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Title: Influence of Lime on Italian Ryegrass Control in Winter Wheat with Five Herbicides

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Liming has been shown to increase the activity of certain soil-applied herbicides. One research worker reported improved weed control with diuron after lime had increased soil pH levels. This could be caused by improved competitive ability of the wheat, greater availability of the herbicide, or a combination of the two factors.

Field studies were conducted at two locations to determine the effect of three lime rates on wheat growth alone, on ryegrass growth alone, and on ryegrass control from five herbicides. Lime rates were 0, 4.5, and 9.0 t/ha, giving an approximate pH range from 5.0 to 6.1. Herbicides used were trifluralin, triallate, diclofop, metribuzin, and diuron, each applied at three rates. Diuron at eight rates was also studied in the greenhouse at five rates of lime.

All of the herbicides in the field studies caused large increases in wheat grain yield when compared to untreated ryegrass-infested wheat. However, liming had no effect on ryegrass growth nor activity

of the herbicides and, except in one case, no effect on wheat growth.

The high rate of metribuzin, 1.12 kg/ha, caused severe wheat injury at one location but only minor injury at the other. The other herbicides caused little or no injury even at double the commercial rate.

In one greenhous experiment, application of lime increased ryegrass growth but did not affect diuron activity. In the other experiment, lime alone did not influence ryegrass growth but tended to increase diuron activity at the 4.5 t/ha lime rate.

The application of lime is not expected to have wide-spread effects on weed control in winter wheat in western Oregon, at least with the five herbicides tested in these studies.

Influence of Lime on Italian Ryegrass Control in Winter Wheat with Five Herbicides

by

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INFLUENCE OF LIME ON ITALIAN RYEGRASS CONTROL IN WINTER WHEAT WITH FIVE HERBICIDES

INTRODUCTION

In western Oregon and western Washington, Italian ryegrass (Lolium multiflorum Lam.) is not only an important seed crop, but also a widespread and competitive weed in winter wheat. Diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], barban (4-chloro-2-butynyl m-chlorocarbanilate), and triallate [S-(2,3,3-trichloroallyl) diisopropylthiocarbamate] are standard herbicides being used commercially for ryegrass control in winter wheat but ryegrass control generally is not complete (14). Sequential treatments of these herbicides are suggested to increase the control, but this practice is inconvenient and sometimes can result in wheat injury (14). Studies at Oregon State University showed that a ryegrass population of about 11 plants/m^2 can reduce wheat grain yields by an average of 275 kg/ha (2). Herbicide studies indicated that any reduction in ryegrass populations will result in increased yields and extra costs may be feasible in striving toward complete ryegrass control (3,5).

An effect of liming on diuron activity to control some grasses (including Italian ryegrass) was observed by Kauffman[1/] in plots

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[1/] Kauffman, M. D. Unpublished data. 4520 S.E. Balboa Place, Albany, Oregon 97321.

established in 1972 and 1973 on Dayton (pH 4.6), Jory (pH 4.7), and Woodburn (pH 5.4) soil series. Plots with the lowest pH had poor grass control, while grass control increased on limed plots with higher pH values.

Bailey and White (4) reported that a major factor affecting availability and activity of herbicides in the soil is adsorption. Several workers have studied the effect of pH on herbicide activity. Adams and Pritchard (1) found that the activity of two s-triazines, prometryn [2,4-bis(isopropylamino)-6-(methylthio)-s-triazine] and secbumeton [N-ethyl-6-methoxy-N-(1-methylpropyl)-1,3,5-triazine-2,4-diamine], was markedly increased by increased soil pH. Frissel and Bolt (9) found that adsorption of several s-triazine herbicides started to increase about 3 to 4 pH units above the dissociation constant and continued to increase as pH decreased to 1.0. However, Weber et al. (18) found that maximum adsorption of seven s-triazines occurred at pH levels in the vicinity of the pK values of the compounds. Lowering of the pH resulted in some desorption of the herbicides which was attributed to the competition of H^+ ions for exchange sites at low pH levels (16).

Effects of pH on adsorption of some s-triazines by soils was also observed by other workers (7, 15). They reported decreased adsorption of some s-triazines with increased soil pH.

Ladlie et al. (12) found that adsorption of the as-triazine,

metribuzin, was decreased when the soil pH was increased from 4.6 to 6.7

Corbin et al. (8) studied the phytotoxicity of other herbicides in soils with pH levels between 4.3 and 7.5. They found no effect from pH on diuron activity in these soils. Similarly, Hance (10) found that adsorption of diuron was pH independent. But Nash (13) found slightly greater activity of diuron in soil at pH 7.9 than at 4.7.

The increase in diuron activity against ryegrass with increasing levels of lime observed by Kauffman could conceivably be explained by (a) reduced diuron adsorption at higher pH, thus increasing herbicide concentration in the soil solution; (b) a more pronounced improvement in wheat growth with liming than in ryegrass growth, thus causing the wheat to be more competitive; or (c) a combination of the two effects.

The objectives of this study were to determine (a) the effect of liming on herbicide toxicity to ryegrass and wheat, (b) the effect of liming on ryegrass growth, and (c) the effect of liming on wheat growth.

MATERIALS AND METHODS

Field Studies

Two field experiments were conducted at the Hyslop and Schmidt Agronomy Experimental Farms near Corvallis, Oregon beginning in the fall of 1976. The soil at both locations is a Woodburn silt loam, a member of the fine, silty mixed mesic family of Aquualtic Argexeralls. Organic matter was approximately 3% at both locations. A fine seedbed was prepared by conventional methods. Fertilizer (16-20-0) at 224 kg/ha was incorporated into the seedbed and 2.5 cm of sprinkler irrigation was applied before planting.

On September 19, 1976, ground limestone flour was applied at rates of 0, 4.5, and 9.0 t/ha. pH determinations were made 1 month after lime was applied and immediately before planting. pH values of 5.20, 5.66, and 6.14 were measured at the Schmidt Farm and 5.0, 5.46, and 6.13 were measured at Hyslop Farm for the 0, medium, and high lime rates, respectively.

The experimental area was sown on October 19 so that each herbicide plot contained a strip of 'Hyslop' winter wheat alone (110 kg/ha), Italian ryegrass alone (approximately 22.4 kg/ha), and a mixture of wheat and ryegrass.

Herbicide treatments (Table 1) were applied with a bicycle-wheel plot sprayer in 280 L of water/ha. Each herbicide was applied

TABLE 1. Herbicide Treatments in Field Studies.

Common Name	Chemical Name	Formulation[1]	Rate (kg/ha)
Trifluralin	α, α, α-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine	Emulsifiable concentrate 0.48 kg/liter	0.56 1.12 2.24
Triallate	S-(2, 3, 3-trichloroallyl)diisopropylthiocarbamate	Emulsifiable concentrate 0.48 kg/liter	0.70 1.40 2.80
Diclofop	Methyl 2-[4-(2, 4-dichlorophenoxy) phenoxy] propanoate	Emulsifiable concentrate 0.36 kg/liter	0.42 0.84 1.68
Metribuzin	4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one	Wettable powder 50%	0.28 0.56 1.12
Diuron	3-(3, 4-dichlorophenyl)-1, 1-dimethylurea	Wettable powder 80%	0.90 1.80 3.60

at three rates, including the commercially recommended rate as well as 50% and 200% of the recommended rate.

The experiments were laid out in a randomized block design with four blocks at Hyslop Farm and five blocks at Schmidt Farm. Each herbicide plot was 2.4 by 8.5 m at Hyslop Farm and 2.4 by 11 m at Schmidt Farm.

On May 12, 1977, 1.95 m^2 samples of ryegrass topgrowth were harvested at the ground level and fresh weights were determined for each plot. Wheat grain was harvested on July 22 at Hyslop Farm and August 3 at Schmidt Farm, using a small-plot combine. Harvested grain samples were recleaned before weighing. The grain yields were harvested both from the wheat-only strips and the wheat + ryegrass strips.

Ryegrass topgrowth and wheat-grain yield data were subjected to statistical analysis.

In the fall of 1977, herbicide treatments were again applied to the same plots without additional lime. Ryegrass growth was visually evaluated on March 1, 1978.

Greenhouse Studies

Two experiments were conducted in the greenhouse to obtain additional information on the influence of liming on wheat and ryegrass growth and the activity of diuron against ryegrass. Soil was

obtained from the Schmidt Farm and screened through a 5-mm screen. Ground limestone flour was applied at rates of 0, 2.25, 4.5, 6.75, and 9.0 t/ha. After the lime was mixed thoroughly with the soil, the soil was stored for a month to allow for pH adjustment. At the end of this period, pH values of 5.10, 5.58, 5.94, 6.34, and 6.75 were measured in the first experiment and 5.10, 5.64, 6.05, 6.33, and 6.55 in the second experiment.

The weighed amount of soil was placed in 10 by 10 by 10 cm plastic pots, leveled, and firmed. Twenty-five Italian ryegrass seeds were distributed evenly on the soil surface of each plot. A weighed amount of soil was applied evenly over the seeds to a depth of about 1 cm. The soil surface was moistened and diuron was applied to the surface at rates of 0, 0.23, 0.45, 0.68, 0.90, 1.13, 1.35, and 1.58 kg/ha, using a track-type sprayer. All pots were placed in shallow watering pans and subirrigated as necessary during the experiment. A commercial formulation of liquid fertilizer (12-6-6) was used periodically to maintain proper nutrient levels.

Visual estimates of the percent reduction in live tissue were made before harvest. When 100% of the ryegrass plants were dead at the highest rate of herbicide, plants were cut off at the soil level and fresh weights were recorded. Fresh weight data were subjected to statistical analysis.

RESULTS

Field Studies

Drastic wheat yield reductions from Italian ryegrass competition were observed (Tables 2 and 3). In the untreated control plots, when heavy ryegrass competition was present, wheat yields were reduced by 80% compared to wheat without ryegrass. However, herbicides were very effective in increasing wheat yields.

At the lowest experimental rate, diuron was the least effective of all the herbicides used in controlling ryegrass. Even at this low efficiency in ryegrass control, diuron almost doubled the wheat yield in wheat-ryegrass plots.

Diclofop was a very effective herbicide at all rates. At both locations the commercially recommended rate gave almost 100% ryegrass control. However, diclofop failed to control annual bluegrass (Poa annua) and broadleaf weeds. During the second year, densities of these weeds had increased to the point that wheat growth was severely retarded.

Metribuzin also was very effective in controlling ryegrass. Both the commercially recommended and the highest rates gave approximately 100% ryegrass control. However, at Schmidt Farm the high rate of metribuzin caused severe injury which resulted in reduced wheat yields. It is unknown why the same injury was not

TABLE 2. Wheat Yields and Italian Ryegrass Growth as Affected by Rates of Herbicides. Hyslop Farm.

Treatment	Rate (kg/ha)	Wheat Yield (kg/ha)		Fresh weight of Italian ryegrass (kg/plot)	Italian ryegrass control (%)
		Wheat	Wheat & Ryegrass		
Post plant Incorporated, October 20, 1976					
Trifluralin	0.56	6947	6705	6.65	66
	1.12	7804	7437	3.13	84
	2.24	7600	7524	0.80	96
Mean		7450	7222	3.52	
Triallate	0.70	6543	5098	11.40	42
	1.40	7121	5967	9.93	50
	2.80	7255	7070	3.62	82
Mean		6973	6045	8.31	
Diclofop	0.42	6845	6825	0.38	98
	0.84	7041	6251	0	100
	1.68	7329	7298	0	100
Mean		7072	6791	0.12	
Postemergence, November 18, 1976					
Metribuzin	0.28	6707	5604	9.06	54
	0.56	7199	7485	0.63	97
	1.12	7288	7301	0	100
Mean		7065	6797	3.23	
Preemergence, October 22, 1976					
Diuron	0.90	6342	2373	17.48	11
	1.80	6476	3593	14.18	28
	3.60	6712	6199	8.06	60
Mean		6510	4055	13.24	
Control	0	6191	1360	19.68	0
LSD(0.05) between herbicides		148	161	1.54	

TABLE 3. Wheat Yields and Italian Ryegrass Growth as Affected by Rates of Herbicides. Schmidt Farm.

Treatment	Rate (kg/ha)	Wheat Yield (kg/ha) Wheat	Wheat Yield (kg/ha) Wheat & Ryegrass	Fresh weight of Italian ryegrass (kg/plot)	Italian ryegrass control (%)
Post plant Incorporated, October 20, 1976					
Trifluralin	0.56	6858	6465	6.51	69
	1.12	7596	7351	1.70	91
	2.24	7382	7334	0.25	99
Mean		7279	7050	2.82	
Triallate	0.70	7558	4804	12.96	29
	1.40	6982	6369	5.62	69
	2.80	7456	7172	1.86	90
Mean		7332	6115	6.81	
Diclofop	0.42	7244	6908	1.80	90
	0.84	7632	7520	0	100
	1.68	7356	7509	0	100
Mean		7411	7312	0.60	
Postemergence, November 18, 1976					
Metribuzin	0.28	7568	6029	9.58	47
	0.56	7484	7234	0	100
	1.12	4912	3968	0	100
Mean		6655	5744	3.18	
Preemergence, October 22, 1976					
Diuron	0.90	6996	2956	16.53	9
	1.80	7092	4300	14.99	18
	3.60	7227	6565	6.26	66
Mean		7105	4604	12.59	
Control	0	6960	1544	18.17	0
LSD(0.05) between herbicides		108	161	1.21	

seen at Hyslop Farm.

Trifluralin and triallate did not give complete ryegrass control. However, ryegrass control was better with increased herbicide rate. Trifluralin appeared to be more effective than triallate and generally resulted in higher wheat yields.

Under the conditions of these experiments, lime did not influence results from any of the herbicides or herbicide rates. Liming did not make herbicides more effective for ryegrass control, and did not increase the effect on wheat when herbicides were applied (Tables 4 and 5). In the untreated control plots, liming did not increase ryegrass growth. At Schmidt Farm, liming alone increased wheat yield but this was not true at Hyslop Farm (Tables 6 and 7). Visual evaluations made in the ryegrass plots during the second year supported the results given above (Appendix Tables 25, 26).

Greenhouse Studies

In both experiments, ryegrass control was increased with increased herbicide rate. However, in Experiment 2 diuron activity against ryegrass was much greater than in Experiment 1. In Experiment 1, 50% ryegrass control was observed at about 1.13 kg/ha herbicide rate. In Experiment 2, about 0.45 kg/ha achieved the same percent of control (Table 8). A possible explanation for the greater diuron activity in Experiment 2 was the longer daylengths during

TABLE 4. Wheat Yields and Italian Ryegrass Growth at Three Lime Rates Averaged Over All Herbicide Treatments. Hyslop Farm.

Lime Rate (t /ha)	Wheat Yield		Fresh weight of Italian ryegrass (kg/plot)	Italian Ryegrass Control (%)
	Wheat	Wheat & Ryegrass		
	(kg/ha)			
0	7126	6022	5.88	70
4.5	6866	6170	5.88	71
9.0	7050	6356	5.30	72
LSD(0.05)	NS	NS	NS	

TABLE 5. Wheat Yields and Italian Ryegrass Growth at Three Lime Rates Averaged Over All Herbicide Treatments. Schmidt Farm.

Lime Rate (t/ha)	Wheat Yield		Fresh weight of Italian ryegrass (kg/plot)	Italian Ryegrass Control (%)
	Wheat	Wheat & Ryegrass		
	(kg/ha)			
0	7137	6153	5.57	71
4.5	7246	6145	5.09	71
9.0	7084	6198	4.77	73
LSD(0.05)	NS	NS	NS	

TABLE 6. Wheat Yields and Italian Ryegrass Growth from Untreated Plots at Three Lime Rates. Hyslop Farm.

Lime Rate (t/ha)	Wheat Yield		Fresh weight of Italian ryegrass (kg/plot)
	Wheat (kg/ha)	Wheat & Ryegrass (kg/ha)	
0	5961	1436	19.77
4.5	6470	1392	20.60
9.0	6142	1250	18.90
LSD(0.05)	NS	NS	NS

TABLE 7. Wheat Yields and Italian Ryegrass Growth from Untreated Plots at Three Lime Rates. Schmidt Farm.

Lime Rate (t/ha)	Wheat Yield		Fresh weight of Italian ryegrass (kg/plot)
	Wheat (kg/ha)	Wheat & Ryegrass (kg/ha)	
0	6131	1202	19.32
4.5	7359	1677	17.81
9.0	7389	1752	17.40
LSD(0.05)	257	NS	NS

TABLE 8. Response of Italian Ryegrass to Diuron Treatments Averaged Across Lime Rates from Two Greenhouse Experiments.

Herbicide Rate (kg/ha)	Experiment 1		Experiment 2	
	(g/pot)	(% reduction)	(g/pot)	(% reduction)
0	5.34	0	3.27	0
0.23	5.72	-7[a]	2.17	34
0.45	5.30	1	1.13	65
0.68	4.49	16	0.54	83
0.90	4.15	22	0.76	77
1.13	2.21	59	0.17	95
1.35	1.48	72	0.22	93
1.58	1.01	81	0.02	99
LSD(0.05)	0.43		0.37	

[a] Higher fresh weights than check plots.

that experiment.

Response of ryegrass to liming was inconsistent between the two experiments. Under the conditions of Experiment 1, ryegrass in the absence of herbicide had higher fresh weights when lime rates were increased (Table 9). When treated with diuron, ryegrass had higher fresh weights when lime rates increased. In Experiment 2, untreated ryegrass did not respond to lime. However, ryegrass growth was significantly reduced at 4.5 t/ha lime level with herbicide treatment (Table 9). The reason for the high degree of herbicide activity at that particular lime rate is not known. In both of the experiments, lime x herbicide rate interactions were not significant, indicating that the differences in ryegrass growth between herbicide-rates were not lime rate dependent.

Wheat growth was not affected by liming (Appendix Tables 35, 36).

TABLE 9. Influence of Lime Rates on Ryegrass Growth and Diuron Activity. Two Greenhouse Experiments.

Lime Rate (t/ha)	Experiment 1			Experiment 2		
	Fresh weight of[a] Italian ryegrass shoots (g/pot)	Fresh weight of[b] Italian ryegrass shoots (g/pot)	Reduction of[c] ryegrass shoot wt. (%)	Fresh weight of[a] Italian ryegrass shoots (g/pot)	Fresh weight of[b] Italian ryegrass shoots (g/pot)	Reduction of[c] ryegrass shoot wt. (%)
0	4.55	2.91	36	3.33	0.76	78
2.25	4.92	3.40	31	3.18	0.69	79
4.50	5.57	3.35	40	3.10	0.41	87
6.75	6.10	3.77	39	3.20	0.85	73
9.00	5.55	3.98	28	3.55	0.89	75
LSD(0.05)	0.84	0.37		NS	0.28	

[a] Ryegrass weights from untreated pots.

[b] Averaged over all diuron rates.

[c] Compared to untreated controls at each lime rate.

DISCUSSION

All of the herbicides were beneficial in reducing the ryegrass competition in wheat fields. Increased benefit was observed when wheat fields were subject to heavy infestation of Italian ryegrass.

Phytotoxicity of the herbicides was not influenced by lime in these experiments. Responses to lime, when they did occur, appeared to be associated with the increased ryegrass response to lime, which resulted in reduced ryegrass control. Burrill and Appleby (6) found a decrease in diuron efficiency with increased ryegrass density. The increase in ryegrass fresh weights with lime could cause the concentration of diuron per unit weight of plant to decrease. This would reduce diuron toxicity.

These results are not similar to those found by Kauffman with diuron, but they are in agreement with those of Hance (10), Corbin et al. (8), and Harris and Sheets (11) who found no correlation between soil pH and soil adsorption of diuron. Because diuron is virtually non-ionic with a very low pK (17), a large increase in diuron concentration in the soil solution would not be expected when soil pH was increased from 5.0 to 6.0. Since trifluralin and triallate are also non-ionic herbicides (17), similar behavior in the adsorption by soil was expected. However, Ladlie et al. (12) studied the adsorption of metribuzin ($pK = 0.99 \pm 0.08$) in soils with a pH range of from

4.6 to 6.7, and found that adsorption was decreased when pH was increased. Another study with metribuzin in the greenhouse over a wider pH range could be valuable. Diclofop is an acidic herbicide. Increased availability of diclofop by reduced adsorption in the soil with liming could occur under some circumstances. However, the pK value of this herbicide is not known, and therefore the effect of soil pH on adsorption of diclofop cannot be predicted.

The build-up of resistant weeds in diclofop plots is of concern. Annually rotating crops or combinations with other herbicides may be necessary to prevent this from occurring on a commercial basis.

Applications of lime to western Oregon soils are not expected to have widespread effects on weed control in winter wheat, at least with the five herbicides tested in these studies.

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APPENDICES

Appendix Table 1. Wheat Yields (kg/ha) from Wheat Plots. Hyslop Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		7087	6082	7272
1.12		9634	7281	6496
2.24		7226	7788	7787
	Mean	7982	7050	7185
Triallate				
0.70		6491	6075	7062
1.40		7028	6629	7708
2.80		6952	7435	7377
	Mean	6824	6713	7382
Diclofop				
0.42		6489	7167	6879
0.84		7463	7258	6403
1.68		7014	7050	7923
	Mean	6989	7158	7068
Metribuzin				
0.28		6121	6869	7130
0.56		7193	6937	7466
1.12		7820	6933	7111
	Mean	7045	6913	7236
Diuron				
0.90		6657	6159	6209
1.80		6611	6297	6518
3.60		7097	6638	6402
	Mean	6788	6365	6376
Control		5961	6470	6142

Appendix Table 2. Analysis of Variance Table for Data in Appendix Table 1.

Source	d.f.	SS	MS	F
Total	179	20822000.		
Block	3	622632.	207544	2.06^{NS}
Herbicide	4	1627912.	406978	4.05^{**}
H. Rate	2	1059280.	529640	5.27^{**}
Lime	2	212984.	106492	1.06^{NS}
Herbicide*H. Rate	8	227520.	28440	0.28^{NS}
Herbicide*Lime	8	825536.	103192	1.02^{NS}
H. Rate*Lime	4	604892.	151223	1.50^{NS}
Herbicide*H. Rate*Lime	16	2390688.	149418	1.48^{NS}
Error	132	13250556.	100383	

CV = 4.51%

Appendix Table 3. Wheat Yields (kg/ha) from Wheat and Italian Ryegrass Plots. Hyslop Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		5863	6949	7304
1.12		7264	7965	7082
2.24		7690	6975	7908
	Mean	6939	7296	7431
Triallate				
0.70		4543	4650	6100
1.40		5957	5778	6166
2.80		6993	6922	7296
	Mean	5831	5783	6521
Diclofop				
0.42		6340	6929	7208
0.84		5481	6706	6565
1.68		6917	7060	7918
	Mean	6246	6898	7230
Metribuzin				
0.28		5320	6353	5139
0.56		8045	7551	6858
1.12		7663	7115	7125
	Mean	7009	7006	6374
Diuron				
0.90		3264	1852	2002
1.80		3370	3076	4332
3.60		5614	6655	6329
	Mean	4083	3861	4221
Control		1436	1392	1250

Appendix Table 4. Analysis of Variance Table for Data in Appendix Table 3.

Source	d.f.	SS	MS	F
Total	179	59883458.		
Block	3	2034468.	678156	5.71**
Herbicide	4	22948680.	5737170	48.33**
H. Rate	2	9278540.	4639270	39.08**
Lime	2	335830.	167915	1.41NS
Herbicide*H. Rate	8	5963000.	745375	6.28**
Herbicide*Lime	8	1230120.	153765	1.29NS
H. Rate*Lime	4	115380.	28845	0.24NS
Herbicide*H. Rate*Lime	16	2310624.	144414	1.21NS
Error	132	15666816.	118688	

CV = 5.57%

Appendix Table 5. Italian Ryegrass Fresh Weights (kg/plot) from Italian Ryegrass Plots. Hyslop Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		5.06	6.37	8.53
1.12		5.53	2.80	1.06
2.24		0	1.13	1.26
	Mean	3.53	3.43	3.61
Triallate				
0.70		14.47	13.27	6.46
1.40		10.97	9.60	9.23
2.80		4.13	2.97	3.77
	Mean	9.85	8.61	6.48
Diclofop				
0.42		1.17	0	0
0.48		0	0	0
1.68		0	0	0
	Mean	0.39	0	0
Metribuzin				
0.28		12.37	8.47	6.37
0.56		1.07	0.30	0.53
1.12		0	0	0
	Mean	4.48	2.92	2.30
Diuron				
0.90		14.27	18.60	19.60
1.80		11.87	16.67	14.03
3.60		7.33	8.13	8.73
	Mean	11.15	14.46	14.12
Control		19.76	20.60	18.90

Appendix Table 6. Analysis of Variance Table for Data in Appendix Table 5.

Source	d.f.	SS	MS	F
Total	134	5226.7		
Block	2	13.68	6.84	0.85^{NS}
Herbicide	4	2852.68	713.17	88.64^{**}
H. Rate	2	952.14	476.07	59.17^{**}
Lime	2	10.	5.00	0.62^{NS}
Herbicide*H. Rate	8	385.2	48.15	5.98^{**}
Herbicide*Lime	8	125.44	15.68	1.95^{NS}
H. Rate*Lime	4	14.6	3.65	0.45^{NS}
Herbicide*H. Rate*Lime	16	165.44	10.34	1.28^{NS}
Error	88	707.52	8.04	

CV = 50%

Appendix Table 7. Wheat Yields (kg/ha) from Untreated Wheat Plots. Hyslop Farm.

Lime Rates (t/ha)	Blocks			
	1	2	3	4
0	6329	5440	5297	6777
4.5	5933	7015	6252	6681
9.0	5670	5822	6299	6777

Appendix Table 8. Analysis of Variance Table for Data in Appendix Table 7.

Source	d.f.	SS	MS	F
Total	11	347630.56		
Block	3	126113.50	42037.83	1.50^{NS}
Lime	2	53372.76	26686.38	0.95^{NS}
Error	6	168144.30	28024.05	

CV = 2.7%

Appendix Table 9. Wheat Yields (kg/ha) from Untreated Wheat & Italian Ryegrass Plots. Hyslop Farm.

Lime Rates (t/ha)	Blocks			
	1	2	3	4
0	1450	2338	1432	525
4.5	1275	1766	1098	1432
9.0	1231	859	1479	1432

Appendix Table 10. Analysis of Variance Table for Data in Appendix Table 9.

Source	d.f.	SS	MS	F
Total	11	220099.29		
Block	3	42628.96	14209.65	0.50^{NS}
Lime	2	7576.09	3788.04	0.13^{NS}
Error	6	169894.24	28315.70	

CV = 12.3%

Appendix Table 11. Italian Ryegrass Fresh Weights (kg/plot) from Untreated Italian Ryegrass Plots. Hyslop Farm.

Lime Rates (t/ha)	Blocks		
	1	2	3
0	18.4	18.8	22.1
4.5	19.2	22.4	20.2
9.0	20.0	15.3	21.4

Appendix Table 12. Analysis of Variance Table for Data in Appendix Table 11.

Source	d.f.	SS	MS	F
Total	8	38.3622		
Block	2	10.0288	5.0144	0.83^{NS}
Lime	2	4.3355	2.1677	0.36^{NS}
Error	4	23.9977	5.9994	

CV = 12.2%

Appendix Table 13. Wheat Yields (kg/ha) from Wheat Plots. Schmidt Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		7046	6932	6596
1.12		7482	7410	7896
2.24		7332	7346	7468
	Mean	7287	7229	7320
Triallate				
0.70		7803	7339	7532
1.40		6889	7060	6996
2.80		7389	7482	7496
	Mean	7360	7294	7341
Diclofop				
0.42		6724	7568	7439
0.84		7611	7475	7811
1.68		7739	7396	6932
	Mean	7358	7480	7394
Metribuzin				
0.28		7510	7589	7603
0.56		7503	7839	7110
1.12		5874	5074	3787
	Mean	6962	6834	6162
Diuron				
0.90		6217	7360	7410
1.80		6732	7335	7210
3.60		7210	7489	6982
	Mean	6720	7395	7201
Control		6131	7359	7389

Appendix Table 14. Analysis of Variance Table for Data in Appendix Table 13.

Source	d.f.	SS	MS	F
Total	224	23846957.		
Block	4	213781.6	53445.4	0.79^{NS}
Herbicide	4	1641360.	410340	6.11^{**}
H. Rate	2	991818.	495909	7.38^{**}
Lime	2	101951.2	50975.6	0.75^{NS}
Herbicide*H. Rate	8	6724560.	840570	12.52^{**}
Herbicide*Lime	8	829152.	103644	1.54^{NS}
H. Rate*Lime	4	522632.	130658	1.94^{NS}
Herbicide*H. Rate*Lime	16	1005361.6	62835.1	0.93^{NS}
Error	176	11816341.	67138.3	

CV = 3.6%

Appendix Table 15. Wheat Yields (kg/ha) from Wheat and Ryegrass Plots. Schmidt Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		6160	6653	6582
1.12		7589	7046	7418
2.24		7932	6574	7496
	Mean	7227	6758	7165
Triallate				
0.70		4402	5059	4952
1.40		6024	6539	6546
2.80		6882	7146	7489
	Mean	5769	6248	6329
Diclofop				
0.42		6589	7060	7075
0.84		7353	7510	7696
1.68		7318	7260	7946
	Mean	7087	7277	7572
Metribuzin				
0.28		6117	6274	5695
0.56		7539	6310	7854
1.12		4709	4395	2801
	Mean	6122	5660	5450
Diuron				
0.90		2594	3594	2680
1.80		4009	4323	4566
3.60		7082	6431	6181
	Mean	4562	4783	4476
Control		1202	2730	1751

Appendix Table 16. Analysis of Variance Table for Data in Appendix Table 15.

Source	d.f.	SS	MS	F
Total	224	74832279.		
Block	4	388252.8	97063.2	0.65^{NS}
Herbicide	4	21179040.	5294760	35.80**
H. Rate	2	6055140.	3027570	20.47**
Lime	2	12405.6	6202.8	0.04^{NS}
Herbicide*H. Rate	8	17593920.	2199240	14.87**
Herbicide*Lime	8	1066744.	133343	0.90^{NS}
H. Rate*Lime	4	949108.	237277	1.60^{NS}
Herbicide*H. Rate*Lime	16	1560788.8	97549.2	0.65^{NS}
Error	176	26026880.	147880	

CV = 6.2%

Appendix Table 17. Italian Ryegrass Fresh Weights (kg/plot) from Italian Ryegrass Plots. Schmidt Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		7.62	4.98	4.24
1.12		1.80	1.68	1.64
2.24		0.64	0	0.12
	Mean	3.35	2.22	2.00
Triallate				
0.70		11.68	14.46	12.76
1.40		5.82	5.34	5.72
2.80		2.44	1.54	1.60
	Mean	6.64	7.11	6.69
Diclofop				
0.42		1.86	2.02	1.54
0.84		0	0	0
1.68		0	0	0
	Mean	0.62	0.67	0.51
Metribuzin				
0.28		10.22	10.78	7.74
0.56		0	0	0
1.12		0	0	0
	Mean	3.40	3.59	2.25
Diuron				
0.90		15.78	16.12	17.70
1.80		17.62	14.52	12.84
3.60		8.08	4.96	5.74
	Mean	13.82	11.86	12.09
Control		19.32	17.81	17.40

Appendix Table 18. Analysis of Variance Table for Data in Appendix Table 17.

Source	d.f.	SS	MS	F
Total	224	8785.20		
Block	4	49.24	12.31	1.47^{NS}
Herbicide	4	4033.00	1008.25	120.94**
H. Rate	2	2232.68	1116.34	133.91**
Lime	2	24.00	12.00	1.43^{NS}
Herbicide*H. Rate	8	826.24	103.28	12.38**
Herbicide*Lime	8	37.20	4.65	0.55^{NS}
H. Rate*Lime	4	11.96	2.99	0.35^{NS}
Herbicide*H. Rate*Lime	16	104.80	6.55	0.78^{NS}
Error	176	1466.08	8.33	

CV = 56%

Appendix Table 19. Wheat Yields (kg/ha) from Untreated Wheat Plots. Schmidt Farm.

Lime Rates (t/ha)	Blocks				
	1	2	3	4	5
0	6003	5574	6324	6789	5967
4.5	7494	8146	7325	7110	6717
9.0	7789	7396	6503	8218	7039

Appendix Table 20. Analysis of Variance Table for Data in Appendix Table 19.

Source	d.f.	SS	MS	F
Total	14	884034.03		
Block	4	120659.70	30164.92	0.97^{NS}
Lime	2	514841.10	257420.55	8.28^{*}
Error	8	248533.22	31066.65	

CV = 2.5%

Appendix Table 21. Wheat Yields (kg/ha) from Untreated Wheat & Italian Ryegrass Plots. Schmidt Farm.

Lime Rates (t/ha)	Blocks				
	1	2	3	4	5
0	929	1615	1143	1322	1000
4.5	1380	1572	2215	1429	1787
9.0	1429	1400	2251	2144	1536

Appendix Table 22. Analysis of Variance Table for Data in Appendix Table 21.

Source	d.f.	SS	MS	F
Total	14	233266.67		
Block	4	64060.89	16015.22	1.59^{NS}
Lime	2	88909.22	44454.61	4.42^{NS}
Error	8	80296.56	10037.07	

CV = 6.4%

Appendix Table 23. Italian Ryegrass Fresh Weights (kg/plot) from Untreated Italian Ryegrass Plots. Schmidt Farm.

Lime Rates (t/ha)	Blocks				
	1	2	3	4	5
0	13.3	23.0	18.4	21.9	20.0
4.5	14.1	17.9	16.0	17.4	23.7
9.0	15.9	15.0	17.2	17.7	21.2

Appendix Table 24. Analysis of Variance Table for Data in Appendix Table 23.

Source	d.f.	SS	MS	F
Total	14	142.8343		
Block	4	83.7793	20.9448	3.43^{NS}
Lime	2	10.2243	5.1121	0.83^{NS}
Error	8	48.8306	6.1038	

CV = 13.6%

Appendix Table 25. Visual Evaluation as Percent Control of Italian Ryegrass in the Second Year. Hyslop Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		81	79	81
1.12		95	95	95
2.24		100	100	100
	Mean	92	91	92
Triallate				
0.70		71	65	65
1.40		79	75	83
2.80		88	96	90
	Mean	79	79	79
Diclofop				
0.42		84	85	73
0.84		98	97	97
1.68		100	100	100
	Mean	94	94	90
Metribuzin				
0.28		69	63	68
0.56		95	98	95
1.12		99	99	98
	Mean	88	87	87
Diuron				
0.90		10	4	10
1.80		43	54	54
3.60		94	90	96
	Mean	49	49	53
Control		0	0	0

Evaluation date: March 1, 1978
Planting date: October 11, 1977

Appendix Table 26. Visual Evaluation as Percent Control of Italian Ryegrass in the Second Year. Schmidt Farm.

Herbicide treatments (kg/ha)		Lime Rates (t/ha) 0	4.5	9.0
Trifluralin				
0.56		58	60	62
1.12		94	88	93
2.24		100	98	97
	Mean	84	82	84
Triallate				
0.70		61	63	68
1.40		65	71	73
2.80		89	85	91
	Mean	72	73	77
Diclofop				
0.42		82	83	74
0.84		93	95	91
1.68		100	100	100
	Mean	92	93	88
Metribuzin				
0.28		78	75	79
0.56		94	96	94
1.12		99	98	97
	Mean	90	90	90
Diuron				
0.90		11	9	7
1.80		47	63	48
3.60		89	94	92
	Mean	49	55	49
Control		0	0	0

Evaluation date: March 1, 1978
Plating date: October 12, 1977

Appendix Table 27. Italian Ryegrass Shoot Fresh Weights (g/pot). First Greenhouse Experiment.

Herbicide Rates (kg/ha)	Lime Rates (t/ha)				
	0	2.25	0.45	6.75	9.00
2.23	4.97	5.55	5.95	6.05	6.07
0.45	4.90	5.12	5.07	5.87	5.52
0.68	3.40	4.70	4.17	5.17	5.02
0.90	3.12	3.65	4.70	4.40	4.87
1.13	1.62	2.20	2.12	1.90	3.20
1.35	1.10	1.27	0.75	2.07	2.27
1.58	1.27	1.27	0.70	0.90	0.92

Appendix Table 28. Analysis of Variance Table for Data in Appendix Table 27.

Source	d.f.	SS	MS	F
Total	139	538.9353		
Block	3	19.7697	6.5899	12.61**
Lime	4	18.8832	4.7208	9.03**
H. Rate	6	429.5646	71.5941	137.07**
Lime*H. Rate	24	17.4432	0.7268	1.39NS
Error	102	53.2746	0.5223	

C.V. = 20.7%

Appendix Table 29. Untreated Italian Ryegrass Shoot Fresh Weights (g/pot). First Greenhouse Experiment.

Lime Rates (t/ha)	Blocks			
	1	2	3	4
0	4.4	4.3	4.3	5.2
2.25	4.1	4.9	5.7	5.0
0.45	5.9	5.1	5.0	6.3
6.75	5.9	5.6	7.0	5.9
9.00	4.9	5.6	6.2	5.5

Appendix Table 30. Analysis of Variance Table for Data in Appendix Table 29.

Source	d.f.	SS	MS	F
Total	19	10.9280		
Block	3	1.4760	0.4920	1.65 NS
Lime	4	5.8930	1.473250	4.96 *
Error	12	3.558999	0.2965833	

CV = 10.1%

Appendix Table 31. Italian Ryegrass Shoot Fresh Weights (g/pot). Second Greenhouse Experiment.

Herbicide Rates (kg/ha)	Lime Rates (t/ha)				
	0	2.25	0.45	6.75	9.00
2.23	2.15	2.05	1.68	2.20	2.80
0.45	1.65	1.30	0.30	1.20	1.18
0.68	1.05	0.55	0.05	0.38	0.70
0.90	0.15	0.48	0.50	1.90	0.80
1.13	1.30	0.10	0.28	0.00	0.20
1.35	0.00	0.33	0.08	0.15	0.55
1.58	0.00	0.00	0.00	0.13	0.00

Appendix Table 32. Analysis of Variance Table for Data in Appendix Table 31.

Source	d.f.	SS	MS	F
Total	139	123.6499		
Block	3	1.4211	0.4737	1.26^{NS}
Lime	4	3.9640	0.9910	2.64*
H. Rate	6	66.9564	11.1594	29.75**
Lime*H. Rate	24	13.0584	0.5441	1.45^{NS}
Error	102	38.250	0.3750	

C.V. = 87.4%

Appendix Table 33. Untreated Italian Ryegrass Shoot Fresh Weights (g/pot). Second Greenhouse Experiment.

Lime Rates (t/ha)	Blocks			
	1	2	3	4
0	3.5	3.6	3.4	2.8
2.25	2.9	2.7	4.4	2.7
0.45	3.0	3.6	3.6	2.2
6.75	3.5	3.5	3.2	2.6
9.00	3.3	3.5	4.1	3.3

Appendix Table 34. Analysis of Variance Table for Data in Appendix Table 33.

Source	d.f.	SS	MS	F
Total	19	5.2020		
Block	3	2.6820	0.8940	5.30*
Lime	4	0.4970	0.12425	0.73NS
Error	12	2.0230	0.168533	

CV = 12.2%

Appendix Table 35. Lime Effect on Wheat Growth (g/pot) in the Greenhouse.

Lime Rates (t/ha)	Blocks			
	1	2	3	4
0	1.3	1.6	1.1	1.4
2.25	1.1	1.2	2.1	2.0
0.45	1.2	1.5	2.3	1.3
6.75	0.9	1.5	1.3	2.0
9.00	1.5	0.9	2.6	1.8

Appendix Table 36. Analysis of Variance Table for Data in Appendix Table 35.

Source	d.f.	SS	MS	F
Total	19	4.142		
Block	3	1.482	0.494	2.53^{NS}
Lime	4	0.317	0.07925	0.40^{NS}
Error	12	2.343	0.19525	

CV = 28.8%

Appendix Table 37. Visual Evaluation as Percent Control of Italian Ryegrass. First Greenhouse Experiment.

Herbicide Rates (kg/ha)	Lime Rates (t /ha)				
	0	2.25	0.45	6.75	9.00
0	0	0	0	0	0
2.23	6	0	0	1	6
0.45	13	10	4	13	15
0.68	28	15	14	13	33
0.90	60	53	25	55	49
1.13	85	70	66	70	62
1.35	84	85	85	78	80
1.58	81	83	89	89	87

Appendix Table 38. Visual Evaluation as Percent Control of Italian Ryegrass. Second Greenhouse Experiment.

Herbicide Rates (kg/ha)	Lime Rates (t/ha)				
	0	2.25	0.45	6.75	9.00
0	0	0	0	0	0
2.23	29	30	40	25	13
0.45	53	59	81	54	60
0.68	80	86	99	91	75
0.90	84	90	74	41	50
1.13	96	94	89	96	94
1.35	95	93	96	90	81
1.58	96	98	100	94	96