)								20			19	

[a] There was not a significant interaction with seeding rate at Lahoma.

[b] There was not a significant interaction with row spacing at Orlando.

CHAPTER II

NET RETURNS FROM ITALIAN RYEGRASS (*Lolium multiflorum*) CONTROL IN WINTER WHEAT (*Triticum aestivum*)

Net Returns from Italian Ryegrass (*Lolium multiflorum*) Control in Winter Wheat (*Triticum aestivum*)

Abstract. In three field experiments, wheat row spacing, seeding rate, and herbicide treatment affected Italian ryegrass control, dockage, wheat yield, and net returns. Net returns were increased at all locations by diclofop and by chlorsulfuron PRE at 18 or 26 g ha^{-1} at two of three locations. Although increasing the wheat seeding rate reduced dockage at two of three locations net returns were maximized by herbicide application alone without increased seeding rates or reduced row spacing.

Nomenclature: Chlorsulfuron, 2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide; diclofop, (±)2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid; Italian ryegrass, *Lolium multiflorum* Lam. #[1] LOLMU; wheat, *Triticum aestivum* L.

Additional index words: Enterprise budgets, chlorsulfuron, diclofop, LOLMU.

INTRODUCTION

Italian ryegrass is a competitive winter annual weed in winter wheat

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[1]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaigne, IL 61820.

(5, 16). Wheat yield was reduced 4.2% for each ten Italian ryegrass plants per m^{-2} (17). Reductions in wheat yield have been attributed to Italian ryegrass competition during wheat tillering, severe lodging, and interference with wheat harvesting because this weed matures later than wheat (5, 16).

Chlorsulfuron applied PRE at 18 to 35 g ai ha^{-1}, controlled Italian ryegrass 73 to 100% (12, 10, 12). Yields of Italian ryegrass infested wheat were increased 22% when chlorsulfuron was applied PRE at 35 g ha^{-1} (10). No wheat injury was observed when chlorsulfuron was applied PRE at 26 g ha^{-1} (12). PRE applications at 18 and 26 g ha^{-1} are registered for Italian ryegrass suppression with the higher rate suggested for use in the southern region (3).

Diclofop, applied POST at 500 to 1500 g ai ha^{-1}, controlled Italian ryegrass 81 to 100% (10, 11). Diclofop was most effective when applied to two-to three-leaf Italian ryegrass at 1500 g ha^{-1}. Diclofop at 560 and 1500 g ha^{-1} increased wheat yields 20 and 60% (10, 11). In Mississippi diclofop POST at 1120 g ai ha^{-1} controlled Italian ryegrass 88% (20). Diclofop is registered for Italian ryegrass control in winter wheat when applied POST at 560 to 1120 g ha^{-1} (4). Typical applications rates seldom exceed 820 g ha^{-1} (9). However, winter wheat is often foraged by cattle (<u>Bos</u> sp.) in the Southern Great Plains which precludes use of diclofop.

In Oklahoma, wheat seeding rates vary with residue management practice, tillage system, and personal preference (6). Increasing wheat seeding rates from 67 to 101 kg ha^{-1} or reducing row spacing from 22.5 to 15 cm increased winter wheat yield over a range of cheat (<u>Bromus secalinus</u> L.) infestation levels (0 to 134 kg ha^{-1}) (15). Increasing wheat seeding density to greater than 60 kg ha^{-1} reduced annual ryegrass (Lolium rigidum Gaudin.) growth up to 50% with no effect on wheat yield (18).

Decreasing row spacing of wheat increases its competitive ability with weeds (19). Reducing the row spacing of cheat infested wheat from 23 to 7.5 cm improved hard red winter wheat yields 12% (21). In other research, reducing row spacing from 23 to 7.5 cm improved wheat yield in two of three experiments with weed-free wheat and six of ten experiments with cheat-infested wheat (14).

Cost estimates for seeding wheat with a 7.5-cm versus a 23-cm drill indicate that for a 120 ha farm, wheat grain yields would have to increase 93 kg ha^{-1} to break-even using the narrow row spacing drill (7). This estimate assumed that drill price would be a function of number of openers per unit of width.

The objectives of this research were to determine whether reducing row spacing and increasing wheat seeding rates would improve Italian ryegrass control obtained with herbicides and to determine whether application rates of Italian ryegrass control herbicides could be reduced to minimize registered rates if wheat was seeded at higher rates in narrow rows. Enterprise budgets were used to estimate the net returns associated with each combination of practices (8).

MATERIALS AND METHODS

Field experiments were conducted during the 1991-92 growing season near Chickasha, Haskell, and Perkins, Oklahoma to determine the interaction of wheat row spacing, seeding rate, and herbicide treatment on wheat grain yields and dockage of the harvested grain.

The experimental design at each site was a randomized complete block with a factorial arrangement of treatments and six replicates. Plot size was 2.1 by 7.5 m. Before seeding wheat, 33 kg ha^{-1} of Italian ryegrass seed and, based on soil test recommendations, fertilizer adequate for 4000 kg ha^{-1} grain yield, were broadcast and incorporated into the soil approximately 5 cm deep.

Wheat seeding dates were Sept. 26, Oct. 7, and Oct. 8, 1991, at Perkins, Haskell, and Chickasha, respectively. At each location, '2180' hard red winter wheat was seeded with two drills. An experimental drill with double disc openers and press wheels was used to seed twenty-four rows in each plot with 7.5-cm wide rows. Plots with 20-cm wide row were seeded with a grain drill with double disc openers and split-v press wheels. Seeding rates with each drill were 67, 100 and 133 kg ha^{-1}.

Herbicide treatments included chlorsulfuron at 18 and 26 g ai ha^{-1} applied PRE, and diclofop at 560 and 840 g ai ha^{-1} applied in the fall to tillered wheat, and an untreated check. All herbicide treatments were applied with a CO_2-pressurized backpack sprayer in a total carrier volume of 190 L ha^{-1}. Italian ryegrass density was estimated in early February by counting the plants in two 15 by 15 cm quadrats in check plots planted at 67 kg ha^{-1} in 20 cm rows (Table 1). Very few broadleaf weeds were present at any site. Italian ryegrass control was estimated visually in the spring. Grain yield was determined by harvesting the plots with a small plot combine adjusted to retain Italian ryegrass seed with the wheat. To determine wheat grain yield, adjusted to 13.5% moisture, the harvested samples were cleaned with a small seed cleaner. Material removed from the wheat included Italian ryegrass seed, chaff, and straw and was considered dockage.

The cleaned grain was graded according to USDA standards to determine market value (1). Established wheat grades include 1 to 5, where Grade 1 is the highest quality and Grade 5 (sample grade) is the lowest quality. The regional average price penalties used for determining the value of inferior quality wheat were 0, 0.11, 0.25, and 0.44 cents per kg for Grades 2 through 5, respectively[2]. Production costs and net returns above all costs except land, labor, overhead, risk, and management were computed for each treatment combination at all locations by using an appropriate enterprise budget (Table 2). Total revenues included those expected from participation in federal wheat commodity programs. The revenue from farm programs was estimated assuming that commodity program payment limitations would not be exceeded (2). The appropriate weighted county average wheat yields used by the USDA Agricultural Stabilization and Conservation Service to determine commodity program benefits were used in calculating government payments[3]. The prices used for chlorsulfuron and diclofop, \$0.58 per g and \$0.016 per g, respectively, are average retail prices in Oklahoma[4]. Net returns were evaluated assuming a baseline input of 67 kg ha^{-1} of wheat seed, no herbicide, and a conventional 20-cm row spacing drill.

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[2] Specter, T. 1992. Personal Communication. CO-OP Farmers Exchange, Perry, OK 73077

[3] Hughes, D. 1992. Personal Communication. Programs assistant USDA-ASCS State Office, Stillwater, OK 74078

[4] Savage, T. 1992. Personal Communication. Sales representitive, Estes Cemical Co. Enid, OK 73701

RESULTS AND DISCUSSION

All diclofop treatments regardless of application rate, controlled Italian ryegrass 90 to 100% (Table 3). Within Diclofop treatments interactions with row spacing or seeding rate were not found in the control data at any location.

Visual estimates of Italian ryegrass control were not affected by seeding rate at Chickasha. Averaged over seeding rates, control with chlorsulfuron at 26 g ha^{-1} was visually estimated to be 30% better in wheat seeded in 20-cm rows than in wheat seeded in 7.5-cm rows.

At Haskell and Perkins, Italian ryegrass control was affected by wheat seeding rate, row spacing, and herbicide treatment. When wheat was seeded at 133 kg ha^{-1} in 7.5-cm rows, chlorsulfuron at 18 g ha^{-1} controlled Italian ryegrass as effectively as chlorsulfuron at 26 g ha^{-1} with any combination of row spacing and seeding rates. Reducing row spacing did not improve control obtained with chlorsulfuron at Perkins. However, with no herbicide, increasing the seeding rate at Perkins appeared to suppress Italian ryegrass.

In spite of the differences in visual control estimates, row spacing did not affect dockage at Chickasha. This may indicate that visual estimations of control are more difficult to obtain when multiple crop seeding rates and row spacing are used within one experiment. In the untreated check, each increase in the seeding rate decreased dockage (Table 4). Also, with the baseline seeding rate of 67 kg ha^{-1}, chlorsulfuron at the lower and higher rates decreased dockage 45 and 63%. With chlorsulfuron at 18 g ha^{-1}, increasing the seeding rate from 67 to 100 kg ha^{-1} reduced dockage an additional 15%. Within the chlorsulfuron treatments, dockage was the lowest with the higher rate of chlorsulfuron and the highest wheat seeding rate.

At Haskell there were no interactions in the dockage data. Averaged over row spacing and seeding rate, chlorsulfuron at 18 and 26 g ha^{-1} reduced dockage 17 and 26% (Table 4). Dockage in the diclofop treatments was attributed primarily to chaff and straw, since little Italian ryegrass survived in these plots. Averaged over the other factors, increasing the seeding rate from 67 to 100 kg ha^{-1} decreased dockage fom 485 to 430 kg ha^{-1} ($P = 0.003$). Dockage was not reduced further by increasing the seeding rate to 133 kg ha^{-1}. Averaged over other factors, dockage was reduced 9% ($P = 0.053$) by reducing row spacing fom 20 to 7.5 cm.

Since diclofop controlled Italian ryegrass 100% at Perkins, row spacing and seeding rate did not affect dockage in diclofop treatments. The 60 to 70 kg ha^{-1} dockage in these treatments is again a good indicator of the amount of material other than Italian ryegrass seed that contributed to dockage in all treatments.

From the baseline input of 67 kg ha^{-1} seeding rate, 20-cm row spacing and no herbicide, increasing the seeding rate to 100 kg ha^{-1} decreased dockage as effectively as applying chlorsulfuron at either rate (Table 4). A further decrease was obtained by increasing seeding rate to 133 kg ha^{-1} and applying chlorsulfuron at either rate. Decreasing row spacing did not decrease dockage in any treatment.

Wheat yield data was pooled across location when interactions with locations were not significant. Pooled over locations and herbicide treatments, decreasing row spacing did not increase wheat yield regardless of wheat seeding rate (Table 5). Increasing wheat seeding rate did not influence yield of wheat seeded in 20-cm rows, but wheat seeded at 133 kg ha^{-1} in 7.5-cm rows yielded more than wheat seeded at 67 or 100 kg ha^{-1} in 7.5-cm rows.

Pooled over locations and seeding rates, decreasing the row spacing to 7.5 cm did not increase yield obtained with any herbicide treatment (Table 6). Pooled across locations and row spacings, within chlorsulfuron and diclofop treatments, increasing wheat seeding rate did not increase wheat yield. In the check, increasing wheat seeding rate from 67 to 100 kg ha^{-1} increased yield 21%. However, yield increases obtained by increasing the seeding rate in the check were less than increases obtained by applying either herbicide at either rate.

A late season hail storm reduced wheat yield an estimated 60 to 70% to a mean yield of 719 kg ha^{-1} at Chickasha. There were no interactions in the net returns data from this location. Averaged over other factors, all herbicide treatments reduced net loss from \$103 per ha to \$82 to \$86 per ha (LSD 0.05 = 14). Averaged over other factors, seeding in 7.5-cm rows increased losses \$77 to \$98 per ha ($P = 0.05$). This difference was not attributed only to the differences in drill cost. At Chickasha, moisture at seeding was marginally adequate and only about 75% of the wheat seeded in 7.5-cm rows emerged until rain fell 15 days after seeding. Thus the wheat seeded in 20-cm rows had some competitive advantage by emerging earlier. Also, the more uniform spatial distribution of wheat stems in the plots seeded in 7.5-cm rows may have made them more susceptible to damage from a sudden hail storm. Increasing the wheat seeding rate did not increase net returns.

Averaged over row spacings, all herbicide treatments increased net returns at Haskell (Table 7). However, increasing the seeding rate did not further increase net returns and decreased net returns in some treatments with diclofop.

Net returns were affected by row spacing, seeding rate, and herbicide treatment at Perkins. No chlorsulfuron treatment improved net returns except chlorsulfuron at the high rate with wheat seeded at 100 kg ha^{-1} in 20-cm rows. However, the single best net return was from diclofop at the low rate applied to wheat seeded at 67 kg ha^{-1} in 7.5-cm rows.

Net returns indicate that narrow row wheat seeding and increased wheat seeding rates can improve net returns, but are not economically viable substitutes for herbicides for Italian ryegrass control in wheat. At two of three sites, net returns from diclofop applied POST at 560 g ha^{-1} were not exceeded by any other treatment combination. At Perkins, the greatest net returns were obtained with the same herbicide treatment combined with 7.5-cm row spacing.

LITERATURE CITED

1. Anderson, K. and L. D. Sanders. 1990. Farm level analysis of budget cutting options in the pending 1990 farm bill. Insert in Agricultural Policy's Economic Issues 5:8. Coop. Ext. Service, Oklahoma State University, Stillwater, OK 74078.
2. Anonymous. 1988. Grain Inspection Handbook. Book II, Wheat. U.S. Dep. Agric., Fed. Grain Inspec. Serv.
3. Anonymous. 1992. Glean labeling. Pages 721-730. Crop Protection Chemicals Reference, 8 ed. Wiley and Sons, New York, NY.
4. Anonymous. 1992. Hoelon Labeling. Pages 907-913. Crop Protection Chemicals Reference, 8 ed. Wiley and Sons, New York, NY.
5. Appleby, A. P., P. D. Olson, and D. R. Colbert. 1976. Winter wheat reduction from interference by Italian ryegrass. Agron. J. 68:463-466.
6. Cuperus, G., R. Thompson, B. Tucker, S. Coppock, E. Williams, J. Stiegler, P. Bloome, H. Greer, J. Pitts, and D. Fain. 1985. Wheat production and pest management in Oklahoma. Cir. E-831. Coop. Ext. Service. Oklahoma State University, Stillwater, OK 74078.
7. Epplin, F. M., V. K. Allread, J. B. Solie, T. F. Peeper, and J. A. Koscelny. 1992. Economics of ultranarrow row planting for hard red winter wheat production in Oklahoma. J. Prod. Agric. 5: (in press).
8. Epplin, F. M., T. F. Rice, S. J. Handke, T. F. Peeper, and E. G. Krenzer, Jr. 1983. Cost estimates of alternative wheat production systems for Garfield County. Agric. Exp. Stn. Bull. B-766. Okla. State Univ. Stillwater, OK 74078.

9. Greer, H. A. L., and T. F. Peeper. 1990. Weed control in winter wheat. Cir. E-2770. Coop. Ext. Service. Oklahoma State University, Stillwater, OK 74078.

10. Griffin J. L. 1986. Ryegrass (Lolium multiflorum) control in winter wheat (Triticum aestivum). Weed Sci. 34:98-100.

11. Khodayari, K., R. E. Frans, and F. C. Collins. 1983. Diclofop-a selective herbicide for Italian ryegrass (Lolium multiflorum) control in winter wheat (Triticum aestivum). Weed Sci. 31:436-438.

12. Kinfe, B. and T.F. Peeper. 1991. Soil as herbicide carrier for Italian ryegrass (Lolium multiflorum) control in winter wheat (Triticum aestivum). Weed Technol. 5:858-863.

13. Klingaman, T. E., and T. F. Peeper. 1989. Weed control on winter wheat (Triticum aestivum) with chlorsulfuron and CGA 131036 and comparison of modes of action. Weed Technol. 3:490-496.

14. Koscelny, J. A., T. F. Peeper, J. B. Solie, and S. G. Solomon, Jr. 1990. Effect of wheat (Triticum aestivum) row spacing, seeding rate, and cultivar on yield loss from cheat (Bromus secalinus). Weed Technol. 4:487-492.

15. Koscelny, J. A., T. F. Peeper, J. B. Solie, and S. G. Solomon, Jr. 1991. Seeding date, seeding rate, and row spacing affect wheat (Triticum aestivum) and cheat (Bromus secalinus). Weed Technol. 5:707-712.

16. Liebl, R. A., and A. D. Worsham. 1987. Effect of chlorsulfuron on the movement and fate of diclofop in Italian ryegrass (Lolium multiflorum) and wheat (Triticum aestivum). Weed Sci. 35:623-628.

17. Liebl, R. A., and A. D. Worsham. 1987. Interference of Italian ryegrass (Lolium multiflorum) in wheat (Triticum aestivum). Weed Sci. 35:819-823.

18. Medd, R. W., B. A. Auld, D. R. Kemp, and R. D. Murison. 1985. The influence of wheat density and spatial arrangement on annual ryegrass, (Lolium rigidium Gaudin), competition. Aust. J. Agric. Res. 36:361-371.

19. Nalewaja, J. D., and W. E. Arnold. 1970. Weed control methods, losses and costs due to weeds, and benefits of weed control in wheat and other small grains. 1st FAO Int. Conf. Weed Control, Davis, CA 95616. p.1-16.

20. Shaw, D. R. and M. T. Wesley. 1991. Wheat (Triticum aestivum) cultivar tolerance and Italian ryegrass (Lolium multiflorum) control with diclofop, BAY SMY 1500, and metribuzin. Weed Technol. 5:776-781.

21. Solie, J. B., S. G. Solomon, Jr., K. P. Self, T. F. Peeper, and J. A. Koscelny. 1991. Reduced row spacing for improved wheat yields on weed-free and weed-infested fields. Trans. Am. Soc. Agr. Eng. 34:1654-1660.

22. U.S. Department of Agriculture. 1990. Agriculture Prices. Agriculture Statistics Board Publications, Washington, DC 20520.

Table 1. Treatment dates, soil characteristics, growth stages, densities, treatment to first rainfall intervals and amount of first rainfall at the three sites.

Location	Treatment date PRE	Treatment date POST	Soil characteristics Series	Soil characteristics Organic matter	Soil characteristics pH	POST growth stage Wheat[a]	POST growth stage Italian ryegrass	Italian ryegrass[b]	Treatment to rain PRE	Treatment to rain POST	First rainfall PRE	First rainfall POST
				%				no./m^2	— d —		— cm —	
Chickasha	Oct. 8	Nov. 21	Reinach[c]	0.9	6.6	2 lf to 2 tl	2 to 3 lf	161±23	20	13	7.3	1.3
Haskell	Oct. 7	Nov. 13	Taloka[d]	1.4	6.7	2 to 4 tl	3 lf to 2 tl	172±16	17	4	2.8	1.7
Perkins	Sept. 26	Nov. 13	Teller[e]	0.8	6.4	2 to 9 tl	1 to 4 tl	150±14	30	6	6.9	1.1

[a] lf = leaf, tl = tillers

[b] ± the standard error

[c] Reinach loam, coarse-silty, mixed, Thermic Pachie, Haplustolls

[d] Taloka silt loam, mixed Thermic, Mollic, Alabaqualfs

[e] Teller sandy loam, fine-loamy, mixed, Thermic, Udic, Argiustolls

Table 2. Wheat grain budget.

Budget parameter	Unit of measure	Price	Quantity	Value[a]
Receipt sources		$ per unit	units per ha	$ ha^{-1}
Wheat grain	kg	0.092[b]	---	---
USDA wheat program	kg	0.039	---[c]	---
Total receipts				---
Operation inputs				
Wheat seed	kg	0.222	---[d]	---
18-46-0 fertilizer	kg	0.267	58	15.5
Ammonium nitrate	kg	0.227	198	45.0
Ammonium application	ha	4.94	1	4.94
Insecticide	kg	8.89	.42	3.73
Insecticide application	ha	11.12	.50	5.56
Chlorsulfuron	g	0.58	---[e]	---
Diclofop	g	0.016	---[f]	---
Fuel, lube, and repairs	ha			---[g]
Annual operating capital	$	0.09	---	---
Custom harvest				
Base charge	ha	29.64	1.0	29.64
Yield above 1334 kg ha^{-1}	kg	0.004	---	---
Hauling	kg	0.004	---	---
Total operating cost				---
Machinery fixed cost	$ ha^{-1}			---[h]
Return above all costs except land, labor, overhead, risk and mgmt.	$ ha^{-1}			---[i]

[a] Values obtained by multiplying price by quantity.

Table 2. Continued.

[b] Local harvest price (\$ kg^{-1}) for USDA No. 1 hard red winter wheat (22) adjusted for price penalties.

[c] County average wheat yield, i.e. 2321, 2441, and 2227 kg ha^{-1} for Chickasha, Lahoma, and Orlando, respectively.

[d] Wheat seeding rates of 67, 100, and 133 kg ha^{-1}.

[e] Two rates of 17.5 and 26.3 g ha^{-1}.

[f] Two rates of 560 and 840 g ha^{-1}.

[g] Rates vary with row spacing [i.e. $27.86, and $26.90 for 7.5 cm and 23 cm, respectively (8)].

[h] Rates vary with row spacing [i.e. $81.99 and $75.57 for 7.5 cm and 23 cm, respectively (8)].

[i] Net returns are tabulated in Table 7.

Table 3. Interactions of herbicide treatment, row width, and seeding rate on Italian ryegrass control at three locations.

				Haskell						Perkins					
				Wheat seeded (kg ha^{-1})											
		Chickasha		67		100		133		67		100		133	
		Row width (cm)													
Treatment	Rate	7.5	20	7.5	20	7.5	20	7.5	20	7.5	20	7.5	20	7.5	20
				%											
Chlorsulfuron	18	40	50	20	30	20	20	40	20	10	30	30	40	50	50
	26	40	70	30	40	40	40	50	50	10	30	20	50	60	50
Diclofop	560	90	90	95	95	95	95	100	100	100	100	100	100	100	100
	840	90	95	95	95	95	100	100	100	100	100	100	100	100	100
Check	---	20	10	0	0	0	0	0	0	0	0	20	30	40	40
LSD (0.05)		17		12						12					

Table 4. Interactions of herbicide treatment, row width, and seeding rate on dockage in harvested wheat at three locations.

						Perkins					
						Wheat seeded (kg ha^{-1})					
		Chickasha			Haskell	67		100		133	
		Wheat seeded (kg ha^{-1})				Row width (cm)					
Treatment	Rate	67	100	133	Mean	7.5	20	7.5	20	7.5	20
	g ha^{-1}	kg ha^{-1}									
Chlorsulfuron	18	280	200	190	650	150	110	120	100	90	90
	26	190	190	170	580	130	120	100	100	100	90
Diclofop	560	70	70	70	90	70	70	70	70	60	70
	840	70	70	70	80	60	70	70	60	70	60
Check	---	510	370	280	780	170	140	120	110	100	100
LSD (0.05)		9			60	11					

Table 5. Interaction of row spacing and seeding rate, averaged across herbicide treatments, on wheat yield pooled over three locations.

Row	Wheat seeded (kg ha^{-1})		
width	67	100	133
cm	kg ha^{-1}		
7.5	1680	1760	1860
20	1820	1800	1800
LSD (0.05)	97		

Table 6. Interaction of herbicide treatment and row spacing averaged across seeding rate on wheat yield pooled over three locations and interaction of herbicide treatment and seeding rate, averaged across row spacing, on wheat yield pooled over three locations.

		Row spacing (cm)		Wheat seeded ($kg\ ha^{-1}$)		
Treatment	Rate	7.5	20	67	100	133
	$g\ ha^{-1}$	$kg\ ha^{-1}$		$kg\ ha^{-1}$		
Chlorsulfuron	18	1520	1560	1500	1510	1610
	26	1660	1730	1670	1710	1710
Diclofop	560	2310	2220	2300	2180	2320
	840	2190	2380	2340	2310	2200
Check	---	1140	1160	940	1200	1310
LSD (0.05)				160		
LSD (0.10)		110				

Table 7. The interaction of wheat seeding rate and herbicide treatment on net returns at Haskell and the interaction of wheat seeding rate, row width and herbicide treatment on net returns at Perkins.

		Haskell			Perkins					
					Seeding rate (kg ha^{-1})					
					67		100		133	
		Seeding rate (kg ha^{-1})			Row width (cm)					
Treatment	Rate	67	100	133	7.5	20	7.5	20	7.5	20
	g ha^{-1}	$ per ha								
Chlorsulfuron	18	31	23	47	21	24	26	31	12	17
	26	74	58	62	23	26	21	40	10	24
Diclofop	560	193	132	188	103	84	76	84	69	45
	840	182	157	104	77	79	60	57	50	50
Check	---	-86	-37	-38	7	29	38	18	23	46
LSD (0.05)		40			18					

VITA

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