HARD WHITE WINTER WHEAT RESPONSE TO HERBICIDES

by

BRIAN E. VINING

B.S., Kansas State University, 1984

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Agronomy Department
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

Approved by:

Oliver G. Russ

Major Professor

TABLE OF CONTENTS

RESEARCH ARTICLE

APPENDIX

INTRODUCTION

Hard white winter wheat. The development of hard white winter wheat (*Triticum aestivum* L.) as an alternative to hard red winter wheat has been an ongoing project at Kansas State University for several years and is occurring within the private wheat breeding sector as well. Like the hard red wheat predominant in Kansas, hard white wheat produces flour to be used in baking breads. However, hard white wheat lacks the seed coat pigmentation present in hard red types. This leads to differences in milling, baking, and final product properties that can be preferable to those of hard red wheat.

These possible advantages include a higher flour extraction rate, greater flour protein content, more favorable appearance of whole-wheat baked products, and more valuable bran (3). These traits and others have led to a preference for hard white over hard red wheat by some nations importing wheat from the United States.

Other than a greater susceptibility to preharvest sprouting, there appear to be no agronomic barriers to the development and production of high yielding hard white winter wheats in the U.S. Great Plains. The predominance of hard red wheat in the region, where much of the wheat is destined for the export market, has been attributed to the introduction of 'Turkey Red' wheat into Kansas in the 1870's. The success of Turkey Red led to red wheat becoming the standard, a situation which persists to this day. However, current wheat use patterns indicate that precedence, more than the marketplace, has kept this standard in place (4,8).

In recent years Kansas has averaged more than 5,000,000 ha of wheat planted annually, virtually all hard red winter wheat. If a significant share of this production is shifted to hard white wheat, there may be benefits to growers, millers, bakers, and exporters; all of which are important to the state of Kansas.

This transition is likely to depend upon several factors, such as classification of the grain and a marketing system that can maintain hard white wheat as a separate entity from hard red. It seems likely that wheat growers will shift production more quickly and more easily if no changes in agronomic production practices are required. This would include factors such as tillage and seeding, fertilization, and weed control.

Herbicides. Weed control is an important part of winter wheat production in Kansas and the use of herbicides is often part of a sound weed control program. Clearly then, if hard white wheat is to become an important part of Kansas agriculture, adequate weed control, which sometimes requires the use of herbicides, will be required.

The objectives of this study were to determine the response of four diverse hard white winter wheat genotypes to nine herbicides used in Kansas wheat production. Two hard red wheats were included, as well as a no herbicide treatment check. Specific objectives included identifying any herbicide sensitivities exhibited by the white genotypes and analyzing yield components to determine the source of any yield reductions that occur. Studies have often found that wheat herbicide injury is better quantified with yield components than actual yield because of compensation among the yield components (2,5,9).

Researchers using some of these same herbicides and red wheat cultivars have sometimes reported significant herbicide treatment by cultivar interactions (5,7,9). Also, differential wheat cultivar tolerance to metribuzin (4-Amino-6-(1.1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H-one) (6) and chlorsulfuron (2-Chloro-N-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) (1) have been reported in the region. For this reason, it is necessary to avoid attributing differential herbicide tolerance to seed coat pigmentation rather than conventional genotype differences.

MATERIALS AND METHODS

Field studies were initiated at the Ashland Research Farm of Kansas State University, near Manhattan, Kansas, and the Hays Experiment Station, in western Kansas, in 1987 and 1988. The studies at Hays were lost to wind erosion and drought the first and second year, respectively, and no data were collected from that site. The Manhattan site was on a Muir silt loam soil (fine-silty, mixed, mesic, Pachic Hapulstoll) with 2.3% organic matter and pH 5.9.

The six wheat genotypes used included four hard white and two conventional hard red wheats. The hard white wheats included 'KS84HW196', developed at the Hays Experiment Station of Kansas State University, and 'Rio Blanco', from Agripro Seed Company. 'KS73256' is a hard white line developed by Kansas State University and has the same parentage as the hard red cultivar 'Newton'. It is no longer under active development. 'White Chief' is a selection from 'Red Chief', which was privately developed and widely grown in Kansas in the 1930's. The hard red wheat cultivars were 'Arkan' and 'TAM 108'. Descriptions of the genotypes are summarized in table 1.

Eight of the nine herbicides were currently registered for use on wheat in Kansas and the ninth had been evaluated as an experimental compound at this site for several years. Two preplant incorporated products, diclofop (methyl 2-[4-(2,4-dichlorophenoxy) phenoxy]propanoate) and triallate [S-(2,3,3-Trichloroallyl)-diisopropylthiocarbamate]) were used. Postemergence herbicides used were 2,4-D ester (2,4-dichlorophenoxyacetic acid), dicamba (3,6-dichloro-o-anisic acid), MCPA ester (2-methyl-4-chlorophenoxyacetic acid), bromoxynil (3-5-dibromo-4-hydroxybenzonitrile), chlorsulfuron, metribuzin, and SMY 1500 ([4-amino-6-(1,ldimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4H)-one). SMY 1500 is an experimental compound from Mobay Chemical Company and had not yet been approved for use on wheat in Kansas. All products were applied in accordance with current label directions and in a system representative of farmer's practices across the state. Metribuzin was scheduled to be applied as a fall postemergence treatment in 1987, but poor fall conditions prevented the crop from reaching the growth stage required by the product label. Application was delayed until spring, when all label requirements were met. No combinations of more than one herbicide were used and no adjuvants were applied.

Experimental design was a randomized complete block with four replications utilizing six wheat genotypes and ten herbicide treatments. Plot size was 1.52 by 9.14 m and consisted of six drill rows 25.4 cm apart. Fertilizer was preplant incorporated as a blend of ammonium nitrate and diammonium phosphate to total 99-88-0 kg ha^{-1} N-P_2O_5-K_2O the first year and 101-68-0 kg ha^{-1} N-P_2O_5-K_2O the second year.

Wheat was drilled into weed-free seedbeds with a double-disc opener grain drill on 7 October 1987 and 3 October 1988. All herbicide treatments were applied with a tractor-mounted compressed-air sprayer delivering 187 L ha^{-1} of water as carrier. Propiconazole (trade name Tilt; 1-[{2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxalan-2-yl}methyl]-1H-1,2,4-triazole) fungicide was applied each spring, but disease levels were minimal both years.

Table 2 presents precipitation amounts and mean temperatures for the two growing seasons, including the month preceding planting. Year one (Sept., 1987 - June, 1988) was somewhat drier than normal with 51.51 cm, or 79.2% of average for that period. However, year two (Sept., 1988 - June, 1989) was one of the driest periods ever in the area, with 33.06 cm, or 50.8% of the average for that period. In addition, a temperature shift on 31 January and 1 February, 1989, led to near total necrosis of all above-ground plant parts as temperatures fell from 22.2°C to -10.3°C in 16 hours.

Plots were harvested with a modified Gleaner E combine. Grain moisture and test weight were obtained with an electronic grain tester, and yields were converted to 12.5% moisture. Kernels per spike and kernel weight were determined by hand harvesting 20 random spikes from each plot shortly before harvest. These spikes were threshed in a small head thresher and grain weight and kernel count were recorded. Kernel counts were divided by 20 to find kernels per spike and grain weight was divided by kernel count to find weight per kernel.

All data were analyzed using analysis of variance. Each response was analyzed for significance of genotype, treatment, and genotype by treatment interaction. Factors with no significant year effect were not averaged over years because of a decrease in significance versus analysis within years. Means of significant responses were separated using Fishers protected LSD test at the 5% level.

RESULTS AND DISCUSSION

All responses examined were highly significant for genotype both years of the study. Genotype effects included genotype by year interactions for some responses. One of these is shown by Table 3 which presents grain yield, test weight, and moisture content by genotype. White Chief, by far the oldest genotype in the experiment, yielded significantly less than all other genotypes the first year. The second year, however, only one genotype yielded significantly more than White Chief. This was likely due to the late maturing White Chief benefiting more from late season rainfall the second year, relative to the earlier maturing genotypes. Discussion of results will emphasize those factors with significant treatment main effects or genotype by treatment interactions.

Yield, test weight, and moisture. Grain yield, test weight, and moisture content ranged widely between the two years but had no significant treatment effect or genotype interaction either year. Mean values are presented in Table 4 by year and genotype.

Yield components. Number of spikes per meter of row was significant for treatment in 1989 at the P=0.07 level but had no genotype interaction. This indicates the herbicide effect was consistent across the different genotypes. Dicamba, metribuzin, bromoxynil, and 2,4-D ester significantly reduced spike number per meter (Table 5).

Number of kernels per spike was significant for treatment but not treatment by genotype interaction in 1988. Chlorsulfuron, dicamba, metribuzin, diclofop, and no treatment each had a reduced kernel number per spike, possibly reflecting greater spike density. Kernel weight was highly significant for genotype but not treatment or genotype by treatment interaction either year.

Grain weight per spike, the product of kernel weight and kernels per spike, was significant for treatment at the P=0.06 level in 1989 and had a genotype by treatment interaction that was significant at P=0.10. Means listed by genotype and treatment (Table 6) indicate the interaction appears across all genotypes, including the hard red wheats, and does not appear to be related to seed coat pigmentation. Although treatment effect was not significant in year one of the study, comparison of the data reveals no trend matching the interaction of year two.

Overall, the study identified no sensitivities to herbicide treatment that could be related to wheat seed coat pigmentation. The difference in which yield component expressed herbicide effect the two years of the study might be due to incongruous weather patterns the two growing seasons.

In year one, a relatively normal wheat growing season, the only herbicide treatment effect was on kernels per spike and there was no genotype interaction, indicating the effect was consistent across the different wheats. In year two, the plot area was exposed to severe cold injury and prolonged drought stress, especially late in the season. These factors lowered yields and likely reduced the plant's ability to compensate for any herbicide injury. Under those conditions, herbicide treatment affected total grain yield per spike but not kernel number per spike or kernel weight individually. This effect on grain yield per spike varied among the wheat genotypes, as shown by the marginally significant treatment by genotype interaction. This suggests that differential tolerance is most likely to be a factor when compounded by other stresses.

Published reports on differential wheat cultivar response to herbicides are complicated by the interactions of various wheat types, (e.g. spring vs. winter) herbicide modes of action, herbicide rates, and application timings. This has prevented the formation of a clear concensus on what factor or combination of factors is most important in predicting and managing differential wheat tolerance of herbicides.

The determination of which yield component best measures wheat herbicide injury has been known to vary with crop growth stage and herbicide application timing. These results indicate the incidence of additional stress factors, such as drought and cold injury, is also a factor in the expression of herbicide injury upon wheat yield components. As with herbicide type and rate, drought and cold injury effects on yield components will likely vary with the timing of the additional stresses in relation to crop development.

Further studies are likely to be most productive if experiments are restricted to herbicides known to bring out differential genotype response. Once a better understanding of the interactions with crop growth stage and herbicide application timing are achieved, additional environmental stress factors can be introduced and analyzed.

LITERATURE CITED

1. Anderson, R. L. 1986. Metribuzin and chlorsulfuron effect on grain of treated winter wheat (*Triticum aestivum*). Weed Sci. 34:734-737.

2. Martin, D. A., S. D. Miller, and H. P. Alley. 1989. Winter wheat (*Triticum aestivum*) response to herbicides applied at three growth stages. Weed Tech. 3:90-94.

3. Paulsen, G. M. and E. G. Heyne. 1981. Development of hard white winter wheats for the Great Plains. WheatGrower 4(5):26-28.

4. Paulsen, G. M., E. G. Heyne, T. L. Walter, and R. C. Hoseney. 1983. Agronomic and quality attributes of sibling hard white and hard red winter wheats. Crop Sci. 23:859-862.

5. Robison, L. R. and C. R. Fenster. 1973. Winter wheat response to herbicides applied postemergence. Agron. J. 65:749-751.

6. Runyan, T. J., W. K. McNeil, and T. F. Peeper. 1982. Differential tolerance of wheat (*Triticum aestivum*) cultivars to metribuzin. Weed Sci. 30:94-97.

7. Schroeder, J. and P. A. Banks. 1989. Soft red winter wheat (*Triticum aestivum*) response to dicamba and dicamba plus 2,4-D. Weed Tech. 3:67-71.

8. Upadhyay, M. P., G. M. Paulsen, E. G. Heyne, R. G. Sears, and R. C. Hoseney. 1984. Development of hard white winter wheats for a hard red winter wheat region. Euphytica 33:865-874.

9. Wicks, G. A., P. T. Nordquist, and J. W. Schmidt. 1987. Response of winter wheat (*Triticum aestivum*) to herbicides. Weed Sci. 35:259-262.

Table 1. Summary of wheat genotypes

genotype	classification	parentage	released
Arkan	hard red	Sage/Arthur	Kansas, 1982
KS73256	hard white	Pitic 62/Chris sib//2*Sonora 64/ Klein Rendidor/4/Scout	experimental
KS84HW196	hard white	Bison/Sturdy/3xSut/3/Eagle/4/ Pawnee/2x Eagle	experimental
Rio Blanco	hard white	privately developed	experimental
TAM 108	hard red	Sturdy sib/Triumph/ (Tx62A4615-7)/ /Centurk	Texas, 1984
White Chief	hard white	selection from Red Chief	Kansas, 1930's

Table 2. Summary of weather data for winter wheat growing seasons at Manhattan, Kansas. Year 1 = September, 1987 - June, 1988; Year 2 = Sept., 1988 - June, 1989.

	------ precipitation -----			----mean monthly temp.----		
Month	Normal[a]	Year 1.	Year 2.	Normal[a]	Year 1.	Year 2.
		(cm)			(°C)	
September	10.26	3.63	4.72	20.7	20.4	21.9
October	7.34	6.93	1.42	14.6	12.3	12.3
November	3.71	6.93	2.54	6.3	8.2	8.3
December	2.31	2.74	0.58	0.4	2.1	2.7
January	2.11	0.76	2.29	-2.7	-2.4	3.5
February	2.11	1.30	1.96	0.7	-0.8	-4.6
March	5.28	1.32	4.29	5.8	7.1	7.8
April	7.09	13.03	1.14	13.1	12.4	15.9
May	11.43	5.77	5.61	18.6	20.8	19.0
June	13.43	9.14	8.51	23.7	25.8	22.6
Total	65.07	51.56[b]	33.07[c]			

[a]Normal values are long term means based on 1951-80 data.
[b]Total is 79.2% of average accumulated precipitation for that period.
[c]Total is 50.8% of average accumulated precipitation for that period.

Table 3. Mean values of grain yield, moisture, and test weight of six hard winter wheat genotypes by year.

	----------1988-----------			----------1989-----------		
Genotype	Yield	Test Wt.	Moisture	Yield	Test Wt.	Moisture
	(kg/ha)	(kg/m^3)	(%)	(kg.ha)	(kg/m^3)	(%)
Arkan	3020	788	8.1	1920	712	10.8
KS84HW196	2290	777	8.1	2270	713	12.3
KS73256	2750	776	8.1	1660	695	11.3
Rio Blanco	3570	808	8.4	2070	723	11.5
TAM 108	3760	766	8.2	2620	704	11.3
White Chief	1780	788	8.3	2170	728	12.4
Mean	2860	784	8.2	2120	713	11.6
LSD (.05)	190	7.7	0.16	185	2.9	0.42
C.V.	15.1%	2.2%	4.5%	19.7%	0.9%	8.3%

Table 4. Spikes per meter of row (1989) and kernels per spike (1988) of winter wheat in response to 10 herbicide treatments averaged across six wheat genotypes.

Treatment	Rate	Spikes/meter	Kernels/spike
	(kg/ha)	(no.)	(no.)
Bromoxynil	0.56	66.8	20.1
Chlorsulfuron	0.0175	74.9	19.0
Dicamba	0.14	67.7	18.9
Diclofop	1.12	73.3	18.8
MCPA	0.56	76.3	20.0
Metribuzin	0.56	67.4	18.8
SMY-1500	1.68	71.4	19.7
2,4-D Ester	0.56	64.8	19.5
Triallate	1.68	71.9	20.5
Untreated	----	70.9	18.4
Mean		70.5	19.4
LSD (0.05)		7.86	1.36
C.V.		19.6%	12.3%

Table 5. Total grain weight per spike of winter wheat in response to 10 herbicide treatments for six wheat genotypes in 1989.

Treatment	Rate	Genotype: Arkan	KS73256	KS84HW196	RIO BLANCO	TAM 108	WHITE CHIEF
	(kg/ha)	(grams)					
Bromoxynil	0.56	0.44	0.14	0.47	0.49	0.74	0.80
Chlorsulfuron	0.0175	0.35	0.51	0.47	0.55	0.56	0.68
Dicamba	0.14	0.47	0.55	0.54	0.57	0.75	0.74
Diclofop	1.12	0.48	0.36	0.49	0.51	0.70	0.52
MCPA	0.56	0.47	0.51	0.48	0.49	0.76	0.74
Metribuzin	0.56	0.58	0.40	0.53	0.51	0.72	0.80
SMY 1500	1.68	0.63	0.37	0.54	0.54	0.65	0.84
2,4-D Ester	0.56	0.46	0.39	0.48	0.51	0.79	0.64
Triallate	1.68	0.50	0.39	0.48	0.45	0.83	0.55
Mean			0.56				
LSD (0.05) Genotype x Treatment			.193				
C.V.			24.9%				

APPENDIX

LITERATURE REVIEW

Studies investigating the response of various wheat (*Triticum aestivum* L.) genotypes to treatment with chemical herbicides originated shortly after the introduction of 2,4-D in the late 1940's. Several of these studies also dealt with application of 2,4-D at various growth stages, including fall treatments of winter wheat which have been determined to cause too much crop injury for general use (6,17,20). Woestemeyer (34) in Kansas, and Elder (9) in Oklahoma both reported in 1949 on trials which applied three formulations of 2,4-D at 0.84 kg ha^{-1} to several hard red winter wheat cultivars. Both studies included applications at early fall tiller, spring full tiller, boot, and dough stages. Elder reported both timing and formulation were significant for yield but all cultivars responded very much alike. Woestemeyer reported significant yield reductions with fall treatments but no distinct difference in cultivar response. That same year Slife (30) in Illinois reported on a study with application of 2,4-D amine at four rates from 0.37 to 2.99 kg ha^{-1} at one fall and two spring growth stages to eight winter wheat cultivars. Again significant yield reductions were found with fall applications of 2,4-D but no differences were observed among cultivars.

Some early work in this field did reveal differences among wheat genotypes treated with 2,4-D. Phillips (22) reported on work in Kansas treating seven hard red winter wheat cultivars with three formulations of 2,4-D at 0.84 kg ha^{-1}. Two spring growth stages, early jointing and late boot, were treated. Growth stage and formulation main effects were not significant for yield but a significant growth stage by cultivar interaction was found. Phillips reported this may indicate genotypic differentiation at various growth stages for yield. Shaw (29), working with six soft winter wheat cultivars in Ohio reported on application of 2,4-D at four rates, from 0.56 to 4.48 kg ha^{-1}. Growth stages included fall, spring tiller, and late jointing. Significant differences were found in injury ratings among cultivars, especially at rates beyond 0.56 kg ha^{-1}. It was not reported if these injury differences led to differences in grain yield.

Two studies on hard red winter wheat were reported in 1950. Elder (10) applied three rates of ester and one rate each of amine and sodium salt of 2,4-D to six cultivars. Growth stages were fall tiller, spring tiller, boot, and dough. Growth stage was found to be significant for yield, reportedly because of the fall treatment. No significant yield reductions were found with the other growth stages and it was reported that all cultivars responded alike for all treatments. Phillips (23) applied three formulations of 2,4-D at 0.84 kg ha^{-1} during jointing, boot, and soft dough stages. Neither formulation nor growth stage was significant for yield and it was reported that all cultivars seemed to be equally tolerant of the chemicals used.

A summarization of the early work involving 2,4-D tolerance of winter wheat finds that significant yield reductions were consistently found to result from fall applications. Formulation of 2,4-D was often significant for yield also. This might be because rates used in these studies, especially for the ester formulations, were often higher than those generally in use today. Reports on differences among cultivars in response to 2,4-D treatments were inconsistent. Where significant differences in herbicide effects were reported, it was often at relatively high rates or for fall application. The lack of tests for interaction by most early researchers detracts from the relevance of much of this work.

Klingman (17) evaluated winter wheat treated with 1.12 kg ha^{-1} 2,4-D ester at one fall and one spring growth stage. For year one of this study, which included 22 cultivars, yield reductions were significant at the 1% level for the fall application and the 5% level for the spring application. Cultivar by treatment interaction was not significant. Year two of this study involved 21 cultivars, 18 of which had been included the previous year. Once again, yield reduction from the fall application was significant at 1%, but the spring application was not significantly different from the handweeded check treatment. Cultivar by treatment interaction was significant for yield, although Klingman reported differential responses were not great. Cultivar height by treatment interaction was not significant.

Price and Klingman (25) applied 2,4-D amine at 0.56 and 2.24 kg ha^{-1} to 27 winter wheat cultivars at one fall and one spring growth stage. Neither rate significantly reduced yield at the spring application. Yield reductions with the fall application were 632 kg ha^{-1} at the low rate and 1055 kg ha^{-1} at the high rate when analyzed across all cultivars. A significant cultivar by treatment interaction was found for both yield and height at maturity, indicating differential responses among genotypes. The authors report the yield differences within cultivars were most pronounced with the 0.56 kg ha^{-1} rate applied in the fall. With this treatment, yield reductions were significant for 14 of the 27 cultivars tested. Presumably, spring treatments did not cause sufficient crop injury to bring out differences in cultivar response and the fall treatment at the high rate led to crop injury sufficient to mask these genotypic differences.

Hodgson *et al.* (15), treated 22 spring wheat cultivars with 2,4-D and other herbicides at higher than normal rates to determine relative tolerance. Significant differences in yield response among cultivars were reported for all treatments. Treatment with 2,4-D at 5.60 kg ha^{-1} led to yields of 63% to 109% of the check. The authors reported the two soft white wheats in the study were among the most susceptible to 2,4-D yield reduction.

Poku *et al.* (24) applied 2,4-D amine at 0.84 kg ha^{-1} to five soft red winter wheat cultivars at the fully tillered and late boot stages. No 2,4-D treatments significantly reduced yield below untreated checks in any of the cultivars.

Oleniczak *et al.* (21) treated three soft white winter and one soft red winter wheat cultivars with 2,4-D at three spring growth stages. They reported that two cultivars exhibited significantly greater visual injury but this did not correspond to yield losses.

Robison and Fenster (26) included 2,4-D in a study evaluating the response of five hard red winter wheat cultivars to 14 herbicide treatments applied at four growth stages. Treatments included 2,4-D amine at 0.56 and 0.84 kg ha^{-1}, and 2,4-D ester at 0.28 and 0.56 kg ha^{-1}. Growth stages were fall seedling, spring tiller, boot, and heading. Herbicide by cultivar interaction was significant for yield for this study. Yield of the 2,4-D amine at 0.56 kg ha^{-1} treatment was not significantly different from the untreated check for any of the cultivars. The 2,4-D amine at 0.84 kg ha^{-1} treatment led to significant yield reductions in three of the five cultivars. The 2,4-D ester significantly reduced yields in one cultivar at the lower rate and in four cultivars at the higher rate.

This study included two dicamba treatments, 0.14 and 0.28 kg ha^{-1}. Dicamba significantly reduced yields from the untreated check in one cultivar at the lower rate and in three of the five cultivars at the higher rate. Dicamba applied at the boot stage at 0.28 kg ha^{-1} caused the greatest yield reduction of any treatment in the trial, approximately 50%.

Behrens and Johnston (3) treated nine spring wheats with 0.56 kg ha^{-1} dicamba at the four leaf stage. Injury ratings were given but the authors state that injury estimates did not closely correspond with yield reductions. Yields ranged from 57% to 101% of the check, with no statistical separations given.

Keys (16) treated three wheat cultivars with 0.28 and 0.56 kg ha^{-1} dicamba at the four to six leaf stage and reported yields were virtually unchanged from the order of the standard performance tests.

The study by Oleniczak (21) mentioned earlier concluded that the two cultivars most susceptible to 2,4-D were also more susceptible to dicamba injury than the remaining two cultivars. Dicamba rates used were 0.28 and 0.56 kg ha^{-1}.

The study by Hodgson *et al.* (15) mentioned above included a treatment of dicamba at 3.36 kg ha^{-1}. Significant differences were reported in yield as percent of the check treatment, which varied from 4% to 52%.

Little has been published on the effects of bromoxynil on wheat genotypes and most reports have included bromoxynil as part of a treatment in combination with other active ingredients. Friesen (12) applied bromoxynil + MCPA at 0.56 kg ha^{-1} to three spring wheat cultivars with no significant differences in yield. Yield as percent of check for the three cultivars ranged from 90.6% to 93.0%. The Robison and Fenster study (26) referred to above included bromoxynil treatments at 0.28 and 0.56 kg ha^{-1}, and a bromoxynil + MCPA treatment at 0.28 + 0.28 kg ha^{-1}. Bromoxynil alone significantly reduced yield from the check in one cultivar at the lower rate and in two of the five cultivars at the higher rate. There were no significant differences in yield between the bromoxynil + MCPA treatment and the untreated check.

The limited published reports on MCPA effects on wheat genotypes, such as Friesen (12), also often include treatments with multiple active ingredients. Edwards and Miller (8) treated ten spring wheats with 0.28 kg ha^{-1} MCPA + 0.14 kg ha^{-1} dicamba at growth stages of 3-5 leaves and 6-7 leaves. They reported more severe injury with the late application and wide differences in cultivar response. Percent yield reduction ranged from 4% to 15% at the early application and from 5% to 41% at the later application. No statistical separations are given. The report by Hodgson *et al.* (15) included a treatment of MCPA at 5.60 kg ha^{-1}. Significant differences in yield as percent of check were reported among cultivars, although considerable crop safety was reported for this treatment. Across all cultivars, the treatment averaged 97% of the untreated check and only 4 of the 22 cultivars differed significantly from the group with yields at the highest percent of the check.

Published reports on the effect of diclofop on various wheat genotypes are also very limited. Behrens and Elakkad (4) preplant incorporated diclofop at 1.12 kg ha^{-1} to nine spring wheat cultivars and found no significant yield differences between the diclofop treatment and the untreated check. Lish *et al.* (18) treated four spring wheat cultivars with diclofop at 1.14 kg ha^{-1} plus three other treatments and reported cultivar by treatment interaction was not significant.

Geddens *et al.* (13) reported a study with diclofop postemergent-applied to six soft white winter wheat cultivars and the effects on take-all disease. Plots were not taken to yield, but a significant cultivar by herbicide treatment by disease interaction was reported for fresh weight. Two of the cultivars were found to have substantially reduced fresh weights when diclofop was applied in the absence of disease. In the presence of take-all, however, diclofop treatment led to fresh weights greater than the no herbicide treatment. No explanation was given for this effect.

In contrast, genotypic differences in wheat response to triallate have been relatively well documented. Stewart and Keener (31) treated seven spring wheat cultivars with preplant incorporated triallate at multiple rates. They reported plant populations were reduced significantly as triallate rate increased and significant population differences among cultivars were found. Significant differences in yield were reported among cultivars due to the rate of triallate. All triallate treatments yielded significantly less than the check and the high triallate rate yielded significantly less than lower rates.

Schaat and Thill (28) examined nine spring wheat cultivars in the greenhouse which they said showed differential susceptibility to triallate. Four of these cultivars were then used in a field experiment which included two planting depths, three planting dates, and three triallate rates. A significant cultivar by rate by planting depth interaction was reported for yield.

Miller and Nalewaja (19) preplant incorporated triallate at 1.12 kg ha^{-1} to five spring wheat cultivars and reported yield reduction from 1% to 23% with no statistical separations given.

Fay and Davis (11) examined a single cultivar treated with preplant incorporated triallate at 1.40 kg ha^{-1} at three seeding rates and two seeding depths. They determined triallate reduced yield and there was no relationship between seeding depth and crop safety. They concluded that increased seeding rate caused a trend toward increased yield but the surviving plants were not able to compensate completely for the triallate damage.

Differential susceptibility to metribuzin has been established to the extent that herbicide labels restricting its use to specific cultivars are in effect. Runyan *et al. (27)* examined 15 hard red winter wheat cultivars treated with several metribuzin rates at 13 sites in Oklahoma. Differences in cultivar response were reported at nine of the 13 sites, with results depending on precipitation and soil moisture. Greenhouse studies were combined with field data to conclude that significant differences in metribuzin tolerance exist in current wheat cultivars.

Apley (2) examined 69 hard red and two soft red winter wheat cultivars for response to 0.60 kg ha^{-1} metribuzin applied postemergent. Chlorosis and stand reduction ratings were taken for one to three years, varying with the cultivar. Based on these ratings, cultivars were classified as either susceptible, moderately susceptible, moderately tolerant, or tolerant to metribuzin. Sixteen of the 71 cultivars classified (22.5%) were identified as susceptible or moderately susceptible.

Wicks *et al.* (33) treated 16 hard red winter wheat cultivars with 0.3 kg ha^{-1} metribuzin for two years. Grain yields were not significantly different from untreated checks for any cultivar either year. Wicks and Nordquist (32) reported that injury and yield reduction from a spring-applied metribuzin + pendimethalin treatment might be related to winter hardiness.

Anderson (1) reported that 0.36 kg ha^{-1} metribuzin significantly reduced yield of 'Vona' hard red winter wheat, which had been classified as susceptible by both Runyan and Apley. In addition, the study found this metribuzin treatment applied with 35 or 70 g ha^{-1} chlorsulfuron significantly outyielded the metribuzin treatment applied alone or with chlorsulfuron at 18 g ha^{-1}, although there was still a significant yield reduction from the no treatment. Anderson concluded this was a significant antagonistic effect as chlorsulfuron at the higher rates diminished metribuzin crop injury to Vona wheat.

SMY 1500 is an experimental compound being developed by Mobay Chemical Company for use as a herbicide in winter wheat. Chemically similar to metribuzin, it is not surprising that differential susceptibility has been established for SMY 1500. Colgan *et al.* (7) reported that studies by Mobay in Texas, Oklahoma, Kansas, and Nebraska involving several rates of SMY 1500 under varying conditions led to classification of cultivars as tolerant or susceptible. Of 77 cultivars classified, 13 (16.9%) were listed as susceptible.

Apley (2) classified the same 71 cultivars of the metribuzin study mentioned above for SMY 1500 tolerance and listed 11 of the 71 (15.5%) as susceptible or moderately susceptible.

Published reports on chlorsulfuron response to wheat genotypes have generally reported a wide safety margin at current use rates. Hageman and Behrens (14) applied chlorsulfuron preemergent and postemergent to four spring wheat cultivars at rates up to 0.25 kg ha^{-1} and reported no significant yield reductions and no significant differences among cultivars. They conclude that differential cultivar response does not appear to be a problem as these rates are approximately eight times normal field use rates. Brewster and Appleby (5) treated a single wheat cultivar with chlorsulfuron at various rates to determine crop tolerance. They report a significant yield reduction at 0.28 kg ha^{-1} but not at 0.56 kg ha^{-1}, which they describe as 21 times the highest labelled rate.

Wicks *et al* (33) applied chlorsulfuron at 0.07 kg ha^{-1} (approximately eight times label rate) to 13 hard red winter wheat cultivars. Yields were significantly reduced from untreated checks in three of the 13 cultivars. Anderson (1) applied chlorsulfuron at 0.18, 0.35, and 0.70 kg ha^{-1} to two hard red winter wheat cultivars. For one cultivar, yields were significantly reduced from the control at the two higher rates, but not at the lowest rates. The other cultivar showed no yield reduction from chlorsulfuron treatment.

LITERATURE CITED

1. Anderson, R. L. 1986. Metribuzin and chlorsulfuron effect on grain of treated winter wheat (*Triticum aestivum*). Weed Sci. 34:734-737.

2. Apley, K. A. 1987. Control of cheat (*Bromus secalinus* L.) in hard red winter wheat (*Triticum aestivum* L.) through competitive and chemical methods. Ph.D. Diss., Kansas State University, Manhattan.

3. Behrens, R. and D. R. Johnston. 1965. Response of wheat varieties to dicamba. *In* North Central Weed Control Conference Research Report, 22:57

4. Behrens, R. and M. A. Elakkad. 1979. Tolerance of spring wheat varieties to wild oat herbicides. *In* North Central Weed Control Conference Research Report, 36:118-120.

5. Brewster B. D. and A. P. Appleby. 1983. Response of wheat and rotation crops to chlorsulfuron. Weed Sci. 31:861-865.

6. Brotemarkle, J. K. 1987. Wheat herbicide application timing by growth stage. Kansas State Univ. Coop. Extension Service, #C-682.

7. Colgan, J. W., V. M. Sorenson, and A. C. Scoggan. 1987. Tycor (SMY 1500) herbicide: wheat research update. *In* Proceedings, Western Weed Control Conference, p.107,108.

8. Edwards, I. B. and S. D. Miller. 1978. Spring wheat varietal tolerance to application of difenzoquat or MCPA-dicamba. *In* Proceedings, North Central Weed Control Conference. 33:57-60.

9. Elder, W. C. 1949. Effect of three formulations of 2,4-D on eight varieties of fall-planted cereal grains when treated at four stages of growth. *In* North Central Weed Control Conference Research Report, 6:72

10. Elder, W. C. 1950. Effect of 2,4-D on six varieties of winter wheat when treated at four stages of growth. *In* North Central Weed Control Conference Research Report, 7:82.

11. Fay, P. K. and E. S. Davis. 1986. The effect of seeding rate and seeding depth on spring wheat injury from triallate. *In* Western Weed Control Conference Research Report, p.227.

12. Friesen, H. A. 1968. Wheat varieties, tolerance to currently used herbicides. *In* North Central Weed Control Conference Research Report, 25:84,85.

13. Geddens, R. M., A. P. Appleby, and R. L. Powelson. 1985. Response of six winter wheat cultivars to diclofop-methyl and take-all disease. *In* Western Weed Control Conference Research Report, p.288-290.

14. Hageman, L. H., and R. Behrens. 1981. Response of small grain cultivars to chlorsulfuron. Weed Sci. 29:414-420.

15. Hodgson, J. M., F. P. Thrasher, and R. F. Eslick. 1964. Effect of eight herbicides on yields of barley and wheat varieties. Crop Sci. 4:307-310.

16. Keys, C. H. 1962. Tolerance of cereal varieties to Banvel D. *In* North Central Weed Control Conference Research Report, 19:42.

17. Klingman, D. L. 1953. Effects of varying rates of 2,4-D and 2,4,5-T at different stages of growth on winter wheat. Agron. J. 45:606-610.

18. Lish, J. M., W. J. Schumacher, D. C. Thill, and R. E. Ohms. 1982. The influence of four herbicides on four spring wheat varieties under weed free conditions in Idaho. *In* Proceedings, Western Weed Control Conference, p.127-128.

19. Miller, S. D. and J. D. Nalewaja. 1979. Wheat cultivar response to several herbicides. *In* North Central Weed Control Conference Research Report, 36:96.

20. Nilson, E. B. 1986. Weed Control *In* Wheat Production Handbook. Kansas State Univ. Coop. Ext. Service, #C-529.

21. Oleniczak, D., W. F. Meggitt, and R. Bond. 1977. Applications of dicamba and 2,4-D to several varieties of winter wheat. *In* Proceedings, North Central Weed Control Conference, 32:33,34

22. Phillips, W. M. 1949. Varietal reaction of winter wheat to 2,4-D. *In* North Central Weed Control Conference Research Report, 6:73.

23. Phillips, W. M. 1950. Effect of several formulations of 2,4-D and 2,4,5-T on six varieties of winter wheat. *In* North Central Weed Control Conference Research Report, 7:83.

24. Poku, J. A., H. D. Kerr, and E. J. Peters. 1981. Response of small grain cultivars to postemergence herbicides. *In* Proceedings, North Central Weed Control Conference, 36:105-109.

25. Price, C. D. and G. C. Klingman. 1958. Wheat and oats varietal responses to application of alkanolamine salt of 2,4-D. Agron. J. 50:200-204.

26. Robison, L. R. and C. R. Fenster. 1973. Winter wheat response to herbicides applied postemergence. Agron. J. 65:749-751.

27. Runyan, T. J., W. K. McNeil, and T. F. Peeper. 1982. Differential tolerance of wheat cultivars to metribuzin. Weed Sci. 30:94-97.

28. Schaat, B. G. and D. C. Thill. 1984. The differential susceptibility of spring wheat to triallate herbicide. *In* Proceedings, Western Weed Control Conference, p.172.

29. Shaw, W. C. and C. J. Willard. 1949. Varietal differences in the effect of 2,4-D on wheat. *In* North Central Weed Control Conference Research Report, 6:74.

30. Slife, F. W. and R. F. Fuellman. 1949. Effect of 2,4-D on winter wheat. *In* North Central Weed Control Conference Research Report, 6:74.

31. Stewart, V. R. and T. K. Keener. 1984. The effect of preplant incorporated triallate on seven spring wheat cultivars. *In* Proceedings, Western Weed Control Conference, p.172.

32. Wicks, G. A. and P. T. Nordquist. 1978. Effect of metribuzin + pendimethalin on winter wheat varieties. *In* North Central Weed Control Conference Research Report, 35:90-91.

33. Wicks, G. A., P. T. Nordquist, and J. W. Schmidt. 1987. Response of winter wheat to herbicides. Weed Sci. 35:259-262.

34. Woestemeyer, V. W. 1949. Effect of 2,4-D on six varieties of winter wheat. *In* North Central Weed Control Conference Research Report, 6:75.

APPENDIX TABLE 1. Analysis of variance of response variables for 1988 and 1989 combined.

		Mean Square			
Source	DF	grain yield	% moisture	test wt.	plant height
year	1	66387716**	1377.7980**	606374.38**	102335.48**
block(year)	6	1847595**	0.1060365	2274.8018**	296.9601**
genotype	5	15833726**	9.068675**	11748.863**	7370.9486**
treatment	9	268118.51	0.361976	98.923571	41.657976
year x genotype	5	11147890**	7.336910**	2287.3848**	1090.1044**
year x treatment	9	233591.52	0.251110	150.02562	55.157606
genotype x treat.	45	168104.82	0.279208	93.520127	26.098693
error	399	175583.09	0.493248	164.85967	35.017897

(continued on next page)

* indicates significance at the 5% level of probability, ** indicates significance at the 1% level

APPENDIX TABLE 1. (continued) Analysis of variance of response variables for 1988 and 1989 combined.

		Mean Square		
Source	DF	grain per spike	kernels per spike	kernel weight
year	1	0.02274	0.64409	12.20813
block(year)	6	0.01744	66.66667**	0.01744
genotype	5	0.53996**	616.69974**	604.16490**
treatment	9	0.01933	12.94836	8.36256
year x genotype	5	0.50812**	361.52280**	259.77226**
year x treatment	9	0.02947**	29.39543*	5.12166
genotype x treat.	45	0.01626	15.67418	6.00401
error	399	0.01496	14.70545	7.32216

* indicates significance at the 5% level of probability, ** indicates significance at the 1% level

Note: As seen above, significance of year effect for the first four response variables (grain yield, moisture content, test weight, and plant height) restricts further analysis to effects within each year. However, treatment effects of the three responses with non-significant year effects (grain per spike, kernels per spike, and kernel weight) are more pronounced when analyzed within years also. Therefore, all further analysis will be based on within-year statistical procedures.

APPENDIX TABLE 2. Analysis of variance of response variables for 1988 data only.

		Mean Square			
Source	DF	grain yield	% moisture	test weight	plant height
block	3	1400981.3**	0.089708	4348.2813**	63.4048
genotype	5	22735449.1**	0.699375**	8216.6778**	3394.3588**
treatment	9	215867.1	0.072523	188.5837	27.7299
genotype x treat.	45	150264.3	0.060189	145.7408	18.3321
error	177	185825.7	0.135697	302.9653	38.6555

(continued)

		Mean Square		
Source	DF	grain per spike	kernels per spike	kernel weight
block	3	0.004934	15.3314*	26.19986*
genotype	5	0.354517**	419.5399**	91.71790**
treatment	9	0.012543	11.1585*	4.48575
genotype x treat.	45	0.010960	6.0123	8.22157
error	177	0.009269	5.7229	7.74439

* indicates significance at the 5% level of probability, ** indicates significance at the 1% level

APPENDIX TABLE 3. Analysis of variance of response variables for 1989 data only.

		Mean Square			
Source	DF	grain yield	% moisture	test weight	plant height
block	3	2294208.8**	0.12236	201.3224**	530.515**
genotype	5	4246166.6**	15.70621**	5819.5696**	5066.694**
treatment	9	285842.9	0.54056	60.3654	69.085*
genotype x treat.	45	155568.3	0.42930	46.5163	27.408
error	177	174964.5	0.92273	43.5650	35.289

(continued)

		Mean Square		
Source	DF	grain per spike	kernels per spike	kernel weight
block	3	0.0299502	118.00184**	85.87924**
genotype	5	0.6935719**	558.68258**	772.21926**
treatment	9	0.0362629*	31.18530	8.99847
genotype x treat.	45	0.0257159	28.24782	4.75909
error	177	0.0192852	22.70136	6.98777

* indicates significance at the 5% level of probability, ** indicates significance at the 1% level

APPENDIX TABLE 4. Analysis of variance of spikes per meter, 1989 data.

Source	DF	--- Mean Square --- spikes per meter
block	3	18255.85**
genotype	5	1017.35**
treatment	9	340.41
genotype x treat.	45	153.10
error	177	190.47

* and ** indicate significance at the 5% and 1% levels of probability, respectively.

Note: Treatment effect on spikes per meter was significant at the p=0.07 level. Separation of means is given in article table three and treatment effects are discussed in the main article. No determination of spikes per meter was made in year one of the study.

APPENDIX TABLE 5. Analysis of variance of percent ground cover after winter injury, 1989.

Source	DF	--- Mean Square --- percent ground cover
block	3	1670.381**
genotype	5	2318.105**
treatment	6	215.998**
genotype x treat.	30	31.435
error	195	49.918

* and ** indicate significance at the 5% and 1% levels of probability, respectively.

Note: An extreme temperature fluctuation from 31 January to 3 February, 1989, led to near total necrosis of all above-ground plant parts for the total plot area. Temperatures fell from 22.3°C to -10.3°C in the span of 16 hours. Crop injury was likely exacerbated by drought stress occuring at the time of the weather shift. Preplant incorporated and fall postemergent (but not spring postemergent) herbicides had been applied at the rating of percent ground cover. While treatment effect was significant, genotype interaction was not.

Treatment	% ground cover
bromoxynil	74
chlorsulfuron	73
diclofop	75
metribuzin	71
SMY 1500	75
triallate	72
untreated	77
mean	75
LSD (.05)	3.8
C.V.	9.4%

APPENDIX TABLE 6. Analysis of variance of plants per meter as a response to triallate treatment, 1988 and 1989 combined.

		--- Mean Square ---
Source	DF	plants per meter
year	1	1344.0067**
genotype	5	49.6729**
treatment	1	189.2816**
year x genotype	5	114.6316**
year x treatment	1	16.5004
genotype x treat.	5	8.8521
error	77	7.8934

* and ** indicate significance at the 5% and 1% levels of probability, respectively.

Note: Visual observations shortly after establishment in 1987 showed apparent stand reductions in triallate-treated plots. Analysis of stand counts found a significant reduction in plants per meter from triallate relative to no treatment. No significant stand reduction was found in 1989. The different results the two years can possibly be attributed to better early season growing conditions in the fall of 1988.

APPENDIX TABLE. 7. Analysis of variance of days to total emergence, 1989 data only.

Source	DF	-- Mean Square -- plants/meter
genotype	5	13.266667**
treatment	2	0.791667
genotype x treat.	10	0.358333

* and ** indicate significance at the 5% and 1% levels of probability, respectively.

Note: Visual ratings were taken as percent stand establishment relative to the most advanced plots at eight, ten and twelve days after planting. Genotype was highly significant but treatment and genotype by treatment interaction were not. Treatment effect consisted of the two preplant incorporated herbicides (diclofop and triallate) and no treatment.

HARD WHITE WINTER WHEAT RESPONSE TO HERBICIDES

by

BRIAN E. VINING

B.S., Kansas State University, 1984

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Agronomy Department
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

Field studies were completed at Manhattan, Kansas, in 1987-88 and 1988-89 to determine the response of hard white winter wheat genotypes to treatment with herbicides. Four genetically diverse hard white wheats (KS84HW196, Rio Blanco, KS73256, and White Chief) and two hard red wheats (Arkan and TAM 108) were treated with nine herbicides at the recommended rates and growth stages. Treatments were 2,4-D ester, bromoxynil, chlorsulfuron, dicamba, diclofop, MCPA, metribuzin, SMY 1500, triallate, and no herbicide. Grain yield, moisture content, and test weight were not significant for herbicide treatment or genotype by treatment interaction either year. The only significant effect on yield components year one was a reduction in kernels per spike in chlorsulfuron, dicamba, metribuzin, diclofop, and no treatment plots, which could result from herbicide injury directly or spike density. Spikes per meter was marginally significant for treatment year two as dicamba, metribuzin, bromoxynil, and 2,4-D reduced spike density. Grain per spike was marginally significant for treatment main effect and genotype interaction year two. Chlorsulfuron, bromoxynil, and diclofop reduced grain yield per spike, although this could have been a response to spike density as well. The genotype by treatment interaction effect did not appear to be related to color. The difference in the expression of herbicide treatment on yield components may have been related to weather differences the two years. The plot area received just over one-half of normal precipitation for the wheat growing season year two. This drought stress likely affected the plants ability to compensate for any herbicide injury. Overall, no particular herbicide sensitivity was identified in hard white winter wheat and incongruous growing conditions likely led to differences in the expression of herbicide effect on yield components the two years.