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Control of Downy Brome with Combinations of BAY-SMY-1500 and Metribuzin

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CONTROL OF DOWNY BROME WITH COMBINATIONS OF BAY-SMY-1500 AND METRIBUZIN

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

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INTRODUCTION

Downy brome (*Bromus tectorum* L.) is a severe weed problem in winter wheat (*Triticum aestivum* L.) throughout North America (29, 33, 45, 46). Downy brome competes for space, light, nutrients in the soil, and most importantly moisture. Rydrych (45) reported that a grower with reasonable control of downy brome can increase yield of winter wheat 6-12 bushels per acre. The lack of selective herbicides which control downy brome in winter wheat and conservation tillage practices have contributed to the spread of downy brome (15, 18, 37, 38, 42, 47, 62). Some herbicides labeled for downy brome control in winter wheat require incorporation (5, 61). Incorporation of herbicides may not be compatible with reduced or no-tillage planting systems which have been implemented to prevent soil erosion and winter kill of wheat (3, 8, 33, 39, 42).

Metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazine-5(4H)-one] controls downy brome in winter wheat in the Pacific Northwest and the lower Great Plains regions. However, metribuzin is not used in South Dakota because of crop injury and inconsistent control (66). Metribuzin applied before the wheat develops secondary roots can accentuate winter kill (5, 66). Freezing conditions or snow cover may inhibit the application of metribuzin at the proper growth stage of winter wheat.

BAY-SMY-1500 [4-amino-6-(1,1-dimethylethyl)-3-ethylthio)-1,2,4-triazine-5(4H)-one] is a herbicide which selectively controls downy brome in winter wheat. BAY-SMY-1500 can be applied to a wider range of wheat growth stages without injury which may be associated with metribuzin.

The objectives of these studies were to evaluate combinations of BAY-SMY-1500 and metribuzin for synergistic interactions and for downy brome control in winter wheat. Additionally the tolerance of five cultivars of winter wheat to BAY-SMY-1500, metribuzin, and combinations of these herbicides was examined.

GEOGRAPHICAL DISTRIBUTION AND HISTORY

Downy brome is the most common of all the European weedy bromes (37) and is a severe problem in winter wheat (2, 45, 47, 62, 63). The species was introduced in the mid-1800s into New York and Pennsylvania from the Mediterranean area of Europe (25) and has spread throughout North American (25, 31, 37).

Downy brome seed usually germinates in the fall and overwinters as a basal rosette of leaves. The seed of downy brome will also germinate in late winter or early spring (32, 48). It is a tufted plant which grows from 20 to 60 cm in height. The leaf blades and sheaths are light green and pubescent. The sheaths are closed, the panicle is rather dense, soft, five to eight cm long, and drooping with nodding spikelets (25). The glumes are billous, with the second being longer than the first. The toothed lemmas are lanceolate and covered with long, soft hairs. Awns of the plant are from 10-18 mm long and sharply pointed. Plants may have several tillers approximately 40 cm tall with hundreds of seeds (24). The panicle may or may not be purplish in color. The entire plant will have purple cast after it has been subjected to low temperatures or moisture stress (53).

The sharp pointed awn of downy brome may penetrate tissue in the mouth and throat of grazing livestock, resulting in great discomfort and feed intake reduction (17). The long awn of downy brome also aids seed dissemination by attaching to animals (17). In some cases, the spread and maintenance of downy brome in cropped lands have been attributed to the advent of self-propelled combines and to livestock grazing of stubble fields where straw and chaff have been piled. (27, 33, 43, 46).

<u>GERMINATION</u>

Downy brome plants which become established in the fall are more competitive with winter wheat than are late winter or early spring germinated plants. Spring germination reduces plant growth, but adequate seed for the perpetuation of the species will still be produced. The change from spring to winter wheat production in the Pacific Northwest also contributed to the increase in downy brome (31). South Dakota is presently having a gradual cropping shift with more acres devoted to winter wheat production (60).

There are conflicting reports on seed dormancy. Older literature indicates little or no dormancy and germination approaching 95-100% soon after seed maturity (54). Later studies indicated that some seeds overwinter and may remain viable for up to five years (28, 59, 64). Downy Brome seed viability in the soil drops to less than 2% by the third year in a wheat-fallow culture (13, 45, 47). Hull and Hansen (28) reported that 30% of Bromus tectorum seed may experience delayed germination. Although most seeds shattered from the panicle following maturity, the seeds that remain in the panicles through the winter germinate more slowly but at a high percentage (13, 28, 45, 51, 58).

Downy brome seeds usually fail to germinate if planted immediately after wheat harvest, even though the embryo is fully mature (1, 10, 12, 64). Before the caryopses begin to turn purple some of the seed is viable even if only in the milk stage (16, 27). Mid-May clipping by mowing would neither prevent the production of all seeds nor eliminate further seed production by plants which emerged later.

Plant residue on the soil surface moderates microenvironmental effects of temperature and moisture near the soil surface (8, 15). The effect of temperature and moisture on the seedbed increases the potential for seed germination and seedling growth of downy brome especially in late fall (8, 10, 15).

Depressions in the soil surface catch wind dispersed seeds and increase seed germination and seedling establishment by altering the immediate physical environment in three ways (11):

1. The depressed sites retain moisture at the surface longer and have more favorable atmospheric moisture.
2. Conditions are created for more adequate soil coverage of the seeds which in turn further modifies the microenvironment.
3. Residues on the soil surface which may contain downy brome seed tends to collect in depressed areas and serve as a mulch to maintain warm soil temperatures conducive to downy brome germination in late fall.

Cold soils and warm dry soils limit the rate and percentage of seedling emergence (11). Low levels of soil moisture reduce downy brome emergence more at warm than at cool soil temperatures (8, 11). Downy brome seeds germinate best at 20^{o}C (28, 57). Downy brome has been observed to germinate where temperatures were subzero for 16 hours a day (11). Massee (28) found that -1^{o}C night temperature in combination with 5^{o}C or greater daytime temperature, no wheat but 10% of the downy brome emerged.

Downy brome germination remains high even at 30 °C. While downy brome becomes dormant in cold winters, it continues to grow during mild winters (26). Roots will continue to elongate at soil temperatures as low as 3 °C (22, 23, 26).

Downy brome growing in both field and glasshouses quickly grow through the soil matrix to a depth of 1 m with little lateral spread to 15 cm. Most of the root growth occurs between December and April; a maximum root mass is coincident with flowering (26). The extensive root system of downy brome helps make it competitive. Top growth resumes development in early spring after winter dormancy (53).

ADVANTAGES OF DOWNY BROME

Downy brome does have some desirable qualities. It can be established easily, has a dense root system and grows rapidly (36). A high-quality forage is produced in the early spring before perennial forage grasses begin growth (36). When not grazed downy brome adds a large amount of organic matter to the soil (57). The rapid top growth and dense root growth of downy brome helps control erosion (27).

PREVIOUS METHODS OF DOWNY BROME CONTROL

Many times the seed of downy brome will shatter from the head before wheat harvest. If the seed does go through a combine it is lighter than wheat and will usually be fanned out with chaff to re-infest the field the following year.

Tillage has long been the standard means of controlling downy brome in fields (33). The increased use of stubble mulch fallow for erosion control, increased use of nitrogen fertilizers, and the use herbicides that control broadleaf weeds have intensified the downy brome weed problem (46). Discing or plowing in the late fall after germination and establishment of downy brome kills plants that have become established and reduces competition in the planted crop (33, 49). Moldboard plowing has been more effective than using a one-way disk or a sweep plow in controlling downy brome in winter wheat fallow rotation (2, 20, 34, 42). Plowing buries much of the downy brome seed at depths too great for emergence and places the seed in contact with soil. Wicks and Smika (65), found that plowing most effectively controlled downy brome when compared with five other tillage treatments. However, the moldboard plow does not always completely invert the stubble (34), and some downy brome seed may remain near the soil surface for re-infestation (42).

Massee (33) found that early stubble-mulch tilling, seeding winter wheat late, and performing a final rod weeding immediately before planting resulted in only four downy brome plants per m^2 as compared to 389 downy brome plants per m^2 for late initial sweep tillage and early seeding without the final (one-day prior to wheat planting) rod weeding. Downy brome infestations can be controlled if the downy brome growing in stubble is not allowed to reseed (32).

Numerous studies have examined various herbicides to determine the efficacy in controlling downy brome in winter wheat (3, 5, 14, 20, 32, 37, 39, 40, 44, 46, 48). Many of the results have been erratic, adequate control with little crop injury has been observed, In some tests poor downy brome control was obtained, in other tests severe injury to winter wheat was observed.

Trifluralin 2,6-dinitro-N,N-dippropyl-4-(trifluoromethyl) benzenamine (61) is registered for control of downy brome in winter wheat in Idaho, Montana, Oregon, and Washington (5). Trifluralin must be incorporated within twenty-four hours of application and the wheat seed must be placed below the treated soil zone. The seedbed must be free of straw residue and large clods and the soil must not be subject to erosion. These restrictions eliminate the use of trifluralin with reduced or no-till systems for winter wheat production. Fall application of trifluralin in South Dakota has produced erratic results (66). Winter survival of winter wheat has been reduced by the application of trifluralin (66). Experiments in South Dakota for winter wheat treated with trifluralin at 0.56 kg/ha had 28% crop injury in 1985 and greater than 50% injury in 1986 (66).

In 1976 Massee (32) reported chemical application in the fall when downy brome had less than three true leaves was the best downy brome control treatment. The larger downy brome in the spring made control more difficult (32).

The most difficult cropping sequence for controlling downy brome in winter wheat is with continuous winter wheat (61). Ramig and Smika (39) reported that downy brome infestations in a winter wheat-winter wheat-fallow rotation virtually eliminated wheat grain yield after eight years. An average downy brome infestation of ten downy brome plants per 30 cm^2 will use about 7.5 cm of soil moisture in a season. Some soils can only hold a few centimeters of moisture, this makes moisture competition critical in dry years. A moderate infestation of five downy brome plants/30 cm^2 can cause a yield reduction of 10-15%, ten plants/30 cm^2 can reduce yields 10-30%, and 15-10 plants/30 cm^2 can reduce yields of the wheat up to 50% (33). Fenster (14) reported that at North Platte and Alliance NE, an infestation of winter wheat with downy brome at densities of only one to two plants/30 cm^2, reduced wheat yields 30%. In Idaho, Massee and Higgins (35) found wheat yields were reduced about four percent by each downy brome plant per 30 cm^2.

In South Dakota most pre-plant herbicides for downy brome control in winter wheat have been either ineffective in controlling downy brome or have caused unacceptable crop injury (66). Rydrych (45) stated that downy brome did not severely depress winter wheat yields except when allowed to compete after March. Theoretically this would allow four to five months after planting winter wheat in which to apply chemicals without suffering yield reductions due to downy brome competition. However, snow-cover, freezing temperatures, or wet field conditions may be limiting factors for timings of application. Competition between downy brome and winter wheat is gradual during the winter months and is greatest during jointing or early boot stage of wheat in the spring (18).

METRIBUZIN FOR CONTROL OF DOWNY BROME IN WINTER WHEAT

The use of metribuzin to control downy brome in winter wheat has produced erratic results in the Northern Great Plains. Some of the winter wheat area has soils with pH levels of 7.0 or greater. At higher pH levels less metribuzin in bound by the soil and is available for plant uptake. Higher levels of uptake can reusult in crop injury. Much of the winter wheat area on the average receives 56 cm or less precipitation a year. Rainfall is needed to activate metribuzin (5, 61); metribuzin is quite soluble in water (980 ppm) and needs precipitation to move into the rooting zone.

In Kansas, Oklahoma, and parts of the Pacific Northwest, metribuzin is used for downy brome control in winter wheat (5, 44). Stahlman (51) reported metribuzin at 0.43, 0.56, and 0.70 kg/ha, applied to winter wheat at Hays, Kansas, caused 0, 35, and 43% injury but only 14, 21, and 43% control of the downy brome was achieved. Rydrych (45) reported 99% and 100% control of downy brome in wheat when metribuzin was applied at 0.28 and 0.30 kg/ha, however there was crop injury resulting in yield reduction.

In Kansas, Oklahoma, and Texas metribuzin is currently labeled for use only on dryland winter wheat on the cultivars 'Eagle', 'Tam W101', 'Newton', 'Tam 105' and in Oklahoma and Texas on the cultivar 'Hawk' (5). In Western Montana metribuzin is labeled for use only on the winter wheat cultivars 'Centurk', 'Cheyenne', and 'Winalta' (5). There are several restrictions for the use of metribuzin in areas where it is labeled for downy brome control in winter wheat (5). Metribuzin should not be applied while the crop is under stress such as winter kill, frost damage, disease, drought, or excessive moisture, or when these conditions follow the application. When soils are high in lime or sodium, have a pH greater than 7.7 or are calcareous, metribuzin should not be used (57). At least 1.5 cm of rain is needed within two to three weeks after application to move metribuzin into the weed root zone (5). Lack of adequate moisture will result in poor control of downy brome. A post emergence application can be made in the fall or spring after the wheat plants are tillered and have developed secondary roots if injury to the winter wheat is to be avoided. Many times in colder climates wheat plants do not reach the proper growth stage for fall application of metribuzin to be effective in controlling downy brome but avoid unacceptable injury to the winter wheat. Therefore, metribuzin is not labeled for downy brome control in winter wheat in much of the Northern Great Plains.

The major route of absorption of metribuzin is through the root system (5, 6, 61). Foliar absorption of metribuzin is minimal unless a surfactant is also used (6). The use of a surfactant with metribuzin decreases the selectivity of the compound (6). Metribuzin is translocated through the xylem upward, and accumulated primarily in the leaves where inhibition of photosynthesis occurs. Downward movement is practically non-existent (6, 61). An important factor in selectivity is whether metribuzin is present in the root zone and how readily the material is absorbed by the roots and translocated to the xylem. Secondary roots must be developed and wheat fully tillered before metribuzin is applied (6, 61). Metribuzin should selectively control the shallower-rooted downy brome plant while not adversely affecting the deeper-rooted winter wheat plant. Most tolerant plants can detoxify metribuzin (6). Wheat has a limited ability to detoxify metribuzin applied at low levels (44). Light and temperature are important factors of translocation and detoxification of metribuzin (6, 44, 61). High air temperatures increases transpiration by the plant and the need for moisture to be taken up by the plant roots. If the metribuzin is soluble in water molecules within the root zone and there is a rapid increase in temperatures above 27 ^{o}C, crop injury can result from the application of metribuzin to winter wheat (5).

In acid soils, free hydrogen ions are present and combine with metribuzin forming positively charged particles which are adsorbed by soil colloids. The lower the pH the more metribuzin is adsorbed to the soil. Because of metribuzins high water solubility (980 ppm) and soil mobility, as much as half the metribuzin applied to the soil can still be available in the soil solution for plant absorption at a pH of 4.6 (5, 6). As the soil pH increases, and the number of free hydrogen ions decrease, less metribuzin is adsorbed. Thus, there is more metribuzin in the soil solution available for uptake by the plant. Wheat injury, as a result of the plant uptake of metribuzin, is greatly influenced by environmental and edaphic factors. Heavy rainfall following application will move metribuzin into the soil solution forming a concentrated band. As the level of clay and organic matter content of the soil increase the movement of metribuzin through the soil decreases. Metribuzin may be adsorbed to clay and organic matter thus decreasing it's availability to the plant.

COMPARISON OF BAY-SMY-1500 TO METRIBUZIN

Shaw, et al. (49) found higher concentrations of BAY-SMY-1500 than metribuzin were necessary to cause equivalent injury to the photosystem of wheat plants. The initial dissipation rate of BAY-SMY-1500 is more rapid than the degradation of metribuzin (49). The soil activity of BAY-SMY-1500 would likely be influenced more by the colloid adsorption because the water solubility of the ethylthio analog is 3.5 times less than that of metribuzin (49).

Study II: Tolerance of Winter Wheat Cultivars to BAY-SMY-1500 and Metribuzin Combinations

Cultivars of several crops, tomato (Lycopersicon esculentm Mill.) (52), potato (Solanum tuberosum L.) (19), soybeans (Glycine max L.) (21, 30, 50), and wheat (44, 48) have been shown to differ in their response to metribuzin.

Smith and Wilkerson (50) reported that soybean cultivar variation in metribuzin sensitivity was related to differences in translocation. The amount of root absorption was not different between cultivars. Leaflets of tolerant compared to sensitive cultivars contained less metribuzin 24, 48, and 72 hours after treatment. Smith and Wilkerson (50) suggested a glucose conjugate was formed in the roots of resistant cultivars, which limited availability of free metribuzin for translocation.

Results of these previous studies raised the question as to whether hard red winter wheat cultivars might differ in their reponse to BAY-SMY-1500 alone and in combination with metribuzin. Winter survival of winter wheat cultivars is an important factor in cultivar selection in South Dakota. Some of the qualities of winter wheat that can be attributed to winter hardiness are prostrate fall growth, RNA and protein synthesis reduction as temperatures are decreased, thin leaves, delayed breaking of winter dormancy, tall plants, and later heading and maturity.

Growth qualities of metribuzin tolerant and non-tolerant cultivars of winter wheat have not been established (44, 48). It has been shown by using radioisotopes of metribuzin that winter wheat absorbs about half as much metribuzin per gram of fresh weight as does downy brome (7). Devlin et al. (7) reported that differential absorption of metribuzin plays an important role in the different tolerances of wheat and downy brome. The difference in tolerance of downy brome and winter wheat to soil-applied metribuzin was not due to differential rates of translocation. Differential species tolerance to metribuzin is also related to the rate of detoxification of metribuzin within the leaves.

Retzinger and Richard (41) noted that cold weather enhanced the phytotoxicity of metribuzin to wheat. Both Runyan et al. and Schroeder et al. (44, 48) found the level of cultivar response to metribuzin to be influenced by the amount of precipitation following treatment.

Schroeder et al. (48) found enhanced phytotoxicity of metribuzin in pot cultures. Because the wheat root systems were confined in a pot culture, the metribuzin could not move out of the root zone nor could the wheat roots explore untreated soil. Cultivar response to metribuzin was much different when evaluated in pot cultures than in field studies (48). Difficulty was involved in attempting to extrapolate results of pot culture studies to a field situation when using metribuzin (48).

The objectives of this study were to evaluate the effect of combinations of BAY-SMY-1500 and metribuzin, on five different cultivars of winter wheat, 'Rose', 'Tam 105', 'Roughrider', 'Scout 66', and 'Hawk'. Rose is one of the most winter hardy varieties of winter wheat grown is South Dakota (55). Fluctuations in late wintner temperatures are less likely to injure Rose because it is slow to break dormance (55). It is medium in height, has a medium to late maturity date, and its tolerance to metribuzin was not known. Tam 105 is known to be very tolerant to metribuzin (44), is short to medium in height, has a early to medium maturity date, and is rated as poor for winter hardiness characteristics (56). The tolerance of Roughrider to metribuzin was not known. It is a tall cultivar, has a medium to late maturity date, and is rated as excellent for winter hardiness characteristics (56). Scout 66 is moderately tolerant to metribuzin, medium height, early maturity, and is rated as fair to poor for winter hardiness characteristics. Hawk has a moderate tolerance to metribuzin (44), short height, early maturity, and is rated fair to poor for winter hardiness characteristics (56). Tolerance of these cultivars of hard red winter wheat to BAY-SMY-1500 or BAY-SMY-1500 plus metribuzin combinations has not been previously documented.

MATERIALS AND METHODS FOR INTERACTION STUDIES

Eight field experiments were conducted in South Dakota during the 1985-86 and 1986-87 growing seasons. The design for each experiment was a randomized complete block with four replications. Dosages of 0, 0.55, 0.84, 1.12, and 1.40 kg ai/ha of BAY-SMY-1500 and 0, 0.05, 0.10, 0.15, and 0.20 kg ai/ha of metribuzin were combined factorially into 25 treatments. Plots size was 3 by 9 m or 3 by 12.2 m.

The edaphic characteristics at each site are presented in Table 1. Dates of herbicide application, planting, growth stage, weed density, and leaf number for both downy brome and wheat for the eight experiments are presented in Table 2. Two experiments were initiated in the fall of 1985, at Doland and at Highmore, SD. Three experiments were initiated in the spring of 1986, at Doland, Highmore and Rapid City, SD. Finally, three experiments were initiated in the fall of 1986, at Doland, Highmore, and Martin, SD. The graphical locations of location sites are presented in Figure 1.

Tillage was not used for the three experiments at Doland. Seedbed preparation for Rapid City consisted of one pass with a tandem disk. Seedbed preparation for other experiments consisted of one pass with a chisel and two passes with a tandem disk.

The three experiments conducted at Doland were all planted to Rose winter wheat using a no-tillage hoe-type

Table 1. Soil charactoristics of the various locations for downy brome experiments.

Location	Soil Type	Sand	Silt	Clay	O.M.	pH	CEC
		-----(%)------					(meq/100)
1. Highmore fall 1985	clay loam	29	34	37	2.4	7.2	22.7
2. Doland fall 1985	clay loam	34	34	32	3.8	6.0	26.4
3. Rapid City spring 1986	clay	29	27	44	5.0	6.3	26.5
4. Highmore spring 1986	clay loam	28	37	35	2.2	7.0	22.1
5. Doland spring 1986	clay loam	32	34	30	3.8	6.1	26.2
6. Martin fall 1987	loamy sand	83	8	9	1.3	6.3	5.5
7. Highmore fall 1987	clay loam	29	34	37	2.4	7.2	22.5
8. Doland fall 1987	clay loam	34	34	32	3.8	6.0	26.4

Table 2. Crop year, planting date, compound application date, downy brome density, stage of growth, and whether tillered or not on the day of application, winter wheat growth stage and whether tillered or not on the day of compound application.

Location	Planting date	Application date	Downy brome density (plts/m2)	Downy brome stage (leaf no.)	Downy brome tillered	wheat stage (leaf no.)	wheat tillered
1. Highmore	9-19-85	10-24-85	16-27	1-2	N	2	N
2. Doland	9-27-85	10-31-85	60-100	2-3	N	1-2	N
3. Rapid City	9-16-85	3-27-86	17-28	3-5	Y	3-4	Y
4. Highmore	9-19-85	4-12-86	9-34	3-4	Y	3-4	Y
5. Doland	9-27-85	4-12-86	>100	2-4	Y	2-4	Y
6. Martin	10-4-86	10-27-86	25-30	2-3	N	3-5	N
7. Highmore	9-8-86	10-07-86	20-35	2-4	N	2-4	N
8. Doland	8-29-86	9-27-86	50-73	1-3	N	2	N

[a] Plant data for downy brome and winter wheat taken on the day of application.

[b] All experiments at Doland site were no-till planted in wheat stubble, all other locations received tillage prior to planting.

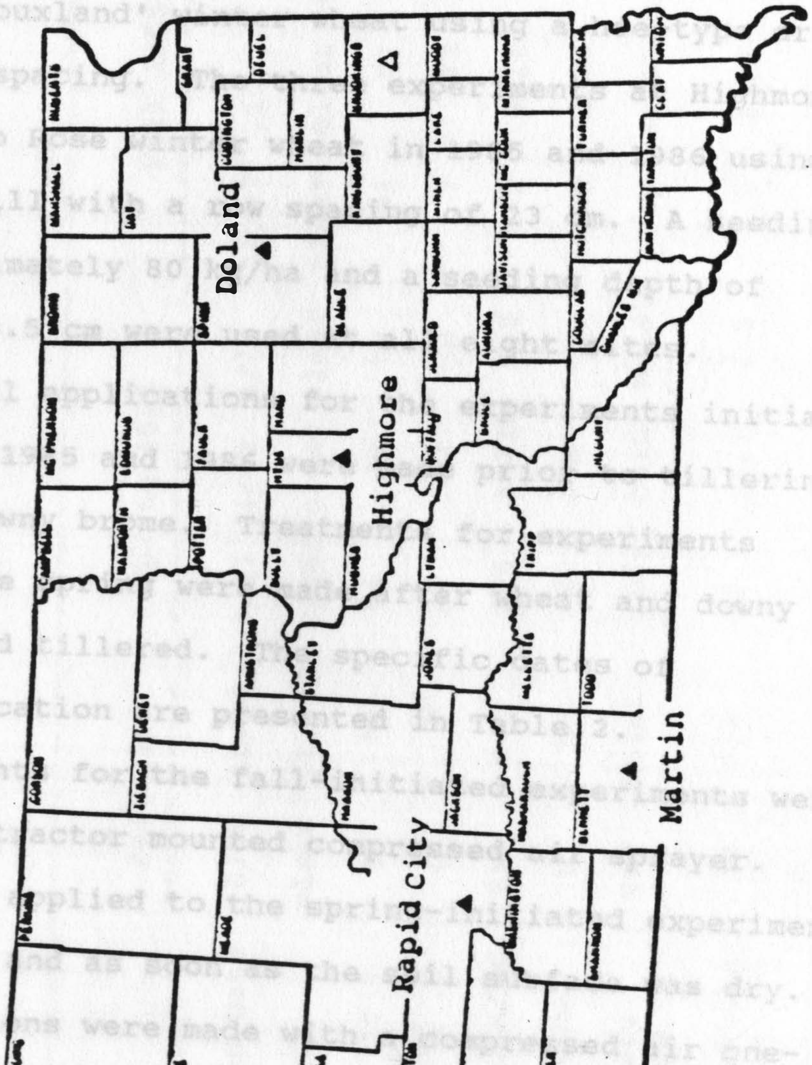

Figure 1.

drill to maintain standing stubble. Row spacing of 23 cm was used. The Rapid City and Martin experiments were planted to 'Siouxland' winter wheat using a hoe-type drill and 33 cm row spacing. The three experiments at Highmore were planted to Rose winter wheat in 1985 and 1986 using a press wheel drill with a row spacing of 23 cm. A seeding rate of approximately 80 kg/ha and a seeding depth of approximately 2.5 cm were used at all eight sites.

Chemical applications for the experiments initiated in the fall of 1985 and 1986 were made prior to tillering of wheat and downy brome. Treatments for experiments initiated in the spring were made after wheat and downy brome plants had tillered. The specific dates of herbicide application are presented in Table 2.

Treatments for the fall-initiated experiments were applied with a tractor mounted compressed air sprayer. Treatments were applied to the spring-initiated experiments after snow melt and as soon as the soil surface was dry. Spring applications were made with a compressed air one-wheel bicycle sprayer. Both fall and spring applications were made with sprayers calibrated to apply 187 L/ha at 276 kPa over a 3 m swath. Climatic conditions at the time of application for each of the various locations are presented in Table 3.

Control of downy brome in winter wheat was evaluated by both visual ratings (0 = no control, 100 =

Table 3. Climatic factors at time of application for the various interaction studies, fall 1985, spring 1986, fall 1986.

	Fall 1985		Spring 1986			Fall 1986		
Application Date	10/24	10/31	3/27	4/12	4/12	10/27	10/7	9/27
Cloud Cover	clear	pt.cld	clear	clear	clear	clear	clear	clear
Rel. Humidity %	40	56	61	70	53	41	52	60
Air Temp., °C	14	9	27	3	2	7	22	21
Wind Speed, k/hr	0-5	0-6	0-5	4-11	0-5	0-5	8-11	6-11
Wind Direction	N	N	S	N	N	W-NW	S-SE	S-SE
Soil Moisture at 5 cm	dry	moist	moist	moist	moist	dry	moist	moist
Soil Temperature at 5 cm, °C	10	6.6	22.2	12.7	4.5	7.2	15.5	16.1

complete control) and counts of downy brome plants. Visual evaluations of downy brome control were taken prior to the boot stage of winter and approximately three weeeks prior to crop harvest (Table 4).

Downy brome culms/m^2 were counted after panicles had matured and changed color, but before wheat had matured and changed color. Six random, meter square counts were taken per plot throughout each experiment. Means of downy brome culms/m^2 were correlated with visual evaluations of percent downy brome control.

Crop injury was evaluated by visual ratings (0 = no injury, 100 = complete kill). Timings of injury evaluations are the first visual evaluation date shown for each location (Table 4).

Grain yield was determined by harvesting each plot with a small plot combine in July of each year. The area harvested was 2.1 by 7.9 m at the Highmore sites and Martin, and 2.1 by 11 m at the Doland sites and Rapid City. Dates of application, visual evaluations, and harvests are presented in Table 4.

Protein content of wheat was determined using a Technicon 300 Infra-analyzer calibrated using federal grain inspection standard equations with bias adjusted using micro-kjeldals. For percent moisture, protein content data is presented on an as is basis.

Table 4. Dates of compound application, planting, visual evaluations, and harvests.

Location	Planting Dates	Application Dates	Visual Evaluations	Harvest Dates
Fall 85 Highmore	9/19/85	10/24/85	5/03/86 5/26/86 7/10/86	7/21/86
Fall 85 Doland	9/27/85	10/31/85	5/02/86 5/26/86 7/08/86	7/23/86
Spring 86 Rapid City	9/16/85	3/27/86	4/26/86 6/05/86	7/17/86
Spring 86 Highmore	9/19/85	4/12/86	5/03/86 5/26/86 7/10/86	7/21/86
Spring 86 Doland 5/26/86	9/27/85	4/12/86	5/02/86 7/08/86	7/23/86
Fall 86 Martin	10/04/86	10/27/86	12/07/86 4/22/87 6/24/87	7/08/87
Fall 86 Highmore	9/08/86	10/07/86	12/06/86 4/21/87 6/25/87	7/13/87
Fall 86 Doland	8/29/86	9/27/86	12/06/86 4/20/87 6/23/87	7/15/87

The data were subjected to a.) analysis of variance to determine the interaction of BAY-SMY-1500 and metribuzin, and b.) to the Waller-Duncan K-ratio t-test with a K-ratio = 100 (P = 0.05), to determine differences between means within experiments for yields, downy brome culms/m^2, visual evaluations of downy brome control, and protein content of winter wheat. Data were not pooled across years because of significant year by treatment interactions.

Tolerance of Wheat Cultivars to Combinations of BAY-SMY-1500 and Metribuzin

MATERIALS and METHODS

Field experiments were used to evaluate cultivar tolerances to combinations of BAY-SMY-1500 and metribuzin. Experiments were conducted during the 1985-86 and 1986-87 cropping seasons at Brookings, SD. Soil type was a Brookings Silt Loam. Tillage prior to planting consisted of using a tandem disc and a field cultivator to prepare a seedbed.

Wheat was seeded at 90 kg/ha with a double disk drill with 23 cm row spacing on September 19, 1985 for wheat harvested in 1986 (hereafter referred to as 1986) and September 5, 1986 for wheat harvested in 1987 (hereafter referred to as 1987).

The experimental design was a randomized split-plot in strips with four replications for both the 1986 and the 1987 experiments. Main plots were weed free and each consisted of one of the five cultivars of winter wheat (Rose, Hawk, Tam 105, Scout 66, Hawk). Using a three by three factorial arrangement herbicide treatments were randomized within the subplots. Chemical treatments were applied to one-to-two leaf wheat on October 31, 1985, and to two-to-three leaf wheat on October 9, 1986. Dosages of metribuzin at 0, 0.035, and 0.07 kg/ha, BAY-SMY-1500 at 0, 0.84 and 1.12 kg/ha, and combinations of BAY-SMY-1500 plus metribuzin at 0.84 plus 0.035, 1.12 plus 0.035, 0.84 plus 0.07 and 1.12 plus 0.07 kg/ha were used. All chemicals were applied with a tractor mounted compressed air sprayer applying 187 l/ha at 276 kPa over the plot width. Climatic condiditons at application times for both years are presented in Appendix Table 38. Precipitation and temperature conditions for the 1986 and 1987 experiments are presented in Appendix Table A-39.

Subplot size was 3 by 5.5 m. Weeds emerging in the 'weed-free' plots were removed by hand or by late spring application of 'Brominal 3+3' which consists of (Bromoxynil) 3,5-dibromo-4-hydroxybenzonitrile plus (MCPA) [(4-chloro-2-methylphenoxy) acetic acid]. The amount applied for both years was 0.05 kg/ha.

Plant height and culms per meter row measurements were taken seven days prior to harvest. Plant height was determined for six random plants per subplot by measuring the distance between the soil surface and the upper tip of the head for the 1987 experiment only. Counts of culms per meter row were randomly taken in six rows 1 m long per subplot for each cultivar.

Grain yield was determined by harvesting each subplot with a small-plot combine on July 16, 1986 and the following year on July 6, 1987.

Protein content of wheat was determined using a

Techicon 300 Infra-analyzer calibrated using federal grain inspection standard equations with the bias adjusted using micro-kjeldals, and protein for percent moisture presented on an as is basis.

Treatment differences for plant height are expressed as percent of the untreated control when the untreated control was 100%. Data was subjected to analyses of variance and the means were statistically compared using the Waller-Duncan K-ratio T-test with a K-ratio of 100 ($P = 0.05$).

RESULTS AND DISCUSSION

Correlations between downy brome culm counts and visual evaluations are presented in Table 5. Visual evaluations were as effective at determining percent weed control as manual counts and required only one fifth the man-hours.

Visual Evaluations and Downy Brome Culm Counts

An analysis of Variance for visual evaluations indicated a significant (0.05 level) interaction occurred between BAY-SMY-1500 and metribuzin for the three experiments performed at Highmore and the experiment done at Martin (Table 6). Results of downy brome control data for these locations are visually represented with the use of response surfaces. Means of visual evaluations for Highmore and Martin experiments are presented in appendix tables A-9 through A-12.

Visual evaluations for the three experiments performed at Doland and the experiment done at Rapid City did not indicate an interaction between BAY-SMY-1500 and metribuzin. For these experiments, levels of BAY-SMY-1500 were averaged over use rates of metribuzin and means statistically compared for each experiment (Table 7).

The multiple regression equation fitted to the data of the fall 1986 initiated, Martin experiment accounted for 80% of the variation in downy brome control (R^2)

Table 5. Correlation between counts of downy brome culms per m^2 taken approximately three weeks prior to harvest, and visual ratings of percent downy brome control where DOBR1 = visual ratings taken before jointing of wheat had began and DOBR2 = visual ratings taken approximately three weeks prior to crop harvest.

Location	Application date	Downy brome density	Correlation DOBR1	Correlation DOBR2
		(plts/m^2)		
1. Highmore	10-24-85	16-27	-0.72	-0.86
2. Doland	10-31-85	60-100	-0.87	-0.71
3. Rapid City	3-27-86	17-28	-0.69	-0.82
4. Highmore	4-12-86	9-34	-0.75	-0.80
5. Doland	4-12-86	>100	-0.85	-0.86
6. Martin	10-27-86	25-30	-0.90	-0.89
7. Highmore	10-07-86	20-35	-0.66	-0.67
8. Doland	9-27-86	50-73	-0.91	-0.94

[a] All experiments at the Doland site were no-till planted into wheat stubble, all other locations recieved tillage prior to planting.

[b] Means of six meter square counts per plot of downy brome culms were used for the correlation analysis.

Table 6. Analysis of variance results for visual ratings of Metribuzin, SMY-1500, and combinations for the various locations for 1986 and 1987.

	Location	Time Applied	VISUAL % CONTROL Metr. x SMY-1500	Metr.	SMY-1500
1.	Highmore	fall 1985	**	**	**
2.	Doland	fall 1985	N.S.	**	**
3.	Rapid City	spring 1986	N.S.	**	**
4.	Highmore	spring 1986	**	**	**
5.	Doland	spring 1986	N.S.	**	**
6.	Martin	fall 1986	**	**	**
7.	Highmore	fall 1986	**	**	**
8.	Doland	fall 1986	N.S.	**	**

a
Visual rating taken prior to boot stage for each experiment at each experimental site.

b
A five by five factorial arrangement was used at each location which included SMY-1500 at the use rates of 0.00, 0.54. 0.84, 1.12, and 1.4 kg ai/ha, and metribuzin at use rates of 0.00, 0.52, 0.105, 0.156, and 0.21 kg ai/ha.

c
Where N.S. = no significant difference
** = significant difference at the 0.01 level
* = significant difference at the 0.05 level

Table 7. Percent control of downy brome averaged over use rates of metribuzin in experiments where there was no significant interaction between metribuzin and SMY-1500 for visual ratings.

		Visual % Control				
		SMY-1500 averaged over use rates of metribuzin kg ai/ha				
		0.00	0.56	0.84	1.12	1.40
2. Doland	fall 1985	27 a	57 b	69 c	73 c	78 c
3. Rapid City	spring 1986	41 a	65 b	70 b	80 c	83 c
5. Doland	spring 1986	27 a	57 b	70 c	72 c	78 c
8. Doland	fall 1986	21 a	50 b	72 c	80 cd	90 d

[a] Values within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan K-ratio T-test.

(Figure 2). As the dosage of BAY-SMY-1500 and metribuzin were increased, the level of downy brome control increased in a synergistic response. This synergism was evident in the upward slope from both herbicide axes. When Colbys method for interactions was used, (Table 8) the synergism was also apparent. The response surface plotted from this equation illustrates that BAY-SMY-1500 at 1.4 kg/ha gave 81% control of downy brome, while the highest rate of metribuzin used (0.21 kg/ha) gave only 41% control. The synergistic interaction of the combination of BAY-SMY-1500 plus metribuzin at 1.4 plus 0.21 kg/ha resulted in 97% control of the downy brome. Means for all 25 treatments are presented in Appendix Table A-14.

Downy brome visual control evaluations for the Martin experiment are further substantiated by the counts of downy brome culms/m^2 for each treatment (Table 9). All chemical treatments resulted in significantly (0.05 level) less downy brome culms/m^2 than the untreated control. Plots which received 1.12 or 1.4 kg/ha BAY-SMY-1500 in combination with metribuzin had significantly (0.05 level) less culms/m than other treatments. Mean culm number/m^2 ranged from 341 in the untreated control to only 1 with the combination of 1.4 plus 0.21 kg/ha BAY-SMY-1500 plus metribuzin. The correlation between culm counts and visual evaluations at Martin were -.90 and -.89 (Table 5).

The multiple regression equation fitted to the fall

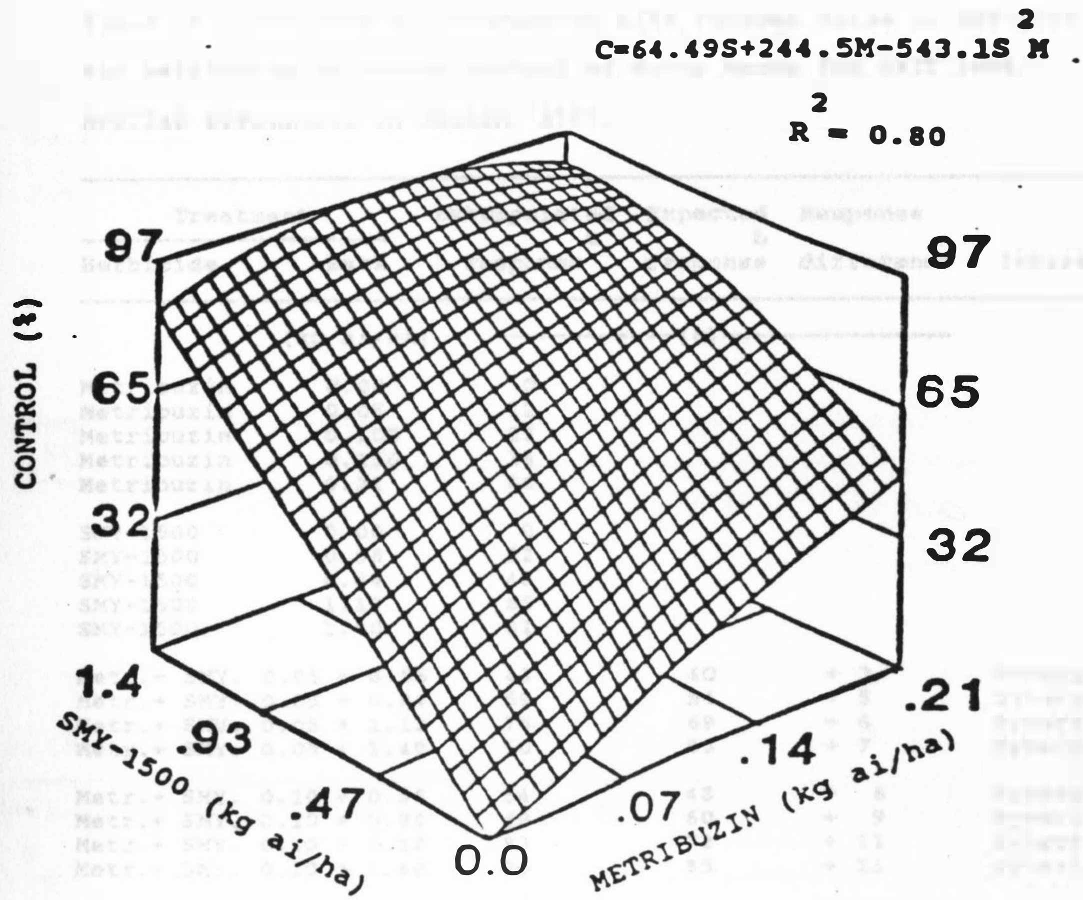

Figure 2. Interaction of various rates of metribuzin and SMY-1500 on visual control of downy brome for fall 1986 applied treatments at Martin, South Dakota. In the equation C = percent control, M = rate of metribuzin, and S = rate of SMY-1500.

Table 8. The type of interaction with various rates of SMY-1500 and metribuzin on visual control of downy brome for fall 1986 applied treatments in Martin, 1987.

Treatment: Herbicide	Treatment: Rate	Extrapolated response[a]	Expected response[b]	Response difference	Interaction
	(kg ai/ha)	------------(%)------------			
Metribuzin	0.00	0			
Metribuzin	0.05	12			
Metribuzin	0.105	23			
Metribuzin	0.156	34			
Metribuzin	0.21	46			
SMY-1500	0.00	0			
SMY-1500	0.56	32			
SMY-1500	0.84	48			
SMY-1500	1.12	65			
SMY-1500	1.40	81			
Metr.+ SMY.	0.05 + 0.56	43	40	+ 3	Synergism
Metr.+ SMY.	0.05 + 0.84	59	54	+ 5	Synergism
Metr.+ SMY.	0.05 + 1.12	75	69	+ 6	Synergism
Metr.+ SMY.	0.05 + 1.40	90	83	+ 7	Synergism
Metr.+ SMY.	0.10 + 0.56	54	48	+ 6	Synergism
Metr.+ SMY.	0.10 + 0.84	69	60	+ 9	Synergism
Metr.+ SMY.	0.10 + 1.12	83	72	+ 11	Synergism
Metr.+ SMY.	0.10 + 1.40	96	85	+ 11	Synergism
Metr.+ SMY.	0.16 + 0.56	64	56	+ 8	Synergism
Metr.+ SMY.	0.16 + 0.84	77	66	+ 10	Synergism
Metr.+ SMY.	0.16 + 1.12	88	77	+ 11	Synergism
Metr.+ SMY.	0.16 + 1.40	98	87	+ 11	Synergism
Metr.+ SMY.	0.21 + 0.56	73	63	+ 10	Synergism
Metr.+ SMY.	0.21 + 0.84	84	72	+ 11	Synergism
Metr.+ SMY.	0.21 + 1.12	91	81	+ 10	Synergism
Metr.+ SMY.	0.21 + 1.40	97	90	+ 9	Synergism

[a] Extrapolated from the response surface equation, $C=64.49S+244.5M-543.1S^2M$, $R^2 = 0.80$.

[b] Expected response of herbicide combinations based on Colby's calculation (4).

Table 9. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Martin, South Dakota.[a, b]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	341 a	247 b	219 b	78 d-h	43 e-j
0.05	205 b	121 cd	88 c-g	74 d-h	37 f-j
0.105	200 b	102 cde	56 e-j	47 e-j	22 hij
0.156	198 b	93 c-f	65 d-i	21 hij	18 hij
0.21	129 c	24 hij	27 g-j	8 ij	1 j

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

1986 initiated Highmore data accounted for 80% of the variation in downy brome control (Figure 3). When BAY-SMY-1500 plus metribuzin dosages were increased, downy brome control increased in a synergistic response. Using Colby's method to analyze the interaction was also determined to be synergistic (Table 10). BAY-SMY-1500 at 1.4 kg/ha resulted in 76% downy brome control. Metribuzin at 0.21 kg/ha resulted in 43% downy brome control. The synergistic interaction of BAY-SMY-1500 plus metribuzin at 1.4 plus 0.21 kg/ha resulted in 91% downy brome control. Visual evaluation means for all treatments of the fall 1986 initiated Highmore experiment are presented in Appendix Table A-15. Downy brome culm counts/m^2 further substantiate the visual evaluations for the fall 1986 Highmore experiment (Table 11). All chemical treatments resulted in significantly less downy brome culms/m^2 than the untreated control. BAY-SMY-1500 at dosages of 1.12, or 1.4 kg/ha in combination with metribuzin resulted in fewer downy brome culms (11 culms/m), than the untreated control (115 culms/m), any dosage of metribuzin used, or 0.56 kg/ha BAY-SMY-1500 alone or in combination with metribuzin at any dosage level used.

The multiple regression equation fitted to spring 1986 Highmore data accounted for 95% of the variation in downy brome control (Figure 4). As dosage levels of BAY-SMY-1500 plus metribuzin combinations increased, downy

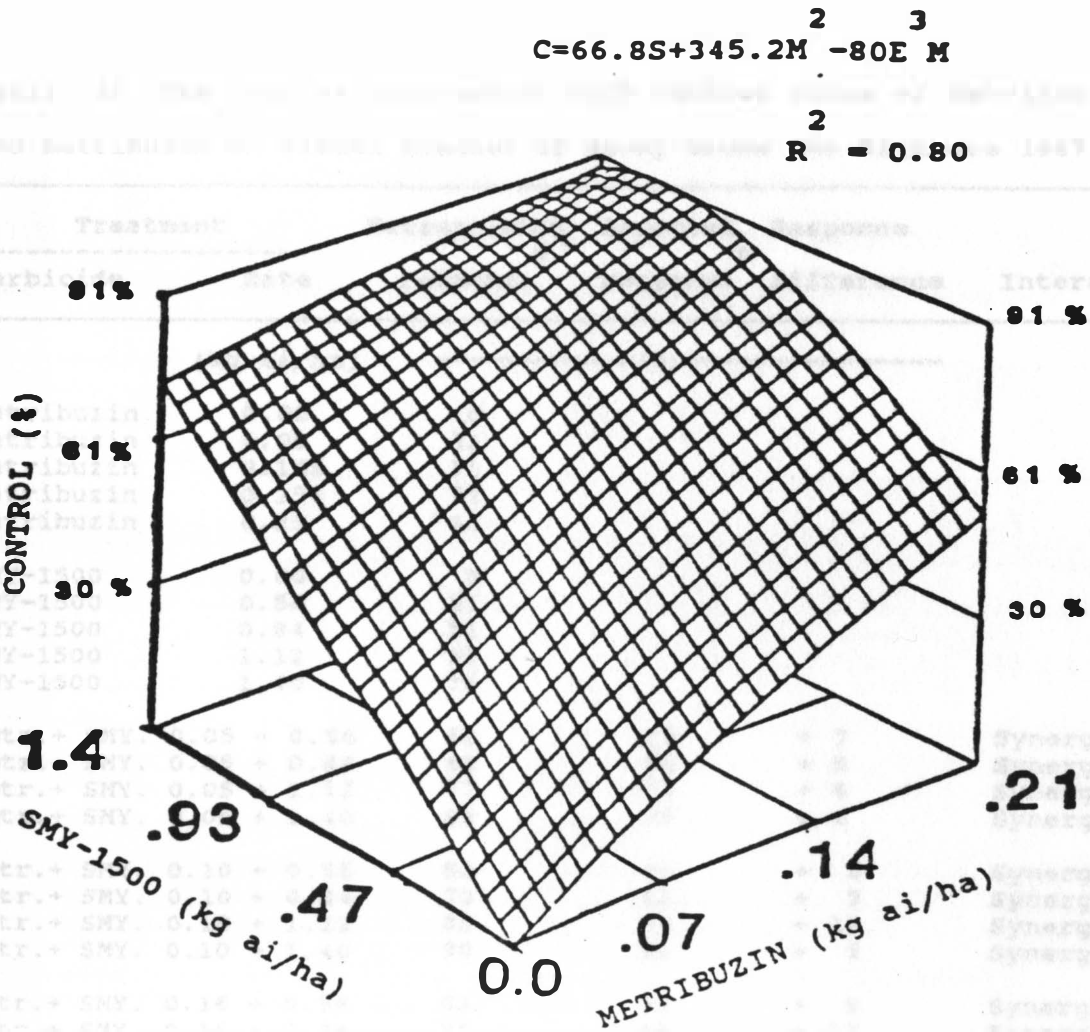

Figure 3. Interaction of various rates of metribuzin and SMY-1500 on visual control of downy brome for fall 1986 applied treatments at Highmore, South Dakota. In the equation C = percent control, M = rate of metribuzin, and S = rate of SMY-1500.

Table 10. The type of interaction with various rates of SMY-1500 and metribuzin on visual control of downy brome for Highmore 1987.

Treatment: Herbicide	Treatment: Rate	Extrapolated response[a]	Expected response[b]	Response difference	Interaction
	(kg ai/ha)	(%)	(%)	(%)	
Metribuzin	0.00	0			
Metribuzin	0.05	11			
Metribuzin	0.105	21			
Metribuzin	0.156	32			
Metribuzin	0.21	43			
SMY-1500	0.00	0			
SMY-1500	0.56	31			
SMY-1500	0.84	51			
SMY-1500	1.12	67			
SMY-1500	1.40	76			
Metr.+ SMY.	0.05 + 0.56	42	39	+ 3	Synergism
Metr.+ SMY.	0.05 + 0.84	61	56	+ 5	Synergism
Metr.+ SMY.	0.05 + 1.12	77	71	+ 6	Synergism
Metr.+ SMY.	0.05 + 1.40	85	79	+ 6	Synergism
Metr.+ SMY.	0.10 + 0.56	52	46	+ 6	Synergism
Metr.+ SMY.	0.10 + 0.84	70	61	+ 9	Synergism
Metr.+ SMY.	0.10 + 1.12	85	74	+ 10	Synergism
Metr.+ SMY.	0.10 + 1.40	90	81	+ 9	Synergism
Metr.+ SMY.	0.16 + 0.56	62	53	+ 9	Synergism
Metr.+ SMY.	0.16 + 0.84	79	66	+ 13	Synergism
Metr.+ SMY.	0.16 + 1.12	91	76	+ 13	Synergism
Metr.+ SMY.	0.16 + 1.40	92	84	+ 8	Synergism
Metr.+ SMY.	0.21 + 0.56	72	61	+ 11	Synergism
Metr.+ SMY.	0.21 + 0.84	87	72	+ 15	Synergism
Metr.+ SMY.	0.21 + 1.12	95	81	+ 14	Synergism
Metr.+ SMY.	0.21 + 1.40	90	87	+ 3	Synergism

[a] Extrapolated from the response surface equation, $C=66.8S+345.2M^{2}-80E^{3}M$ $R^{2}=0.80$.

[b] Expected response of herbicide combinations based on Colby's calculation (4).

Table 11. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for 1986 fall applied treatments at Highmore, South Dakota.[a. b.]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	115 a	65 bc	50 bcd	23 de	30 cde
0.05	106 a	81 ab	42 cde	14 e	22 de
0.105	38 cde	42 cde	27 de	13 e	9 e
0.156	46 b-e	15 e	40 b-e	12 e	15 d-e
0.21	35 cde	30 cde	20 de	13 e	11 e

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

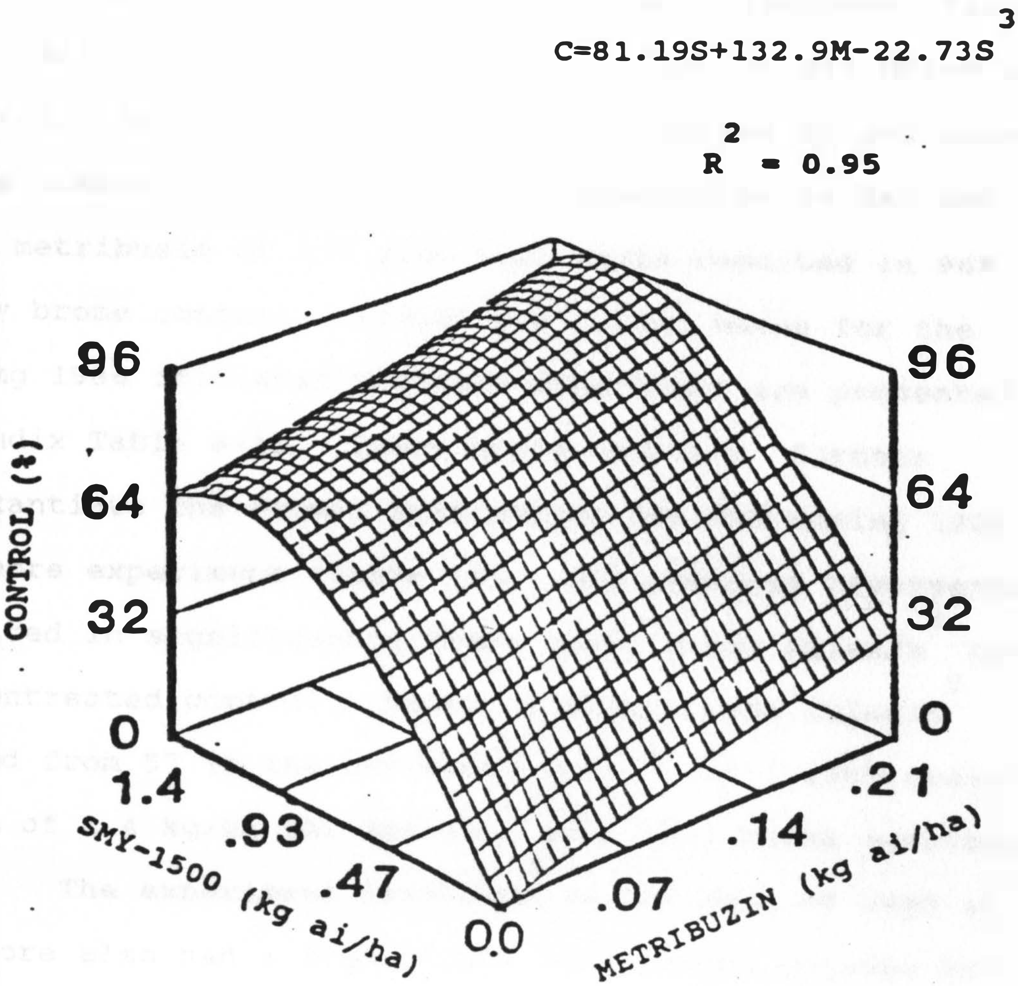

Figure 4. Interaction of various rates of metribuzin and SMY-1500 on visual control of downy brome for spring 1986 applied treatments at Highmore, South Dakota. In the equation C = percent control, M = rate of metribuzin, and S = rate of SMY-1500.

brome control increased in a synergistic response (Table 12). BAY-SMY-1500 at 1.4 kg/ha resulted in 64% downy brome control. Metribuzin at 0.21 kg/ha resulted in 28% downy brome control. The synergistic interaction of BAY-SMY-1500 plus metribuzin at 1.4 plus 0.21 kg/ha resulted in 96% downy brome control. Visual evaluation means for the spring 1986 initiated Highmore experiment are presented in Appendix Table A-12. Downy brome counts/m^2 further substantiate the visual evaluations for the spring 1986 Highmore experiment (Table 13). All chemical treatments resulted in significantly fewer downy brome culms/m^2 than the untreated control. Means of downy brome culms/m^2 ranged from 57 in the untreated control to 1 with treatments of 1.4 kg/ha BAY-SMY-1500 plus 0.21 kg/ha metribuzin.

The experiment initiated in the fall of 1985 at Highmore also had a significant interaction between BAY-SMY-1500 and metribuzin. The multiple regression equation fitted to the data of the fall 1985 Highmore experiment accounted for 91% of the variation in downy brome control. BAY-SMY-1500 at 1.4 kg/ha resulted in 81% downy brome control. Metribuzin applied 0.21 kg/ha resulted in 33% downy brome control. Using Colby's method to analyze the interaction it was determined to be a synergistic interaction (Table 14). The combination of 1.4 kg/ha BAY-SMY-1500 and 0.21 kg/ha metribuzin resulted in 95% control of the downy brome. Means of visual evaluations for each

Table 12. The type of interaction with various rates of SMY-1500 and metribuzin on visual control of downy brome for spring applied treatments at Highmore, South Dakota.

Treatment: Herbicide	Rate	Extrapolated response[a]	Expected response[b]	Response difference	Interaction
	(kg ai/ha)	(%)			
metribuzin	0.00	0			
metribuzin	0.05	6			
metribuzin	0.105	12			
metribuzin	0.156	19			
metribuzin	0.21	25			
SMY-1500	0.00	0			
SMY-1500	0.56	42			
SMY-1500	0.84	45			
SMY-1500	1.12	49			
SMY-1500	1.40	53			
metr.+ SMY.	0.05 + 0.56	44	42	+ 2	Synergism
metr.+ SMY.	0.05 + 0.84	58	54	+ 4	Synergism
metr.+ SMY.	0.05 + 1.12	64	61	+ 3	Synergism
metr.+ SMY.	0.05 + 1.40	64	60	+ 4	Synergism
metr.+ SMY.	0.10 + 0.56	50	46	+ 4	Synergism
metr.+ SMY.	0.10 + 0.84	63	57	+ 6	Synergism
metr.+ SMY.	0.10 + 1.12	71	64	+ 7	Synergism
metr.+ SMY.	0.10 + 1.40	70	63	+ 7	Synergism
metr.+ SMY.	0.15 + 0.56	56	49	+ 7	Synergism
metr.+ SMY.	0.15 + 0.84	70	60	+ 9	Synergism
metr.+ SMY.	0.15 + 1.12	77	66	+ 10	Synergism
metr.+ SMY.	0.15 + 1.40	76	65	+ 11	Synergism
metr.+ SMY.	0.21 + 0.56	63	53	+ 10	Synergism
metr.+ SMY.	0.21 + 0.84	76	63	+ 13	Synergism
metr.+ SMY.	0.21 + 1.12	83	69	+ 14	Synergism
metr.+ SMY.	0.21 + 1.40	82	68	+ 14	Synergism

[a] Extrapolated from the response surface equation,

$C=81.19S+132.9M-22.73S^3$

[b] Expected response of herbicide combinations based on Colby's calculation (4).

Table 13. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Highmore, South Dakota.[a, b]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	57 a	24 b-e	31 bcd	10 efg	12 efg
0.05	42 ab	17 c-g	7 efg	7 efg	2 g
0.105	34 bcd	24 b-e	9 efg	2 g	2 g
0.156	18 c-g	13 efg	7 efg	4 fg	6 efg
0.21	23 b-f	9 efg	8 efg	3 g	1 g

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

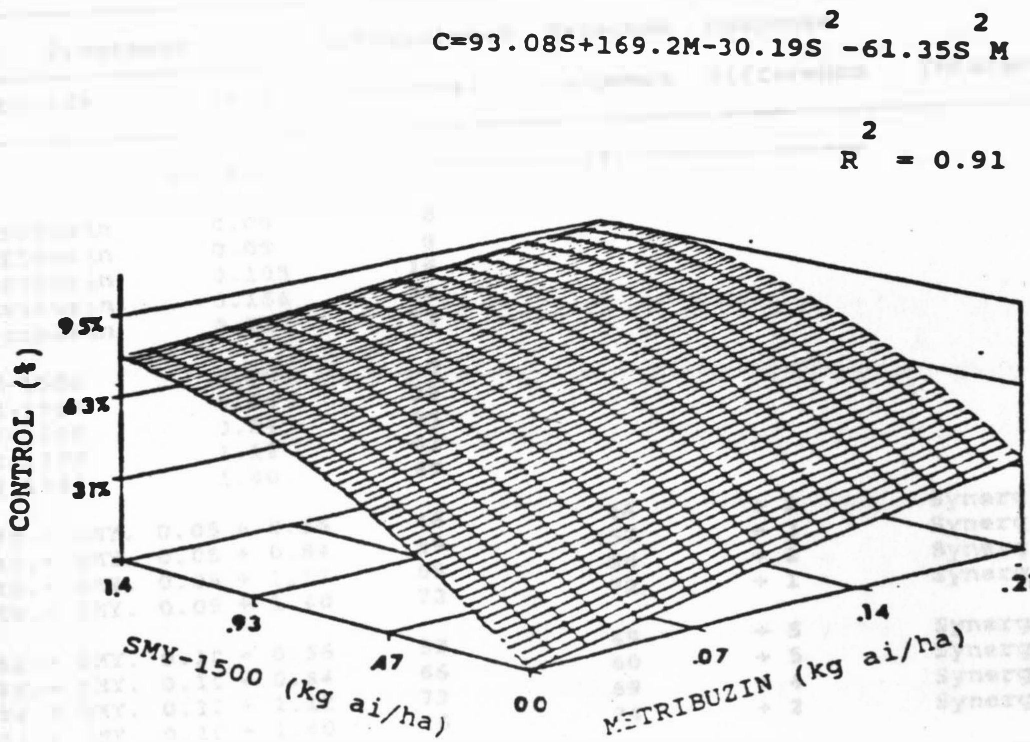

Figure 5. Interaction of various rates of metribuzin and SMY-1500 on visual control of downy brome for fall 1985 applied treatments at Highmore, South Dakota. In the equation C = percent control, M = rate of metribuzin, and S = rate of SMY-1500.

Table 14. The type of interaction with various rates of SMY-1500 and metribuzin on visual control of downy brome for fall 1985 applied treatments at Highmore, South Dakota.

Treatment: Herbicide	Treatment: Rate	Extrapolated response	Expected response	Response difference	Interaction
	(kg ai/ha)	------------(%)---------------			
metribuzin	0.00	0			
metribuzin	0.05	8			
metribuzin	0.105	16			
metribuzin	0.156	24			
metribuzin	0.21	32			
SMY-1500	0.00	0			
SMY-1500	0.56	39			
SMY-1500	0.84	53			
SMY-1500	1.12	63			
SMY-1500	1.40	69			
metr.+ SMY.	0.05 + 0.56	46	44	+ 2	Synergism
metr.+ SMY.	0.05 + 0.84	59	57	+ 3	Synergism
metr.+ SMY.	0.05 + 1.12	68	66	+ 2	Synergism
metr.+ SMY.	0.05 + 1.40	73	72	+ 1	Synergism
metr.+ SMY.	0.10 + 0.56	53	49	+ 5	Synergism
metr.+ SMY.	0.10 + 0.84	66	60	+ 5	Synergism
metr.+ SMY.	0.10 + 1.12	73	69	+ 4	Synergism
metr.+ SMY.	0.10 + 1.40	76	74	+ 2	Synergism
metr.+ SMY.	0.16 + 0.56	61	54	+ 7	Synergism
metr.+ SMY.	0.16 + 0.84	72	64	+ 8	Synergism
metr.+ SMY.	0.16 + 1.12	78	72	+ 6	Synergism
metr.+ SMY.	0.16 + 1.40	80	77	+ 3	Synergism
metr.+ SMY.	0.21 + 0.56	61	54	+ 7	Synergism
metr.+ SMY.	0.21 + 0.84	72	64	+ 8	Synergism
metr.+ SMY.	0.21 + 1.12	78	72	+ 6	Synergism
metr.+ SMY.	0.21 + 1.40	80	77	+ 3	Synergism

[a] Extrapolated from the response surface equation,

C=93.08S+169.2M-30.19S -61.35S M, R = 0.91.

[b] Expected response of herbicide combinations based on Colby's calculation (4).

treatment are presented in Appendix Table A-9. Counts of downy brome culms/m^2 further substantiate the visual evaluations and are presented in Table 15. All chemical treatments resulted in significantly fewer downy brome culms/m^2 than the untreated control. Means of culm counts/m^2 ranged from 71 in the untreated control to 5 culms/m^2 when 1.4 plus 0.21 kg/ha BAY-SMY-1500 plus metribuzin were applied.

Generally, as the dosage of BAY-SMY-1500 increased, downy brome control increased and culm number/m^2 decreased. Metribuzin did not satisfactorily control (20-78%) downy brome in the winter wheat for any of the eight locations.

BAY-SMY-1500 at 0.84 kg/ha resulted in 77% or less control of downy brome for the eight locations. BAY-SMY-1500 at 1.12 kg/ha resulted in 58, 63, 64, 71, 80, 87, 87, and 88% control of downy brome with no significant crop injury for the eight locations. These levels of control may be inadequate for heavy infestations of downy brome which may produce over 450 kg/ha of seed. Survival of only 10% of this seed could result in over 400 plants/m^2. BAY-SMY-1500 and metribuzin applied in combination controlled downy brome in excess of 90% at all eight locations.

An analysis of variance for downy brome culm counts/m^2 as affected by combinations of BAY-SMY-1500 and metribuzin is presented in Table 16. A significant interaction occured between BAY-SMY-1500 and metribuzin in

Table 15. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for fall 1985 applied treatments at Highmore, South Dakota.[a. b.]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	71 a	27 cde	20 d-g	17 e-h	14 e-h
0.05	43 b	31 bcd	24 ed	9 fgh	8 fgh
0.105	31 bcd	21 def	8 fgh	6 gh	6 gh
0.156	36 bc	21 def	9 fgh	6 gh	4 h
0.21	39 bc	14 e-h	13 e-h	5 h	5 h

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table 16. Analysis of variance results for stand counts of downy brome for Metribuzin, SMY-1500 and combinations for the various locations for 1986 and 1987.

	Location	Time Applied	Downy Brome Stand Counts		
			Metr. x SMY-1500	Metr.	SMY-1500
1.	Highmore	fall 1985	N.S.	**	**
2.	Doland	fall 1985	N.S.	*	**
3.	Rapid City	spring 1986	*	N.S.	N.S.
4.	Highmore	spring 1986	N.S.	N.S	**
5.	Doland	spring 1986	N.S.	**	N.S.
6.	Martin	fall 1986	**	**	**
7.	Highmore	fall 1986	**	**	**
8.	Doland	fall 1986	N.S.	**	**

a
Stand counts of downy brome culms/m2 were taken approximately three prior to harvest for each experiment at each experimental site.

b
A five by five factorial arrangement was used at each location which included SMY-1500 at the use rates of 0.00, 0.54. 0.84, 1.12, and 1.4 kg ai/ha, and metribuzin at use rates of 0.00, 0.52, 0.105, 0.156, and 0.21 kg ai/ha.

c
Where N.S. = no significant difference
** = significant difference at the 0.01 level
* = significant difference at the 0.05 level

experiments initiated in the spring 1986 at Rapid City, fall 1986 at Martin, and fall 1986 Highmore. Means of downy brome culms/m^2 for each of these experiments are presented in Table 8, 10, and Appendix Table A-11. Experiments initiated in the fall 1985 and spring 1986 at Highmore, fall 1985, spring 1986, and fall 1986 at Doland did not have a significant (0.05 level) interaction between BAY-SMY-1500 and metribuzin for downy brome culm counts. Levels of BAY-SMY-1500 were averaged over rates of metribuzin for experiments where there there were no interaction for downy brome culm counts. Treatment comparisons of culm counts for these experiments are presented in Table 17. All plots which received BAY-SMY-1500 had significantly higher levels of downy brome control than either the untreated control or plots which received treatments of metribuzin alone.

Wheat Yields as Affected by Combinations of BAY-SMY-1500 and Metribuzin

A significant interaction between BAY-SMY-1500 and metribuzin for yield of winter wheat occurred at the Martin location but did not occur for the other seven locations. Means of wheat yield data for Martin are presented in Table 18. All treated plots at Martin had significantly higher yields than the untreated controls. Best yields were obtained in plots treated with higher dosage combinations of BAY-SMY-1500 plus metribuzin.

Table 17. Downy brome culm means averaged over use rates of metribuzin in experiments where there was no significant interaction between metribuzin and SMY-1500 for counts per square meter of downy brome culms.

		Downy Brome Culms/m2				
		SMY-1500 averaged over use rates of metribuzin kg ai/ha				
		0.00	0.56	0.84	1.12	1.40
1. Highmore	fall 1985	68 a	47 b	37 c	21 d	15 d
2. Doland	fall 1985	45 a	23 b	15 bc	9 c	7 c
4. Highmore	spring 1986	34 a	16 b	10 bc	7 bc	4 c
5. Doland	spring 1986	219 a	136 b	95 bc	93 bc	71 c
8. Doland	fall 1986	363 a	225 b	144 c	90 d	25 d

[a] Values within a row followed by the same letter are not significantly different at the 5% level.

Table 18. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Martin, South Dakota[a].

Metribuzin kg ai/ha	SMY-1500 kg ai/ha				
	0.00	0.56	0.84	1.12	1.4
	(Mg/ha)				
0.00	1.18 i	1.70 e-g	1.30 hi	1.77 e-g	2.12 b-f
0.05	1.48 fg	1.71 e-g	2.30 abc	2.09 b-f	2.12 b-f
0.105	1.32 hi	1.89 d-g	1.82 a-f	2.35 abc	2.71 abc
0.156	1.39 hig	1.94 d-g	2.19 a-f	2.67 abc	2.63 ab
0.21	1.71 e-g	2.78 a	2.57 abc	2.36 abc	2.71 a

[a] Means within columns and rows followed by the same letter are not significantly different at the 5 % level using Waller Duncan test.

Levels of BAY-SMY-1500 were averaged over rates of metribuzin when no interaction occurred between BAY-SMY-1500 and metribuzin for grain yield. Treatment comparisons for these experiments are presented in Table 19. Yields increased significantly (0.05 level) with increasing dosages of herbicide combinations for seven of the eight experiments.

Only the spring applied treatments at Doland did not result in higher yields with increasing dosage combinations of BAY-SMY-1500 and metribuzin. This lack of yield response at Doland was probably due to crop injury. The crop injury possibly could be a result of a hard freeze (-5 ^{o}C) two days after applications were made, from stress caused by the chemical combinations, or both of these factors. Significant crop injury was not observed at any of the other seven locations.

Protein Content of Wheat as Affected by Combinations of BAY-SMY-1500 and Metribuzin

An analysis of variance for protein content of wheat is presented in Table 20. Experiments initiated in the fall 1985 at Highmore, fall 1986 at Martin, and fall 1986 at Highmore, had a significant interaction between BAY-SMY-1500 and metribuzin. Where there was no significant interaction (experiments initiated in the fall 1985 at Doland, spring 1986 at Rapid City, Highmore, Doland, and fall 1986 at Doland), levels of BAY-SMY-1500

Table 19. Yield of winter wheat (Mg/ha) for experiments which did not have a significant interaction between SMY-1500 and metribuzin when tested for yield. Use rates of SMY-1500 were averaged over use rates of metribuzin.[a, b]

Experiment	Planting date	Application date	Downy brome density (plts/m2)	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.40
				Mg/ha				
1. Highmore	9-19-85	10-24-85	16-27	2.11 a	2.30 a	2.22 a	2.18 a	2.24 a
2. Doland	9-27-85	10-31-85	60-100	0.61 c	1.02 b	1.06 b	1.07 b	1.39 a
3. Rapid City	9-16-85	3-27-86	17-28	2.10 b	2.27 ab	2.29 a	2.31 a	2.36 a
4. Highmore	9-19-85	4-12-86	9-34	2.61 a	2.48 ab	2.44 ab	2.39 ab	2.29 b
5. Doland	9-27-85	4-12-86	>100	0.76 a	0.73 a	0.60 a	0.51 a	0.47 a
7. Highmore	9-08-86	10-07-86	20-35	1.25 c	1.28 bc	1.31 abc	1.46 ab	1.49 a
8. Doland	8-29-86	9-27-86	50-73	0.98 c	1.28 b	1.53 ab	1.55 a	1.72 a

[a] Values followed by the same letters within rows are not significantly different using the Waller-Duncan test.

[b] For each dependant variable (wheat yield), independant variables (SMY-1500 use rates) having a significant F value at the 0.05 level and no interaction were averaged over levels of other independant variables (metribuzin use rates).

Table 20. Analysis of variance results for wheat protein analysis of metribuzin, SMY-1500 and combinations for the various locations for 1986 and 1987.

	Location	Time Applied	Protein Analysis for Winter Wheat		
			Metr. x SMY-1500	Metr.	SMY-1500
1.	Highmore	fall 1985	**	**	**
2.	Doland	fall 1985	N.S	N.S.	N.S.
3.	Rapid City	spring 1986	N.S.	N.S.	N.S.
4.	Highmore	spring 1986	N.S.	N.S	N.S.
5.	Doland	spring 1986	N.S.	N.S.	N.S.
6.	Martin	fall 1986	*	N.S.	N.S.
7.	Highmore	fall 1986	**	**	**
8.	Doland	fall 1986	N.S.	**	N.S.

a
A five by five factorial arrangement was used at each location which included SMY-1500 at the use rates of 0.00, 0.54. 0.84, 1.12, and 1.4 kg ai/ha, and metribuzin at use rates of 0.00, 0.52, 0.105, 0.156, and 0.21 kg ai/ha.

b
Where N.S. = no significant difference
** = significant difference at the 0.01 level
* = significant difference at the 0.05 level

were averaged over rates of metribuzin and results are presented in Table 21.

The chemical treatments had little effect on percent protein content of the winter wheat. Protein content of wheat increased for only one experiment as the level of downy brome control increased. The increase in wheat protein content was probably due to more available nitrogen to the wheat when downy brome was controlled. Means of wheat protein content for the eight experiments are presented in Appendix Tables A-28 through A-36.

Conclusions for Downy Brome Control Studies

These data analyses indicate that acceptable downy brome control in winter wheat can consistently be obtained with combinations of BAY-SMY-1500 at 1.12 or 1.4 kg/ha plus metribuzin at 0.15 or 0.21 kg/ha.

Table 21. Means of percent protein content of wheat for experiments wh did not have a significant interaction between SMY-1500 and metribuzin when subjected to an analysis of variance of protein content.

Experiment	Application	Downy Brome	SMY-1500 kg ai/ha			
	date	density	0.00	0.56	0.84	1.12
		(plts/m2)				
2. Doland	10-31-85	60-100	12.4 a	12.4 a	12.3 a	12.5 a
3. Rapid City	3-27-86	17-28	12.9 a	12.8 ab	12.7 ab	12.8 ab
4. Highmore	4-12-86	9-34	11.2 b	11.3 ab	11.3 ab	11.4 ab
5. Doland	4-12-86	>100	12.9 ab	12.7 b	12.9 ab	12.9 ab
8. Doland	9-27-86	50-73	12.7 a	12.8 ab	13.1 bc	13.1 bc

[a] Means followed by the same letters within experiment are not significantly different at the 5% level using the Waller-Duncan F-ratio T-test.

Tolerance of Wheat Cultivars to Combinations of BAY-SMY-1500 and Metribuzin

RESULTS and DISCUSSIONS

There was not a significant year by grain yield interaction for the wheat cultivars so grain yield data were combined for 1986 and 1987. There was a significant year by wheat protein content and year by wheat culm per meter row interaction so data for 1986 and 1987 were not combined for these observations.

Grain yields are presented in Table 22. An analysis of variance for yields indicated no cultivar yield by herbicide interactions for Rose, Tam 105, Roughrider, or Scout 66. Hawk did have a cultivar yield by herbicide interaction, however, no treatments resulted in significantly lower yields than the untreated control. Yield means of other cultivars treated with combinations of BAY-SMY-1500 plus metribuzin were not significantly different from those of untreated, treated with metribuzin (0.035 or 0.07 kg/ha) or BAY-SMY-1500 (0.84 or 1.12 kg/ha) treatments.

Plant height means for each of the various treatments for the 1987 experiment are presented in Table 23. A plant height by herbicide interaction occurred only with the cultivar Scout 66. Plant height for Scout 66 was reduced by 0.07 kg/ha metribuzin, and combinations of BAY-

Table 22. Grain yields averaged over years, as affected by various rates and rate combinations of metribuzin and SMY-1500.[a]

	Untreated	SMY 1500		Metribuzin		SMY-1500 + Metribuzin			
	Control	0.84	1.12	0.035	0.07	0.84 +0.035	0.84 +0.07	1.12 +0.035	1.12 +0.07
	(kg/ha)								
Rose	4050	4040	3880	3870	3790	3860	4020	3730	3930
Tam 105	2740	2780	2690	2610	2720	2730	2630	2750	2800
Roughrider	2930	2840	2750	2630	2440	2570	2680	2670	2710
Scout 66	3900	3970	3870	4040	3850	3920	3820	4020	3770
Hawk	3450	3670	3620	3570	3590	3360	3590	3650	3930*

a An asterisk indicates that the sprayed plots are significantly different from the untreated plots of the same cultivar a the 5% level.

Table 23. Plant height for each treatment in 1987.[a]

	untreated	SMY 1500		Metribuzin		SMY 1500 + Metribuzin			
	control	0.84	1.12	0.035	0.07	0.84 +0.035	0.84 +0.07	1.12 +0.35	1.12 +0.07
	Plant Height (m)	(% of nontreated)[b]							
Rose	0.91	98	97	96	99	97	95	96	96
Tam 105	0.77	99	95	97	95	96	95	96	96
Roughrider	0.95	102	100	98	103	99	99	102	101
Scout 66	0.99	94	96	97	90*	92*	94	95	90*
Hawk	0.77	105	103	103	100	100	96	99	98

[a] An asterisk indicates that the sprayed plots are significantly less than the un-treated plots of the same cultivar at the 5 % level.

[b] Analysis was performed on data before being converted to percentages of untreated control.

SMY-1500 plus metribuzin at 0.85 plus 0.35 and 1.12 plus 0.07 kg/ha. However yields of the cultivar Scout 66 were affected only at the highest dosage combination applied of BAY-SMY-1500 and metribuzin (1.12 plus 0.07 kg ai/ha).

Culm number per meter row for each of the chemical treatments is presented in Table 24. There was not a significant interaction between BAY-SMY-1500 and metribuzin for wheat culm counts, so count numbers for levels of BAY-SMY-1500 were averaged over counts for levels of metribuzin. The cultivar Rose had a significant increase in culms per meter row with the dosage of 1.12 kg/ha BAY-SMY-1500 when compared to other treatments. The increase in culm number for Rose may be the result of additional tiller production after chemical application. The chemical may have had a stimulatory affect on axillary bud development, thus increasing tiller number and culm number per meter row. The culm number of the cultivars Tam 105, Roughrider, Scout 66, and Hawk were unaffected by applications of BAY-SMY-1500 plus metribuzin combinations.

Protein content for each cultivar and chemical treatments are presented in Table 25. The protein content of the cultivars Scout 66, Roughrider, and Hawk were not significantly affected by any of the chemical treatments in 1986 or 1987. The protein content of the cultivar Tam 105 in 1987, (when averaged over use rates of metribuzin

Table 24. Wheat culms per meter row for 1986 and 1987 averaged over rates of metribuzin (0, 0.03, 0.07 kg ai/ha).[a]

		BAY-SMY-1500 kg ai/ha		
		0.00	0.84	1.12
Rose	1986	67 b	71 ab	72 a
	1987	64 b	67 a	67 a
Tam 105	1986	60 a	58 a	56 a
	1987	61 a	62 a	60 a
Roughrider	1986	65 a	64 a	60 a
	1987	62 a	63 a	64 a
Scout 66	1986	56 a	55 a	60 a
	1987	66 a	64 a	65 a
Hawk	1986	61 a	61 a	59 a
	1987	60 a	61 a	58 a

[a] Values within a row followed by the same letter are not significantly different using the Waller-Duncan test.

Table 25. Wheat protein percent for 1986 and 1987 averaged over rates of metribuzin (0, 0.03, 0.07 kg ai/ha).

		BAY-SMY-1500 kg ai/ha		
		0.00	0.84	1.12
Rose	1986	13.1 a	13.0 b	13.0 b
	1987	14.0 a	14.3 a	14.2 a
Tar 105	1986	12.0 a	11.9 a	12.0 a
	1987	13.1 b	13.2 b	13.5 a
Roughrider	1986	12.1 a	12.3 a	12.2 a
	1987	14.8 a	14.7 a	14.9 a
Scout 66	1986	12.0 a	11.9 a	12.0 a
	1987	14.6 a	14.7 a	14.5 a
Hawk	1986	11.4 a	11.3 a	11.3 a
	1987	14.4 a	14.4 a	14.5 a

[a] Values within a row followed by the same letters are not significantly different at the 5% level using the Waller-Duncan test.

0, 0.035, and 0.07), was significantly increased with 1.12 kg/ha BAY-SMY-1500.

The cultivars evaluated (Rose, Tam 105, Roughrider, Scout 66, and Hawk) were all quite tolerant to BAY-SMY-1500 when applied alone at use rates of up to 1.12 kg/ha. When 0.035 or 0.07 kg/ha of metribuzin was applied in combination with BAY-SMY-1500, there was no substantial adverse affects for wheat yield, wheat culms per meter row, wheat plant height, or protein content of wheat produced. A clear relationship between plant characteristics (winter hardiness, plant height, culm number per meter row, or maturity date) and wheat tolerance to combinations of BAY-SMY-1500 plus metribuzin was not found.

SUMMARY AND RECOMMENDATIONS

All cultivars evaluated (Rose, Hawk, Tam 105, Scout 66, and Roughrider) exhibited acceptable tolerance to combinations of BAY-SMY-1500 and metribuzin at the highest level tested (1.12 plus 0.07 kg/ha). Only two years of tolerance data is available for these cultivars. Additional studies should be performed to evaluate these and other cultivars at various locations and under various environmental conditions.

A synergistic interaction between BAY-SMY-1500 and metribuzin occurred at four of eight locations resulting in greater control of downy brome than expected from the combined effect of the two chemicals applied separately. Combinations of BAY-SMY-1500 plus metribuzin effectively controlled downy brome resulting in significantly (0.05 level) higher yields (350-1750 kg/ha) when compared to the untreated control plots for seven of eight locations.

Acceptable downy brome control in winter wheat can consistently be obtained in South Dakota with BAY-SMY-1500 at 1.12-1.4 kg ai/ha plus metribuzin at 0.15-0.21 kg ai/ha. Effective downy brome control may not be obtained without adequate precipitation to move the chemicals into the root zone. The larger dosage combination (1.4 kg/ha BAY-SMY-1500 plus 0.21 kg/ha metribuzin) may be needed for control of heavy downy brome infestations.

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APPENDIX

Table A-1. Average temperature and precipitation for fall 1985 applied treatments at Highmore, South Dakota for two weeks prior and four weeks following application of compounds to wheat.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature	(C)				
High	22	24	17	5	4
Low	-3	-11	-10	-10	-3
Avg.	10	9	5	-4	-8
	(mm)				
Precip.	21.6	0	0	23.9	5.6

a. Application date: October 24, 1985

Table A-2. Average temperature and precipitation for fall 1985 appplied treatments at Doland, South Dakota for two weeks priot and four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature	(C)				
High	23	15	3	1	-8
Low	-6	-4	-9	-19	-27
Avg.	11	6	-4	-8	-17
	(mm)				
Precip.	0.5	0.3	6.4	16.2	3.6

a. Application date: October 31, 1985

Table A-3. Average temperature and precipitation for spring 1986 applied treatments at Rapid City, South Dakota for two weeks prior and four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature			(C)		
High	26	27	20	17	28
Low	-7	-4	-1	-9	1
Avg.	4	12	6	2	5
			(mm)		
Precip.	15.5	6.1	26.9	9.1	39.6

a. Application date: March 27, 1986

Table A-4. Average temperature and precipitation for spring 1986 applied treatments at Highmore, South Dakota for two weeks prior adn four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature			(C)		
High	26	21	21	16	28
Low	-2	-9	-2	-1	1
Avg.	9	3	10	8	13
			(mm)		
Precip.	40.6	31.8	33.0	73.7	21.6

a. Application date: April 12, 1986.

Table A-5. Average temperature and precipitation for spring 1986 applied treatments at Doland, South Dakota for two weeks prior and four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature	(C)				
High	23	18	23	18	26
Low	1	-5	-2	1	4
Avg.	10	4	10	8	12
	(mm)				
Precip.	21.8	96.5	21.8	19.0	37.6

a. Application date: April 12, 1986

Table A-6. Average temperature and precipitation for spring 1986 applied treatments at Doland, South Dakota for two weeks prior and four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature	(C)				
High	25	23	18	10	20
Low	-7	-3	-19	-25	-12
Avg.	10	8	-2	-6	4
	(mm)				
Precip.	4.3	0	7.6	3.6	1.5

a. Application date: October 27, 1986

Table A-7 Average temperature and precipitation for fall 1986 applied treatments at Highmore, South Dakota for two weeks prior and four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature	(C)				
High	26	24	23	24	20
Low	4	-6	-5	-1	-9
Avg	14	7	11	9	7
	(mm)				
precip.	16.5	6.4	0	2.5	2.5

a. Application date: October 7, 1986.

Table A-8. Average temperature and precipitation for fall 1986 applied treatments at Doland, South Dakota for two weeks prior and four weeks following application of compounds.

	Time from application date in days				
	14 day prior	1-7	7-14	14-21	21-28
Temperature	(C)				
High	25	23	23	19	22
Low	4	1	-2	-4	3
Avg.	13	13	5	4	12
	(mm)				
Precip.	40.3	7.6	0	0	0

a. Application date: September 27, 1986

Table A-9. Means of visual ratings of percent control of downy brome where 100% = complete control and 0% = no control, for fall 1985 applied treatments at Highmore, South Dakota.

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0 k	55 ij	77 d-g	80 b-f	83 a-f
0.05	55 ij	75 fgh	78 c-f	81 a-f	84 a-f
0.105	62 hi	65 ghi	86 a-f	92 ab	90 a-d
0.156	55 ij	76 d-g	91 abc	92 ab	90 a-d
0.21	44 i	79 b-f	83 a-f	94 a	93 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-10. Means of visual percent control ratings of downy brome where 100% = complete control and 0% = no control for fall 1985 applied treatments at Doland, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0 k	30 hij	36 ghi	63 c-f	75 a-f
0.05	4 k	35 g-j	71 a-f	77 a-d	84 abc
0.105	16 ijk	53 fgh	65 b-e	77 a-d	69 a-f
0.156	16 ijk	60 def	57 efg	70 a-f	91 a
0.21	35 g-j	60 def	73 a-f	86 ab	83 ab

[a] Means followed by the same letter are not significantly different at the 5% level using Waller-Duncan test.

Table A-11. Means of visual percent control of downy brome where 100% = complete control and 0% = no control for spring 1986 applied treatments at Rapid City, South Dakota.

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0 j	55 hi	53 hi	64 f-i	72 c-g
0.05	54 hi	61 ghi	70 d-g	77 b-f	84 a-d
0.105	62 ghi	72 c-g	80 a-e	86 abc	90 ab
0.156	54 hi	68 e-h	86 abc	88 ab	89 ab
0.21	68 e-h	82 a-e	88 ab	92 ab	92 a

[a] Means followed by the same letter are not significantl different at the 5% level using the Waller-Duncan test.

Table A-12. Means of visual ratings of percent control of downy brome where 100% = complete control and 0% = no control, for a spring 1986 applied treatments at Highmore, South Dakota.

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	0.0 h	64 fg	65 fg	88 a-d	91 abc
0.05	70 d-g	77 c-f	88 a-d	84 a-d	93 abc
0.105	55 g	66 efg	91 abc	94 abc	95 ab
0.156	55 b-f	66 efg	92 abc	93 abc	95 ab
0.21	78 c-f	93 abc	95 ab	98 a	98 a

[a] Means followed by the same letter are not significantly different at the 5% level using Waller-Duncan test.

Table A-13. Means of visual ratings of percent control of downy brome where 100% = complete control and 0% = no control, for spring 1986 applied treatments at Doland, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	0 h	51 g	59 d-g	87 abc	78 a-f
0.05	18 h	65 c-g	65 c-g	80 a-f	82 a-d
0.105	20 h	55 fg	68 b-d	85 abc	93 ab
0.156	22 h	64 c-g	62 c-g	81 a-d	87 abc
0.21	20 h	56 efg	83 a-d	92 ab	95 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-14. Means of visual ratings of percent control of downy brome where 100% = complete control and 0% = no control, for spring 1986 applied treatments at Martin, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0 j	28 i	24 i	71 d-g	80 cde
0.05	24 i	50 h	67 efg	72 bcd	84 bcd
0.105	36 hi	65 fg	80 cde	84 abc	89 abc
0.156	26 i	65 fg	79 c-f	89 abc	91 abc
0.21	68 efg	91 abc	87 abc	95 ab	99 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-15. Means of visual ratings of percent control of downy brome where 100% = complete control and 0% = no control, for fall 1986 applied treatments at Highmore, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0 k	48 ij	73 d-f	88 abc	87 abc
0.05	36 j	56 ghi	76 cde	90 ab	91 ab
0.105	50 hi	61 fgh	75 cde	91 ab	92 ab
0.156	56 ghi	65 efg	76 cde	91 ab	91 ab
0.21	64 efg	69 d-g	81 bcd	94 a	93 a

[a] Means followed by the same letter are not significantly difference at the 5% level using the Waller-Duncan test.

Table A-16. Means of visual ratings of percent control of downy brome where 100% = complete control and 0% = no control, for spring 1986 applied treatments at Doland, South Dakota.

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0 n	25 lm	48 h-k	58 f-i	81 a-e
0.05	15 mn	44 ijk	64 e-h	77 b-e	87 a-d
0.105	21 lm	57 f-j	73 c-f	83 a-d	88 a-d
0.156	32 klm	54 g-j	84 a-d	90 abc	95 a
0.21	39 jkl	70 d-g	90 abc	91 abc	93 ab

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-17. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for fall 1985 applied treatments at Doland, South Dakota. [a, b]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha				
	0.00	0.56	0.84	1.12	1.4
0.00	257 a	213 ab	124 bcd	95 d	103 dc
0.05	240 a	112 dc	98 d	92 d	64 d
0.105	218 ab	101 d	86 d	105 dc	66 d
0.156	213 ab	135 bcd	68 d	78 d	65 d
0.21	195 abc	137 bcd	90 d	49 d	54 d

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-18. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Doland, South Dakota.[a. b.]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	252 a	206 ab	112 c-f	100 e-f	113 c-f
0.05	250 a	123 b-f	100 ef	99 f	63 f
0.105	218 ab	101 ef	86 f	105 ef	66 f
0.156	204 a-d	128 b-f	118 f	64 f	71 f
0.21	191 a-d	117 c-f	112 c-f	48 f	63 f

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-19 . Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Doland, South Dakota.[a, b]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	477 a	324 bc	300 cd	200 ef	112 g-k
0.05	352 bc	238 de	182 e-h	94 h-l	30 kl
0.105	389 b	247 de	139 g-j	78 i-l	57 jkl
0.156	297 cd	187 e-i	64 jkl	60 jkl	16 l
0.21	303 bcd	160 e-i	57 jkl	32 kl	28 kl

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-20. Means of downy brome culms per square meter for each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Rapid City, South Dakota.[a, b]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	73 a	52 ab	54 ab	58 ab	30 abc
0.05	52 ab	43 ab	39 abc	30 abc	14 bc
0.105	70 a	30 abc	37 abc	8 c	10 c
0.156	49 abc	43 abc	14 bc	7 c	8 c
0.21	59 bc	59 bc	18 bc	10 c	9 c

[a] Six meter square counts per plot were taken approximately three weeks prior to crop harvest.

[b] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-21. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for fall 1985 applied treatments at Doland, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
	(Mg/ha)				
0.00	0.62 bc	1.14 bc	0.80 bc	1.54 abc	1.03 bc
0.05	0.86 bc	1.22 bc	1.61 abc	0.78 bc	1.00 bc
0.105	0.52 c	0.92 bc	2.26 ab	0.92 bc	1.45 abc
0.156	0.43 c	0.89 bc	1.20 bc	0.83 bc	0.93 bc
0.21	0.63 bc	1.12 bc	1.06 bc	1.02 bc	0.90 bc

[a] Mean followed by the same letter are not significantly different at the 5 % level using Waller-Duncan test.

Table A-21. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for fall 1985 applied treatments at Highmore, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
	-----------	-----------	Mg/ha	-----------	-----------
0.00	2.88 a	3.10 a	3.21 a	3.46 a	3.50 a
0.05	3.05 a	3.45 a	3.53 a	2.72 a	3.18 a
0.105	3.30 a	3.26 a	3.15 a	3.34 a	3.25 a
0.156	3.39 a	3.39 a	2.76 a	3.28 a	3.28 a
0.21	2.55 a	3.40 a	3.35 a	2.93 a	2.99 a

[a] Means followed by the same letter are not significantly different at the 5 % level using Waller-Duncan test.

Table A-23. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Rapid City, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
	(Mg/ha)				
0.00	2.56 bc	2.65 abc	2.61 bc	2.76 abc	2.78 ab
0.05	2.72 abc	2.96 ab	2.91 ab	2.78 ab	3.08 ab
0.105	2.68 abc	2.88 ab	2.73 abc	2.79 ab	2.82 ab
0.156	2.36 c	2.66 abc	2.83 ab	2.90 ab	2.91 ab
0.21	2.58 bc	2.80 ab	2.85 ab	2.84 ab	2.78 ab

[a] Means followed by the same letter are not significantly different at the 5 % level using Waller-Duncan test.

Table A-24. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Highmore, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
	(Mg/ha)				
0.00	2.40	2.57	2.50	2.55	2.76
0.05	2.48	2.26	2.65	2.55	2.52
0.105	2.61	2.45	2.60	2.51	2.38
0.156	2.62	2.50	2.28	2.47	2.53
0.21	2.69	2.49	2.39	2.47	2.69

[a] Means followed by the same letter are not significantly different at the 5 % level using the Waller-Duncan test.

Table A-25. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Doland, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0.68	0.61	0.74	1.02	0.79
0.05	0.40	0.43	0.57	0.56	0.37
0.105	0.76	0.63	0.90	0.69	0.68
0.156	0.33	0.63	0.55	0.91	0.57
0.21	0.51	0.65	0.48	0.40	0.47

[a] Means followed by the same letter are not significantly different at the 5 % level.

[b] Significant crop injury occured with most chemical treatments, temperatures dropped to -5 °C one day after applications of chemical were made.

Table A26. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Highmore, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
	(Mg/ha)				
0.00	1.67 abc	1.72 abc	1.27 c	1.81 abc	1.55 bc
0.05	1.44 bc	1.27 c	1.53 bc	1.85 abc	1.52 abc
0.105	1.41 bc	1.74 abc	1.91 abc	1.97 abc	1.97 ab
0.156	1.76 abc	1.74 abc	1.89 abc	1.78 abc	2.26 a
0.21	1.52 bc	1.72 abc	1.98 abc	1.94 abc	1.89 abc

[a] Means followed by the same are not significantly different at the 5 % level using the Waller-Duncan test.

Table A-27. Yield of winter wheat (Mg/ha) for each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Doland, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	0.98 i	1.39 f-i	1.23 ghi	1.80 d-h	1.91 b-g
0.05	0.94 i	1.55 d-i	1.80 d-h	1.97 a-f	2.01 a-f
0.105	1.16 hi	1.50 e-i	1.64 d-i	1.82 c-h	2.36 abc
0.156	1.49 e-i	1.72 d-h	2.25 a-d	2.16 a-e	2.55 ab
0.21	1.59 d-i	1.78 d-h	2.64 a	1.95 a-f	1.92 a-f

[a] Means followed by the same letter are not significantly different at the 5 % level using the Waller-Duncan test.

Table A-28. Means of percent protein content of wheat when subjected to use levels of metribuzin, SMY-1500, and combinations for fall 1985 applied treatments at Highmore, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	11.3 a	11.3 a	11.3 a	11.3 a	11.4 a
0.05	11.3 a	11.3 a	11.2 a	11.1 a	11.3 a
0.105	11.4 a	11.4 a	11.6 a	11.6 a	11.5 a
0.156	11.6 a	11.5 a	11.9 a	11.5 a	11.5 a
0.21	11.6 a	11.8 a	11.6 a	11.6 a	11.5 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-29. Means of percent protein content of wheat when subjected to use levels of metribuzin, SMY-1500, and combinations for fall 1985 applied treatments at Doland, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	12.2 a	12.5 a	12.7 a	12.6 a	12.5 a
0.05	12.3 a	12.3 a	12.2 a	12.1 a	12.2 a
0.105	12.7 a	12.5 a	12.3 a	12.4 a	12.6 a
0.156	12.3 a	11.2 a	12.0 a	12.8 a	12.7 a
0.21	12.5 a	12.4 a	12.5 a	12.6 a	12.7 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-30. Means of percent protein content of wheat when subjected to use levels of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Rapid City, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	12.9 ab	13.3 ab	12.2 ab	13.2 ab	12.4 ab
0.05	12.8 ab	13.3 ab	13.1 ab	13.2 ab	12.6 ab
0.105	13.8 a	12.4 ab	12.8 ab	12.3 ab	12.5 ab
0.156	12.9 ab	12.8 ab	12.5 ab	12.5 ab	13.0 ab
0.21	12.6 ab	12.2 ab	12.9 ab	12.4 ab	12.6 ab

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-31. Means of percent protein content of wheat when subjected to each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Highmore, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha 0.00	0.56	0.84	1.12	1.4
0.00	11.3 ab	11.4 ab	11.5 ab	11.4 ab	11.6 ab
0.05	11.4 ab	11.2 ab	11.2 ab	11.3 ab	11.3 ab
0.105	11.4 ab	11.2 ab	11.2 ab	11.7 a	11.3 ab
0.156	11.0 ab	11.4 ab	11.4 ab	11.2 ab	11.5 ab
0.21	10.9 ab	11.2 ab	11.2 ab	11.4 ab	11.6 ab

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-32. Means of percent protein content of wheat when subjected to each use level of metribuzin, SMY-1500, and combinations for spring 1986 applied treatments at Doland, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha				
	0.00	0.56	0.84	1.12	1.4
0.00	12.7 a	12.9 a	12.9 a	12.7 a	12.9 a
0.05	13.0 a	12.8 a	12.8 a	12.7 a	12.9 a
0.105	13.0 a	12.6 a	13.0 a	12.9 a	13.2 a
0.156	13.1 a	13.0 a	12.8 a	12.7 a	12.9 a
0.21	12.9 a	12.9 a	13.0 a	13.0 a	13.2 a

[a] Means followed by the same letter are not significantly different at the 5 % level using the Waller-Duncan test.

Table A-34. Means of percent protein content of wheat when subjected to each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Highmore, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	12.6 a	12.7 a	12.9 a	12.9 a	13.0 a
0.50	12.9 a	12.9 a	13.1 a	13.1 a	13.1 a
0.105	12.6 a	12.9 a	13.0 a	13.0 a	13.6 a
0.156	13.0 a	13.2 a	13.1 a	13.5 a	13.2 a
0.21	13.3 a	13.4 a	13.5 a	12.9 a	13.3 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-35. Means of percent protein content of wheat when subjected to each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Martin, South Dakota.[a]

Metribuzin kg ai/ha	SMY-1500 kg ai/ha				
	0.00	0.56	0.84	1.12	1.4
0.00	12.6 a	12.8 a	12.3 a	11.9 a	12.5 a
0.50	12.5 a	11.7 a	12.7 a	11.7 a	12.0 a
0.105	12.3 a	11.8 a	11.6 a	12.5 a	13.0 a
0.156	13.1 a	11.8 a	12.3 a	13.0 a	12.5 a
0.21	12.0 a	12.9 a	12.6 a	12.2 a	12.7 a

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-36. Means of percent protein content of wheat when subjected to each use level of metribuzin, SMY-1500, and combinations for fall 1986 applied treatments at Doland, South Dakota.[a]

	SMY-1500 kg ai/ha				
Metribuzin kg ai/ha	0.00	0.56	0.84	1.12	1.4
0.00	12.3 c	12.9 abc	12.5 bc	12.8 abc	13.0 abc
0.50	12.8 abc	12.3 c	13.3 abc	13.2 abc	13.4 ab
0.105	12.8 abc	12.8 abc	12.9 abc	13.1 abc	13.7 a
0.156	12.7 abc	12.8 abc	13.2 abc	13.2 abc	13.5 ab
0.21	12.9 abc	13.4 ab	13.6 a	13.2 abc	13.4 ab

[a] Means followed by the same letter are not significantly different at the 5% level using the Waller-Duncan test.

Table A-37 Precipitation received from application date to harvest for each of various locations

	App. Date	Harvest Date[a]	A	S	O	N	D	J	F	M	A	M	J	J	Total
			Month												
			Precip. (cm)												
Highmore	4-12-86	7-21-86	-	-	-	-	-	-	-	2.3	17.9	7.1	8.7	8.5	44.5
Doland	4-12-86	7-23-86	-	-	-	-	-	-	-	1.2	15.7	5.4	10.1	3.0	35.4
Rapid City	3-27-86	7-17-86	-	-	-	-	-	-	-	0.0	12.0	3.6	11.6	0.4	63.0
Doland	10-31-85	7-23-86	-	-	0.0	4.9	0.2	0.3	2.8	1.4	15.7	5.4	10.1	3.0	43.8
Doland	8-29-86	7-15-87	0.0	8.8	0.1	0.1	0.0	0.2	2.1	6.9	0.9	4.5	4.5	4.5	32.6
Martin	10-27-86	7-08-87	-	-	0.0	1.6	0.0	0.1	5.1	5.7	1.1	6.0	4.5	3.4	27.5
Highmore	10-24-86	7-21-87	-	-	0.0	2.0	0.0	0.4	6.5	10.2	2.0	4.9	4.1	7.5	37.6
Highmore	9-27-86	7-15-87	-	0.0	2.5	2.0	0.0	0.4	6.5	10.2	2.0	4.9	4.1	5.8	38.4

[a] Precipitation for July for July 1 to harvest date only.

Table A-38. Average temperature and precipitation at Brookings, South Dakota for two weeks prior and four weeks following application of compounds.[a]

		Temperature			Precipitation
		High	Low	Avg.	
		°C			mm
1986	1-14 day prior	24	-8	8	0.00
1987	to application	25	2	6	0.86
1986	1-7 days	16	-8	4	1.50
1987		12	-6	0	0.28
1986	7-14 days	6	-8	-4	3.80
1987		24	-3	11	0.00
1986	14-21 days	0	-17	-7	8.90
1987		22	-3	8	0.15
1986	21-28 days	-6	-26	-15	4.10
1987		15	-9	2	0.30

[a] Application of compounds were made to the 1986 and 1987 experiments on October 31, 1985 and October 9, 1986 respectively.