A preliminary evaluation of herbicides in dryland cropping systems for saline seep control

by Alan Vonn Tasker

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agronomy
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Abstract:
Herbicides were evaluated for Bromus tectorum control in a reduced tillage cropping program, and for establishment and maintenance of Agropyron elongatum snow barrier strips. Control of Avena sativa (to simulate Avena fatua) and broad leaf weeds was also evaluated for A. elongatum establishment.

Fall applications of dalapon + 2,4-D, glyphosate, and paraquat controlled B. tectorum in wheat stubble in preparation for seeding spring barley. Dinoseb did not provide acceptable control. Sixty-two per cent of the winter moisture received was stored in the soil.

Control of B. tectorum did not result in increased moisture storage when sampled May 9.

Charcoal was tested for protecting A. elongatum seedlings from herbicide injury. Significant protection in the glasshouse 90 days , after treatment was obtained for atrazine and terbutryn. All plants were killed by the non-charcoal atrazine treatment. Although the charcoal treatment gave some protection, plant numbers were significantly lower than the check. Linuron was the only herbicide which did not injure A. elongatum. Chlorbromuron, diuron, metribuzin, simazine, Sumitol, and terbacil injured A. elongatum seedlings regardless of charcoal treatment. In field applications, 2.5 cm charcoal strips over the seeded rows of A. elongatum at 336 kg/ha protected seedlings from some herbicides without reducing weed control by any herbicide. Seedling protection by charcoal was not equally effective for all herbicides. A. elongatum was protected from diuron, linuron, terbutryn, and simazine. Some grass injury occurred regardless of charcoal with metribuzin, Sumitol, and the high rate of simazine.

Selective weed control in seedling A. elongatum was obtained on A. sativa, B_. tectorum, and broadleaves using metribuzin. Terbutryn controlled only A. sativa. Simazine and Sumitol controlled B_. tectorum and broadleaves, although a high rate of simazine was needed for effective broadleaf control.

One month old A. elongatum in the glasshouse was injured by dalapon, atrazine, atrazine + simazine, Sumitol, and terbacil, while barban, chlorbromuron, diuron, linuron, metribuzin, MSMA, pronamide, simazine, Sumitol, and terbutryn did not cause damage.

Fall applications of amitrole + 2,4-D, dalapon, Sumitol, and a high rate of terbacil to one year old A. elongatum snow barriers reduced forage yields about 70%. Atrazine + simazine, chlorbromuron, diuron, linuron, metribuzin, simazine, terbutryn, and a low rate of terbacil caused little damage. B. tectorum control was achieved with amitrole + 2,4-D, dalapon, linuron, and terbacil; and high rates of diuron and metribuzin. Simazine and Sumitol at high rates gave some control.

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A PRELIMINARY EVALUATION OF HERBICIDES IN DRYLAND CROPPING SYSTEMS FOR SALINE SEEP CONTROL

by

ALAN VONN TASKER

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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ABSTRACT

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INTRODUCTION

The rapid increase of the saline seep problem in the northwestern United States has alarmed farmers, conservationists, researchers, and much of the general public. Summer fallow, a widespread cropping system in that area, has been implicated as a contributing cause of saline seep. Several moisture conservation practices to replace summer fallow have been found helpful in saline seep control, but associated weed problems have limited their application.

This study was initiated to evaluate herbicides for control of *Avena fatua* L. and *Bromus tectorum* L. in the following moisture conservation systems:

1. Reduced tillage annual cropping.
2. Tall wheatgrass (*Agropyron elongatum* [Host] Beauv.) snow barrier strips (during and after establishment).

REVIEW OF LITERATURE

Dry farming is defined as farming without irrigation in an area where mean annual precipitation is between 25 and 51 cm (39). Since winter wheat--a common crop in semi-arid to subhumid regions--uses about 27 cm of water from the late tiller stage to maturity in producing a 1090 kg/ha crop (12), and winter precipitation storage rates are low, it is apparent that special methods of water conservation are necessary for maximum yields. Although mean annual precipitation is often used for defining dry-farming regions, de Brichament (18) says that precipitation during the growing season is more important, along with such factors as drought probabilities, climatic factors, and potential evapotranspiration.

Various tillage techniques and crop rotations have been used to conserve water (18). One such special technique is summer fallow. This system involves leaving land without a crop, while controlling weeds, for one growing season to allow moisture storage. While average annual yields per acre are not as high with this system as with annual cropping, since half the acreage is fallowed, yields are stabilized over dry years due to the development of a moisture reserve (10).

The summer fallow system was advocated as early as 1880, but was not widely accepted until 40 years later. Krall (34) lists several reasons for its early lack of acceptance: 1) 1915 to 1917 were some of the wettest years on record; 2) Few annual weeds were serious problems before the 1920's; 3) During World War I it was unpatriotic to have "idle" land; and 4) Effective summer fallow techniques and equipment were not yet developed.

A serious drought in 1919 convinced many that summer fallow was needed to stabilize yields. This led to promotion of summer fallow in the early 1920's by such groups as Bill Reed's "Summer Fallow Club of 1921" (10). By the mid-1920's summer fallow for cereal production was widely practiced in the drier parts of the U. S. dryland farming areas.

In parts of the northwestern U. S. and southwestern Canada, however, the summer fallow system has been implicated as a cause of saline seep. This problem was mentioned by Warden (54) about 20 years ago. The Northwest has always had naturally salty areas which would not support plant growth, but in 1954 Warden (54) called attention to certain areas--especially on north-facing slopes--occurring in formerly productive farmland. These "alkali spots", as he called them, were wet salty areas which increased in size each year (Fig. 1).

In 1969, 19 counties in Montana east of the Continental Divide reported significant seep areas saline enough to prevent seed germination and wet enough to prevent tillage (12). Farmer concern was emphasized by the formation of the Highwood Alkali Control Association in northern Montana. Statistics indicate reason for concern. In 1971, 25 counties in the above eastern Montana area reported saline seeps invol-

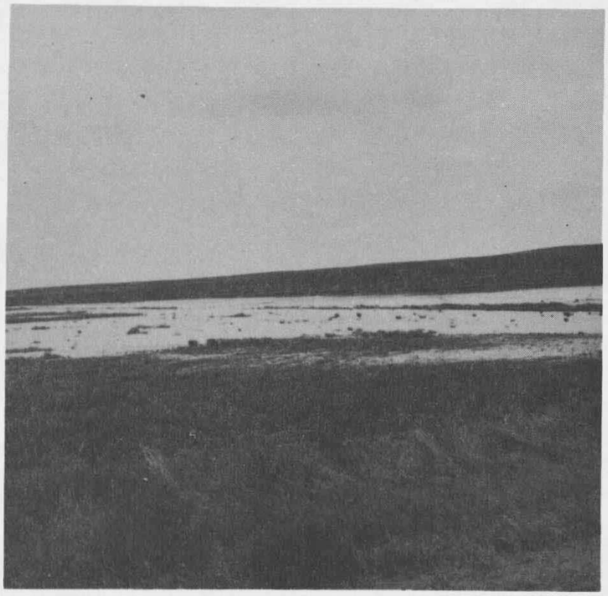

Figure 1. Typical saline seep in northern Montana cropland.

ving 3,300 ha of land. This did not include areas out of production because of the irregular shape of the seeps. These seeped areas are estimated to be increasing at a rate of two to ten per cent per year (13).

Geologists consider about 331,000 sq km in North and South Dakota, Montana, Alberta, Saskatchewan, and Manitoba to have a potential for this problem. These are areas overlying the Colorado Group and Bearpaw Formation (black marine shales) and the Fort Union Formation (siltstone, sandstone, shale, and coal). This includes 3,200,000 ha in Montana alone (41).

Summer fallow is considered to contribute directly to the saline seep problem. Annual cropping or virgin prairie uses almost all available water, since growing plants are present during most of the growing season (22). Effective summer fallow, however, may cause excess moisture accumulation. This moisture percolates, picking up soluble salts as it moves through the profile. A shale or coal layer causes the formation of a salty aquifer, which emerges, or approaches the soil surface at some point (16, 21). When this occurs, a saline seep appears as the water evaporates, leaving the soluble salts on the soil surface. In addition to summer fallow farming and an impermeable soil layer, Clark (17) lists three more conditions aggrevating the saline seep problem:

1. "High" annual precipitation (32-48 cm/year)
2. Good summer fallow management (high moisture storage efficiency).
3. Large fallow areas.

Sisson[1/] divided saline seeps into three areas: 1) The discharge area, actually a low volume spring; 2) The underground aquifer; and 3) The recharge area, or the total land area contributing to the aquifer.

The economic effects of saline seep areas are extensive. Probably the most significant concern is the loss of land. This loss includes not only the discharge area itself but also the fringe areas lost from production due to the irregular shape of the seep. High moisture prevents crossing of these areas, thus farming time and costs are increased. The saline aquifers also contaminate streams and ponds, destroying fish habitat and fish, as well as destroying domestic water supplies. The salts involved make seep reclamation very expensive, if possible at all (23).

Ferguson et al. (23) indicate that most moisture is lost to the aquifer in May and June of the fallow year. This suggests two main approaches to saline seep control (13, 23): 1) Removal of the underground aquifer; or 2) Prevention or reduction of water loss to the aquifer from the topsoil.

[1/] Sisson, J. B. 1972. Hydraulic Properties of the Gerber Soil M. S. Thesis. Montana State University, Bozeman, Montana.

Aquifer interception or drainage seems unlikely, mainly because of water disposal problems. Since these waters are extremely saline, drainage into surface water creates additional problems. Utilization of plants to intercept or remove the water is a possible alternative. Deep-rooted, salt-tolerant, perennial plants with high water requirements growing in or immediately upslope from the seep area could achieve this goal. Forage removal in the fall would be necessary to prevent snow trapping which could aggravate the problem by increasing spring run-off into the seep area (22).

Annual cropping of the recharge area, either in an annual rotation or with perennial forage or seed crops, could prevent percolation of water to the aquifer. Since summer fallow was introduced to compensate for limited growing season moisture, alternative methods of moisture conservation are needed. Snow trapping is such an alternative. Two possible methods of snow trapping are: 1) Reduced tillage to leave stubble standing; and 2) Snow barriers in the fields. Both of these methods pose certain problems, especially regarding weeds.

When annual cropping without tillage, winter wheat is seeded into the stubble with minimum soil disturbance. This practice leaves the stubble standing, thus decreasing wind speed near the soil surface. Snow deposits will then be increased and made more uniform. Smika and Whitfield (49) report an increase in water storage efficiency from a mean of 15% for bare tillage to a maximum mean of 99% for standing stubble. As a side benefit, frost penetration of the soil may be reduced, thus reducing winter kill (40).

Snow barrier strips are also designed to increase soil moisture without necessarily eliminating tillage. Although mechanical barriers such as snow fences are possible, the most favored technique (7, 8, 26, 48) seems to be a two row barrier of a perennial grass, usually Agropyron elongatum. The barriers are placed at approximately 15 m intervals at right angles to the prevailing winter wind (Fig. 2).

Greb and Black (26) show wind speed reduction at 1.5, 3.4, 4.9, and 7.0 m from the barrier of 83, 61, 42, and 33%, respectively. This wind reduction would reduce snow drifting into the seep area, holding it on the field (13, 14) to increase moisture storage (7, 8, 48). The wind speed reduction could also reduce crop evapotranspiration (49).

Black and Siddoway (7) and Black et al. (8) reported water storage efficiency increased up to 77% with barriers over tilled continuous cropping without barriers. They showed a storage of 3.3 cm more water than standing stubble alone. Over a four year period, approximately the same moisture storage was attained under continuous cropping minimum tillage with barriers as with a conventional summer fallow system.

The two major grassy weed problems in the northern cereal growing region of the U. S. are downy brome (Bromus tectorum L.) and wild oat (Avena fatua L.). Some major broadleaf weeds which cause problems are Russian thistle (Salsola kali L.), kochia (Kochia scoparia Roth.),

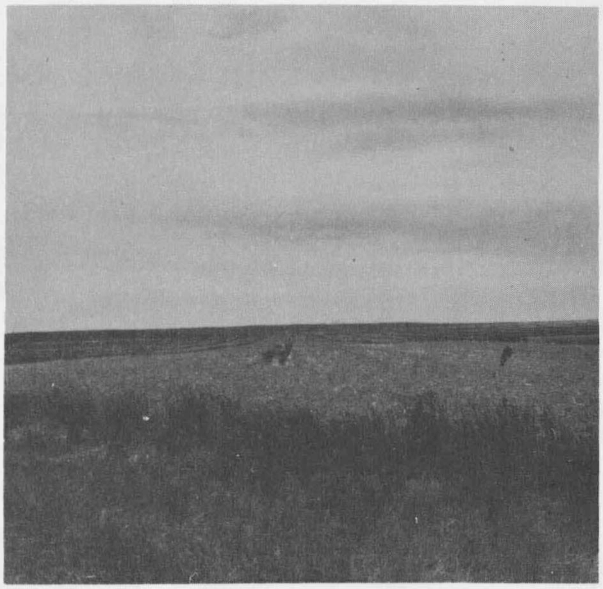

Figure 2. Agropyron elongatum snow barrier strips in northern Montana.

field pennycress (*Thlaspi arvense* L.), tumbling pigweed (*Amaranthus graecizans* L.) and wild mustards (*Brassica* spp.).

The literature of *B. tectorum* has been reviewed by several workers (27, 33, 50). This grass is usually a winter annual, but can also germinate in early spring. Optimum germination occurs after 30 hours in a wet 16° C environment if the four to five week primary dormancy has been broken (27, 50). Since *B. tectorum* has little dormancy (16, 27, 56), most seed will germinate the first year (16). These plants may be controlled by spring tillage. Since the seed ripens in June and early July (56), early treatment with a contact herbicide to prevent seed production can be valuable (21, 56). This treatment is often used to prevent seed set in plants escaping other herbicide treatments (21). Early control is desirable, however, since most competition occurs early in the spring. Rydrich (45), in Oregon, shows only 6% yield reduction in wheat if *B. tectorum* plants were removed by March, compared to 40% yield reduction when plants were removed after March. *B. tectorum* roots can also develop in cool weather when winter wheat is dormant (27).

Several workers (16, 27, 56) report that it is possible to eliminate *B. tectorum* populations if seed production is prevented for two to three years. The fact that B. tectorum remains a serious problem indicates that seed is escaping in the field, migrating in from field borders and waste areas, and being planted with the grain. Hulbert (27) reports a germination of 96% for *B. tectorum* seed stored for 11½ years in dry conditions. This indicates *B. tectorum* seed's ability to survive in machinery and stored seed grain. Because of its lack of major dormancy, probably the best *B. tectorum* control measure is preventing seed production over a three to four year period.

Avena fatua, the other major weed problem in cereal cropping systems, is a spring annual. Optimum germination occurs when weekly mean minimum temperature does not exceed 20° C and weekly mean maximum temperature does not exceed 28° C (42).

Chepil (16) reported a three to four year period of maximum wild oat dormancy. He found a total of about 30% seed germination in the field; about 90% of this the first year. Approximately 2% of the seed remained viable after 18 months (42). Thurston (51) found enough seed still viable after 6½ years of a sod crop to infest a cereal crop. She speculated that lack of disturbance allowed seeds to survive longer.

Seed dormancy of *A. fatua* contributes greatly to its persistance. The dormancy pattern varies according to genotype (46), position on the panicle and in the spikelet (29), soil temperature and moisture levels, afterripening period, and other factors.

Competition by *A. fatua* can reduce yields significantly. Bell and Nalewaja (6) reported that *A. fatua* densities of 77 and 175 seedlings per m^2 reduced wheat yields by 22% and 39% and barley yields of 7% and 26%. Heavy wild oat infestations may also reduce wheat protein due to competition for nitrogen (24).

Weathering on the soil surface may reduce dormancy of the A. fatua seed, but germination is best in darkness (29). Chepil (16) suggests an early spring tillage to bury the seed, and a late spring tillage before seeding to destroy emerged plants.

Broadleaf infestations in cereals are commonly controlled with 2,4-D [(2,4-dichlorophenoxy) acetic acid], dicamba (3,6-dichloro-o anisic acid), or bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), while A. fatua is controlled with barban (4-chloro-2-butynyl-m-chlorocar= banilate), and triallate [S-(2,4,4-trichloroallyl) diisopropylthio- carbamate] (5). Specific application timing with barban and the necessity for soil incorporation with triallate, however, have restricted their use. New foliage applied chemicals with less restrictive application requirements are presently being developed. Chemicals for selective control of B. tectorum in cereals are not presently available. Therefore, non-selective herbicides and tillage methods must be used as effectively as possible.

The goal of annual cropping with minimum tillage is weed control with minimum stubble disturbance. Herbicides to replace tillage should be broad spectrum, thus eliminating field operations, both to reduce stubble trampling and tillage costs. Since residues could cause problems in subsequent cereal crops, the chemicals should either leave no soil residue, or residues non-toxic to cereals.

The barrier-strip system, which can be used in conjunction with no-tillage, presents a two-fold problem. Selective herbicides to control annual grass weeds in established perennial grass need to be selected. Many such herbicides, however, will kill or seriously injure seedlings if used in grass barrier establishment, where weed control is most critical. Because of this, alternative herbicides, or techniques to protect the grass seedlings from herbicide injury must be found for perennial grass establishment.

A recent development in seedling protection is the use of activated charcoal. The adsorbant qualities of charcoal have been used for odor removal and water purification for many years. The process of activating charcoal with steam heat increases the surface area of carbon from 100 to 2000-2800 m^2/gm. Development of this process has greatly expanded charcoal uses (53).

Lucas and Hamner in 1947 (38) suggested the use of charcoal in sprayer cleaning and other herbicide detoxification. They showed 2,4-D detoxification using activated carbon. More recent work on the adsorbtion of herbicides by charcoal suspensions has been done by Leopold et al. (36) and Jordan and Smith (32). Their work indicates that activation of the charcoal is necessary for maximum effectiveness.

Practical field use has been approached in several ways. Root dipping of transplant stock has been investigated extensively (1, 2, 3, 4). Direct seeding of vegetables has been attempted using a vermiculite wafer incorporating the seed, charcoal, fertilizers, and sometimes herbicides (19, 20, 20, 30, 52). A broadcast application of charcoal tilled into the soil has been shown to tie up undesirable herbicide residues before planting (1, 4, 27). Charcoal strips placed in or on the soil directly over the seeded row at planting have been used to allow later broadcast applications of normally toxic herbicides (11, 15, 25, 35, 37, 43). A compilation of literature citations and workers in the field of charcoal protection is available from ICI American[2/]. The charcoal strip technique has been used successfully in perennial grass seed production in Oregon, using chemicals toxic to unprotected seedlings (11, 15, 25).

[2/] ICI American. 1973. Grow-Safe[R] Activated Charcoal References. Wilmington, Delaware.

METHODS AND MATERIALS

Reduced Tillage Annual Cropping. An area in a wheat stubble field on the Norris Hanford farm near Fort Benton, Montana was selected which had a *Bromus tectorum* stand density of approximately 40%. The experimental area was on a Gerber silty clay loam soil (fine montmorillonitic Vertic Argiborolls), which receives a mean annual precipitation of 35 cm. This area had one year old *Agropyron elongatum* snow barriers at 15 m intervals. Nine treatments were randomized and replicated four times on plots 4.6 x 7.3 m in size. Soil samples were taken for gravimetric moisture determinations prior to treatment September 14, 1972. A King tube was used to take the soil moisture samples to a depth of 61 cm by 15 cm increments.

Treatments applied are listed in Table 1. Characteristics of the herbicides used in all of the studies are summarized in Appendix Table 1. Herbicides were applied using a 3 m, 6 nozzle, handheld boom and a compressed air backpack sprayer. TeeJet brass 9502 nozzles were used at 51 cm spacings. Water was used as the carrier except for the dinoseb treatment, where a 3:1 water to diesel fuel mixture was used. Ortho X-77 non-ionic surfactant at .5% by volume was added to the paraquat treatments. The herbicides were applied in 281 l/ha of carrier. Weeds were removed from the handweed plots by hoeing.

Visual ratings of weed control were made October 6 and November 16, 1972, and May 9, 1973. A 1 to 4 scale was used with 1 indicating no control, 4 indicating complete control. At the May rating, B. tectorum seedlings were also rated, and soil samples were taken for moisture determinations from the weedy and handweeded plots and from the two most effective herbicide treatments.

Spring barley was planted across the plot area by the grower as he seeded the rest of the field. The grain drill did not penetrate properly due to the firmer untilled soil in the study area. As a result, barley stand density was so erratic that the barley yield portion of the study was terminated in early summer to allow B. tectorum control on the infested plots.

Agropyron elongatum Establishment. On March 21, 1972, a greenhouse study was initiated to determine the effect of charcoal on herbicidal toxicity to A. elongatum seedlings. A. elongatum was seeded 1 cm deep in 10 x 10 cm plastic pots. All treatments except diuron and the check had both charcoal and non-charcoal applications. A 1:1 suspension of water:charcoal (w, w) was pipetted onto the soil surface of the charcoal pots at 168 kg/ha before herbicide application. All treatments were triplicated. Herbicides listed in Table 4 were applied by placing all pots for a treatment in a line, then spraying each set of pots. Herbicides were carried in water at 281 l/ha, and applied using a compressed air sprayer with a single TeeJet 9502 brass nozzle.

The pots were top watered throughout the study. Live plants were counted at weekly intervals until the study was terminated July 11, 1972.

Two field trials were also conducted on the Montana State University Agronomy Research Farm to test charcoal protection of grass seedlings from herbicides. The experimental area contained Amsterdam and Bozeman silt loam soils (fine-silty mixed families of Argic Pachic Cryborolls and Typic Cryborolls, respectively), which receive a mean annual precipitation of 38 cm.

One experiment was initiated on May 29, 1973, on an area which had been in small grains the previous summer. The site was prepared by fall plowing, and spring discing and harrowing. The experiment was designed as a strip-block with two charcoal treatments across 14 herbicide treatments. Herbicide plot size was 3 x 3 m, with all treatments replicated four times. Prior to seeding _A. elongatum_, Park oats were broadcast over the area to simulate _Avena fatua_, and double harrowed. Handweed treatments were done twice during the summer.

A. elongatum was seeded approximately 1 cm deep with a gang of Planter-Jr. seeders mounted 30 cm apart on a tractor mounted tool bar. Ten rows at 30 cm spacings were seeded the length of each block at a rate of 14.5 kg/ha pure live seed. The seed had a laboratory germination of 91% and was 97.6% pure.

Charcoal was applied in a 2.5 cm band using TeeJet 9506 brass spray nozzles mounted behind the press wheels of four of the seeders.

Charcoal was applied at 336 kg/ha in water carrier equal to 5600 l/ha on treated plots. Figure 3 shows the charcoal strips immediately after application.

The second experiment was established September 17, 1973, on summer fallowed land. Four rows of B. tectorum were seeded on one foot spacings at right angles to the A. elongatum rows through the center of the plots. An additional row of B. tectorum was planted the length of each sub-block between the center two A. elongatum rows. No handweeding was done.

Treatments are listed in Table 5. Herbicides were applied the same day as planting to reduce charcoal deactivation by dust or dispersal by rain. A compressed air, backpack sprayer was used with a 3 m handheld boom containing 6 brass 9502 TeeJet Nozzles spaced 51 cm apart to apply water carrier equal to 281 l/ha. Herbicides were applied at right angles to the A. elongatum rows.

The spring planted plots were rated on a 1 to 4 scale (1 = no control, 4 = complete control) for broadleaf and oat control on July 9 and September 7, 1973. The number of A. elongatum plants per subplot was recorded at the July rating by placing a .6 x 3 m transect across the A. elongatum rows in the center of the plot. Data were recorded for four rows in each sub-block, the outer rows (rows 1 and 10) of each block being designated border rows. Fall planted plots were rated on October 30 for B. tectorum control using the 1 to 4 scale. On November

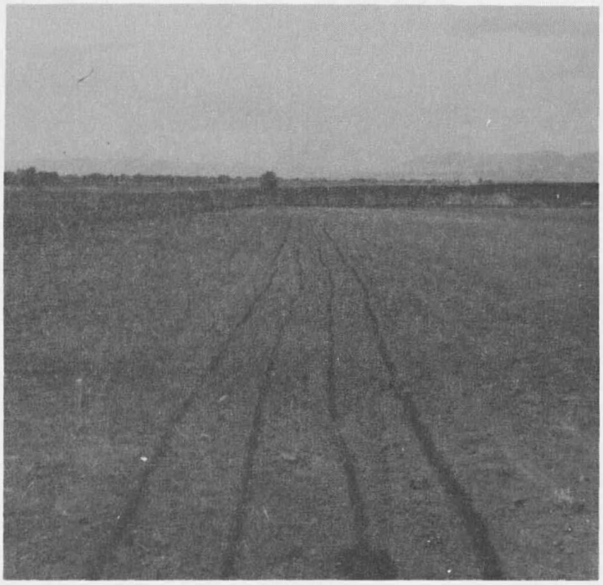

Figure 3. Charcoal strips applied to a planting of *Agropyron elongatum*.

30 and April 30, B. tectorum plants in the .6 x 3 m transect in each subplot were recorded, along with the number of A. elongatum plants in that transect. The transect was placed across the center of the plot so that the two center B. tectorum rows were included.

Established Agropyron elongatum. A greenhouse study was conducted to determine herbicide damage to one month old A. elongatum plants. The A. elongatum was seeded July 24, 1972, 1 cm deep in 13 cm diameter plastic pots. To prevent settling, the pots were filled with soil and water before seeding. Seed was then placed and the last 1 cm of soil added. Pots were subirrigated until the herbicides (Table 10) were applied in triplicate on August 30, 1972. After treatment, pots were top watered as needed.

Foliar applications were made by placing all pots for a treatment in a line and spraying them with a handheld sprayer using a single 8002 brass TeeJet nozzle. Water was used as carrier at 187 l/ha. Soil treatments were pipetted onto the soil surface in 100 ml of water to prevent foliage interception. Plants were clipped at the soil surface for forage yield on September 28, 1972. After two weeks of regrowth, the pots were moved to an open cold frame and set in sawdust up to the soil surface. Winterkill ratings were taken on a 0 to 10 scale June 21, 1973.

Spring established two row A. elongatum snow barrier strips were selected in early fall on the Norris Hanford farm near Fort Benton, Montana, on the basis of B. tectorum infestation. Row spacing was 30 cm, with barriers at 15 m intervals. The experimental area contained Gerber silty clay loam soil (fine montmorillonitic Vertic Argiborolls), which receives a mean annual precipitation of 35 cm. Three barriers were treated, each barrier constituting a replication. Plots were 1.5 x 7.6 m. Treatments were applied September 14, 1972 (Table 11). Handweeding was done at that date only. Herbicides were applied with a compressed air, backpack sprayer using a 1.5 m handheld boom equipped with TeeJet 9502 brass nozzles at 30 cm spacings. Water carrier was used at 280 l/ha. The area was sprayed with 2,4-D for broadleaf control by the farmer during the summer.

Plots were visually rated for B. tectorum control and A. elongatum damage, using a 0 to 10 scale (0 = no damage or control, 10 = complete damage or control). Ratings were made November 16, 1972, May9, June 9, and July 31, 1973. Figure 4 shows barriers in late spring and midsummer. At the July rating, 3 m of both rows of A. elongatum was harvested at the center of each plot by handcutting at ground level. These samples were dried and weighed to quantify A. elongatum damage.

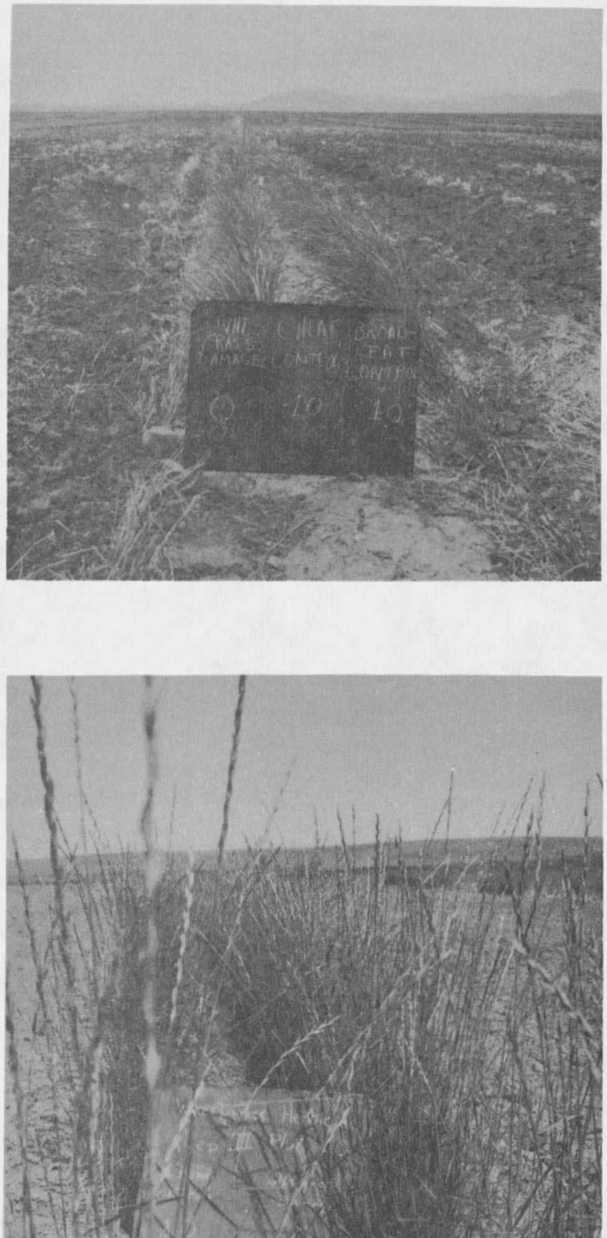

Figure 4. A two row Agropyron elongatum barrier strip in late spring (above) and midsummer (below).

RESULTS AND DISCUSSION

Reduced Tillage Annual Cropping. Several fall applied herbicides significantly reduced stands of *Bromus tectorum* in wheat stubble (Table 1; Appendix Table 2). Herbicide effectiveness increased from fall to spring for dalapon (2,2-dichloropropionic acid) + 2,4-D, and glyphosate (*N*-phosphomethyl glycine), the two translocated materials. Dalapon completely controlled this weedy grass, but without yield data it is not possible to estimate the residual effect of dalapon on barley yield. The high rate of paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) and both rates of glyphosate also gave good control of *B. tectorum*. Dinoseb (2-*sec*-butyl-4,6-dinitrophenol) was the least effective of the four chemicals tested.

Moisture storage was not significantly affected by any treatment (Table 2). This is surprising, since the *B. tectorum* cover varied from 40% on the check to none on the plots treated with dalapon + 2,4-D. Rydrich (45) reported that yield reduction became serious in Oregon winter wheat if *B. tectorum* plants were allowed to compete after January, with the most serious reduction occurring after early March. The area he referred to is a winter rainfall area which receives 42 cm precipitation annually. Our experimental area has very cold winters and receives 35 cm of rainfall annually. It is possible that poor growing conditions prevented the use of significant amounts of moisture by May. Barley yield data would probably show reduced grain production due to *B. tectorum* competition.

Table 1. Control of Bromus tectorum in wheat stubble by fall applied herbicides.

Treatment		Weed Control Ratings 1/	
Herbicide	Rate (kg/ha)	Oct 6 2/	May 9 3/
Dalapon + 2,4-D	5.6	1.00 d	4.00 a
Dinoseb	1.12	1.00 d	1.50 c
	2.24	1.50 cd	1.75 bc
Glyphosate	0.56	2.00 bc	3.75 a
	1 68	2.50 ab	3.50 a
Paraquat	0.28	2.00 bc	2.25 b
	0.56	3.00 a	3.25 a
Handweed	--	3.00	2.00 bc
Check	--	1.00	1.00 c

1/ Means of 4 replications applied September 14. Values in the same column followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

2/ 1 to 3 visual rating (1 = no control, 3 = complete control).

3/ 1 to 4 visual rating (1 = no control, 4 = complete control).

Table 2. The effect of *Bromus tectorum* control on soil moisture storage in untilled wheat stubble.

Herbicide	Rate (kg/ha)	*B. tectorum* Ground Cover in Spring (%)	Soil Depth (cm)	Total Soil Water[1/] (cm) Fall	Spring
No treatment	--	40	0 - 15	3.42	4.05
			15 - 31	2.76	4.68
			31 - 46	2.45	5.05
			46 - 61	1.99	3.65
			(Total)	10.62	17.43
Handweed	--	25	0 - 15	3.59	4.24
			15 - 31	2.89	4.84
			31 - 46	2.78	5.08
			46 - 61	2.23	4.46
			(Total)	11.49	18.92
Glyphosate	1.68	10	0 - 15	--[2/]	4.54
			15 - 31	--	4.44
			31 - 46	--	5.25
			46 - 61	--	4.28
			(Total)	--	18.51
Dalapon + 2,4-D	5.6 + 1.12	0	0 - 15	--	4.44
			15 - 31	--	4.76
			31 - 46	--	4.59
			46 - 61	--	4.54
			(Total)	--	18.33
			(Mean)	11.06	18.30

[1/] Means of 4 replications determined gravimetrically September 14 (Fall) and May 9 (Spring).

[2/] Not determined.

In evaluating the reduced tillage cropping system, crop moisture requirements must be considered. Winter wheat requires 27 cm of moisture to produce a 1090 kg/ha yield (12). In a 35 cm mean annual rainfall area such as the study area, part of this must come from stored moisture, since about half of the expected precipitation occurs during the growing season (May to mid-August) (12). Assuming 17.5 cm of moisture fell during the growing season, and 90% of it was available to the crop, 11.25 cm of moisture would be required from stored soil moisture. In a year with 35 cm of precipitation, that would require a 64% moisture storage efficiency in the winter months.

Total soil moisture in the study area increased from an average of 11.1 cm in the top 61 cm on September 14, 1972, to an average of 18.3 cm on May 9, 1973, an increase of 7.2 cm. Precipitation during this period totaled 11.6 cm[3/] [4/]; a moisture storage efficiency of 62%. This efficiency rate would probably store sufficient soil moisture for a crop in most years.

The actual amount of plant available water in the soil can be calculated to determine if the storage efficiency was sufficient. In dry areas, a winter wheat crop extracts most of the available soil

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3/ Ibid.

4/ _______ and H. Ferguson. 1973. Management of Saline Seep Areas. Annual Research Report. Mont. Ag. Exp. Sta. & USDA-ARS.

moisture to at least 90 cm (12). The Gerber silty clay loam soil in the experimental site was assumed to be near the permanent wilting point to that depth after harvest in 1972. About 3 cm of precipitation occurred between the date of harvest and the date of the moisture determinations[5/]. This amount of water would not wet a dry soil of this type deeper than 30 cm. Using the amount of water remaining in the 46 - 61 cm soil increment as the permanent wilting point of the soil, an average of 2 cm of moisture remained in that increment after wheat harvest (Table 2). From this value it was calculated that about 8 cm of water remained in the top 61 cm of soil when most of the plant available water had been depleted. In the spring, an average of about 18 cm total water was present. Subtracting from this the calculated wilting point value, approximately 10 cm of plant available water were in the top 61 cm of soil in the spring of 1973. Using Brown's value (12) of 27 cm of moisture needed to produce a 1090 kg/ha wheat crop, about 17 cm of additional plant available water would be needed during the growing season. This amount of rainfall could be expected most years in the study area.

The data obtained show that _B. tectorum_ can be controlled without tillage. Grain stubble undisturbed by tillage increases snow trapping,

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5/ Brown, P. L. 1974. Unpublished data.

improving soil moisture storage. Additional water necessary for a crop can be determined from spring soil moisture data. The grower can use this information together with probabilities for expected growing season moisture to estimate crop yield. This could be valuable in making management decisions.

Agropyron elongatum Establishment. Protection of seedling Agropyron elongatum by charcoal was studied in the glasshouse for nine herbicides. Observations made at approximately weekly intervals (Table 3; Appendix Table 3) showed the mean number of seedlings to increase until a gradual decrease began about three weeks after treatment. The early increase was due to continued germination regardless of herbicide treatment. The decline in population was attributed to herbicide injury. Plant numbers stabilized after 30 days, indicating most damage occurred in the first month after treatment.

No herbicide treatment had significantly reduced plant numbers 16 days after treatment (Table 4; Appendix Table 3). By 23 days after treatment, populations were reduced below the check level by non-charcoal treatments of atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) and chlorbromuron (3-(bromo-3-chlorophenyl)-1-methoxy-1-methylurea); diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea) with charcoal; and both charcoal and non-charcoal treatments of metribuzin (4-amino-6-tert-butyl-3-(methylthio)-as-triazine-5-(4H)-one), simazine 2-chloro-4,6-bis-(ethylamino)-s-triazine), Sumitol (2-sec-butylamino-

Table 3. The effect of herbicides on <u>Agropyron</u> <u>elongatum</u> seedling population density in the glasshouse.

Days After Treatment[1/]	Live Plants[2/]
7	5.4 abc
9	7.9 bc
16	8.8 c
23	4.7 ab
30	3.1 a
40	3.2 a
47	3.3 a
56	3.3 a
65	3.3 a
71	3.1 a
78	3.1 a
90	2.9 a
111	2.6 a

[1/] Treated March 21, 1972.

[2/] Means of 3 replications. Values followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

Table 4. *Agropyron elongatum* response in the glasshouse to herbicides, as affected by charcoal.

Treatment			Live Plants[1]		
Herbicide	Rate (kg/ha)	Charcoal Rate (kg/ha)	16 Days[2]	23 Days	90 Days
Atrazine	3.36	0	8.0	1.0 ab	0.0 a
		168	9.3	7.0 efg	4.3 b
Chlor-bromuron	2.24	0	9.0	3.3 abcd	1.0 a
		168	9.0	6.7 defg	3.3 ab
Diuron	3.36	168	8.7	4.7 cde	2.0 ab
Linuron	1.12	0	9.3	8.7 fg	8.0 c
		168	9.7	10.0 g	8.7 c
Metribuzin	2.24	0	9.0	0.0 a	0.0 a
		168	9.0	0.0 a	0.0 a
Simazine	3.36	0	8.3	1.3 abc	0.0 a
		168	9.0	4.3 bcde	0.0 a
Sumitol	3.36	0	7.7	0.0 a	0.0 a
		168	8.7	2.3 abc	0.7 a
Terbacil	1.12	0	9.0	0.3 a	0.0 a
		168	9.0	4.0 bcde	0.0 a
Terbutryn	2.24	0	9.0	6.3 def	4.3 b
		168	8.0	7.0 efg	9.3 c
Check	--	--	9.0	9.0 fg	10.0 c

[1] Means of 3 replications. Values within columns followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

[2] No significant differences.

4-ethylamino-6-methoxy-s-triazine) and terbacil (3-tert-butyl-5-chloro-6-methyluracil). Ninety days after treatment, charcoal protected A. elongatum seedlings against only atrazine and terbutyrn (2-tert-butylamino-4-(ethylamino)-6-(methylamino)-s-triazine). Possibly a lower charcoal rate would still protect plants from terbutryn. Atrazine killed all plants on the non-charcoal treatments. When charcoal was used, atrazine treatments had a mean of 4.3 plants present, significantly higher than the non-charcoal treatments, but still significantly lower than the check (Table 4). Linuron (3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea) was the only herbicide which did not damage A. elongatum regardless of charcoal treatment. These data indicate a higher rate of charcoal is necessary for seedling protection against most herbicides on the Bozeman silt loam soil.

Field applications of charcoal at a rate of 336 kg/ha in 2.5 cm bands were applied over the seeded rows of A. elongatum for herbicide protection. In the spring seeded study, five treatments on Avena sativa (to simulate Avena fatua) received control ratings of 3.0 or higher six weeks (July 9) after treatment (Table 5; Appendix Table 4). These treatments were: handweeding, both levels of Sumitol, and the high levels of metribuzin and simazine. Two months later, only three treatments controlled oats significantly better than the untreated check: handweeding and the high levels of metribuzin and terbutryn.

Table 5. The effect of herbicides on weeds in spring seeded Agropyron elongatum.

Treatment		Weed Control Ratings[1/]			
		Oat		Broadleaf	
Herbicide	Rate (kg/ha)	July 9	Sept 7	July 9	Sept 7
Diuron	1.68	1.0 c	2.3 bcd	1.0 d	1.0 d
	3.36	1.5 c	2.3 bcd	2.5 c	1.3 d
Linuron	0.56	1.3 c	1.8 cd	1.5 d	1.3 d
	1.12	1.3 c	2.0 bcd	2.8 bc	1.0 d
Metribuzin	0.56	3.0 b	2.3 bcd	3.0 abc	3.0 b
	1.12	3.5 ab	3.3 ab	3.5 abc	3.8 a
Simazine	1.68	1.8 c	1.3 d	3.8 ab	2.0 cd
	3.36	3.0 b	1.5 d	3.0 abc	3.0 b
Sumitol	1.68	2.8 b	2.0 bcd	3.0 abc	2.8 bc
	3.36	3.3 b	3.0 abc	3.0 abc	3.5 ab
Terbutryn	1.12	1.0 c	1.3 d	1.0 d	1.0 d
	2.24	1.3 c	3.3 ab	2.8 bc	1.3 d
Handweed	--	4.0 a	4.0 a	4.0 a	4.0 a
Check	--	1.0 c	1.8 cd	1.5 d	1.8 d

[1/] Means of 4 replications treated May 29. 1 = no control, 4 = complete control. Values within columns followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

Broadleaf control July 9 (Table 5; Appendix Table 4) was rated at 3.0 or higher for handweeding, and both levels of metribuzin, simazine, and Sumitol. Broadleaf control September 9 significantly better than the check was obtained with both levels of metribuzin and Sumitol, the high level of simazine, and handweeding.

In the fall seeded study, _B. tectorum_ control ratings (Table 6; Appendix Table 5) of 3.25 or better were obtained for metribuzin at both levels, and the high levels of simazine and Sumitol six weeks after establishment. Plant counts two weeks later showed the same four treatments plus the low level of Sumitol to give significantly better weed control than the treatments with the highest _B. tectorum_ populations, although only the high level of metribuzin received a control rating significantly higher than the check. At the spring rating, both levels of metribuzin, simazine, and Sumitol gave significantly better weed control than the check.

Visual ratings at six weeks correlated with the plant count taken two weeks later were related (r^2=.83), while a rank correlation gave r^2=.81. In both cases, t tests gave $P<.001$, 11 d. f. These data indicate that the visual ratings were an accurate measure of herbicide performance.

A. elongatum stand density was reduced significantly in the spring seeded study by both levels of metribuzin and Sumitol, and the high level of simazine (Table 7; Appendix Table 7). In the fall seeded study, no

Table 6. Control of Bromus tectorum with several herbicides in a fall seeding of Agropyron elongatum.

Treatment		Weed Control 1/		
		Oct 30	Nov 13	June 12
Herbicide	Rate (kg/ha)	Visual Rating 2/	Plant Count (plant/m)	Plant Count (plant/m)
Diuron	1.68	1.00 g	5.3 ef	9.5 bc
	3.36	2.25 def	4.3 cdef	7.9 bc
Linuron	0.56	2.00 def	6.0 f	8.8 bc
	1.12	1.50 g	5.1 ef	10.2 bc
Metribuzin	0.56	3.50 ab	0.3 ab	0.2 a
	1.12	4.00 a	0.0 a	0.0 a
Simazine	1.68	2.75 bcd	2.2 abcde	2.2 a
	3.36	3.25 abc	0.7 abc	0.1 a
Sumitol	1.68	2.50 cde	1.3 abcd	1.4 a
	3.36	3.75 a	0.7 abc	0.1 a
Terbutryn	1.12	2.00 def	3.7 bcdef	8.0 bc
	2.24	1.50 fg	4.6 def	9.0 bc
Check	--	1.75 efg	3.6 bcdef	12.3 c

1/ Means of 4 replications treated September 12. 1 to 4 rating (1 = no damage, 4 = complete damage). Values within columns followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

2/ 1 to 4 rating (1 = no damage, 4 = complete damage).

Table 7. The response of Agropyron elongatum to several herbicides.

Treatment		Plants per m of Row[1/]		
			Sept 17 Seeding[3/]	
Herbicide	Rate (kg/ha)	May 29 Seeding[2/]	Fall Rating	Spring Rating
Diuron	1.68	5.7 fg	5.0	5.0 d
	3.36	3.8 cde	6.5	5.3 d
Linuron	0.56	6.8 g	5.5	4.0 bc
	1.12	4.8 defg	4.9	5.2 d
Metribuzin	0.56	1.6 ab	3.0	0.9 a
	1.12	1.2 a	3.4	0.2 a
Simazine	1.68	3.5 bcde	5.7	3.1 bc
	3.36	2.9 abcd	3.6	1.0 a
Sumitol	1.68	2.4 abc	5.2	2.7 b
	3.36	1.2 a	4.9	1.0 a
Terbutryn	1.12	6.6 g	5.8	6.0 d
	2.24	5.8 fg	6.3	5.8 d
Handweed	--	5.0 efg	--	--
Check	--	5.4 efg	5.5	5.3 d

1/ Means of 4 replications. Values within columns followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

2/ Plant counts taken September 9.

3/ Plant counts taken November 30 and June 12.

herbicide reduced *A. elongatum* stands significantly when rated in the fall (Table 7; Appendix Table 8). Spring ratings, however, indicated both levels of metribuzin, simazine, and Sumitol to be damaging (Table 7; Appendix Table 9). The significant stand reduction due to linuron at the low level was not considered real, especially in light of the greenhouse results with linuron (Table 4).

Protection of *A. elongatum* seedlings by charcoal was not equally effective for both seeding dates. No significant protection of *A. elongatum* was detected in the spring seeded study (Fig. 5; Appendix Table 7). Statistical differences between stand densities for charcoal and non-charcoal treatments were obtained for both fall and spring evaluation of the fall seeded study (Figures 6 and 7); Appendix Tables 8 and 9). Mean stand density for the charcoal treated plots evaluated in the fall was nearly 50% higher than for the non-charcoal treatments (Fig. 6). Fewer plants were present in the spring. Charcoal treatments declined 40% compared to 16% for those without charcoal; however, charcoal treated stands remained 30% higher (Fig. 7).

The effect of charcoal on *A. elongatum* stand reduction due to herbicides varied significantly among herbicides (Appendix Tables 7, 8, and 9). This significant interaction may have been due to non-uniform *A. elongatum* stands, late emergence of *A. elongatum* on some plots, or possibly insufficient charcoal for the Bozeman silt loam soil.

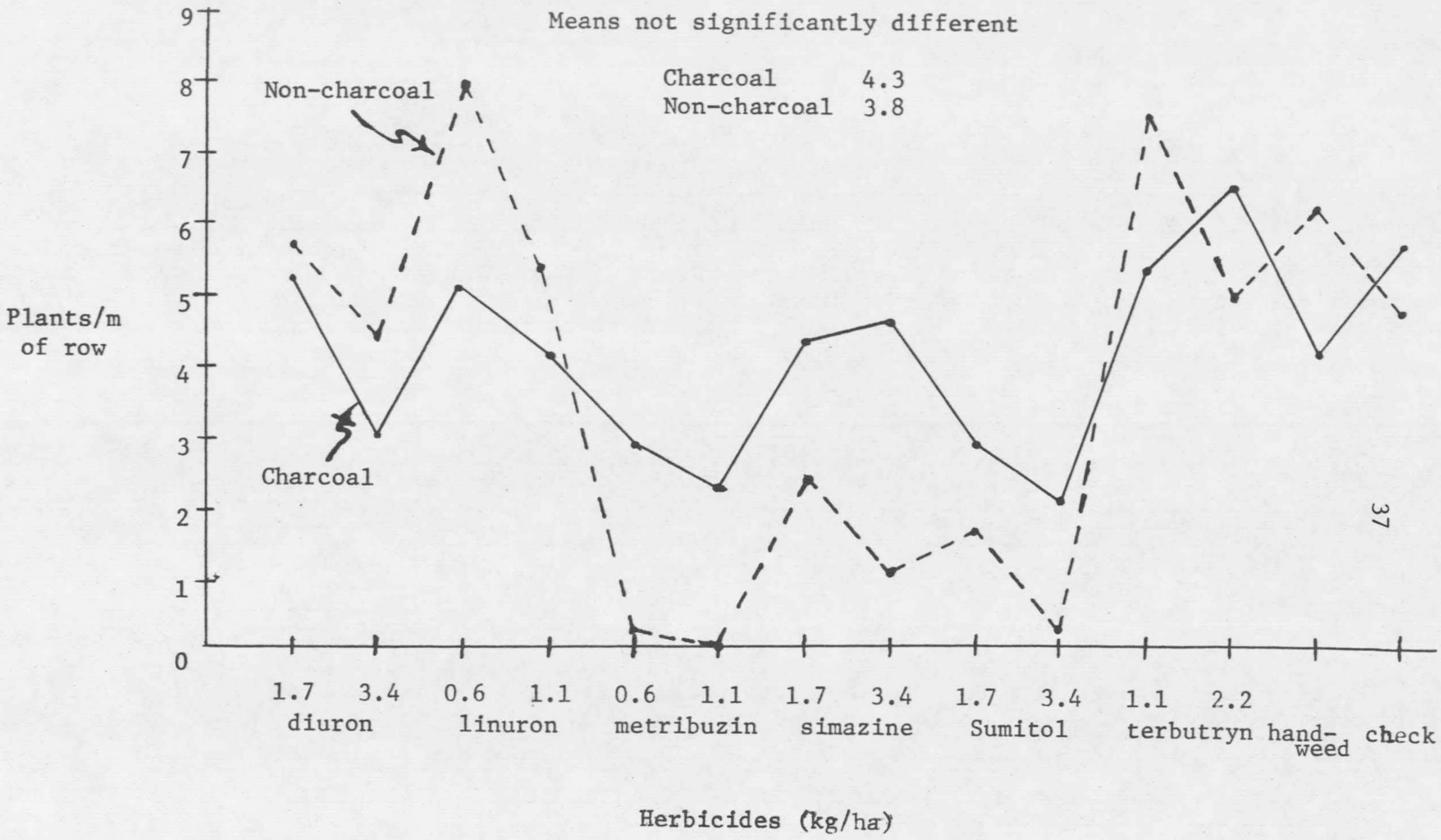

Figure 5. The effect of charcoal on the response of spring seeded Agropyron elongatum to herbicides.

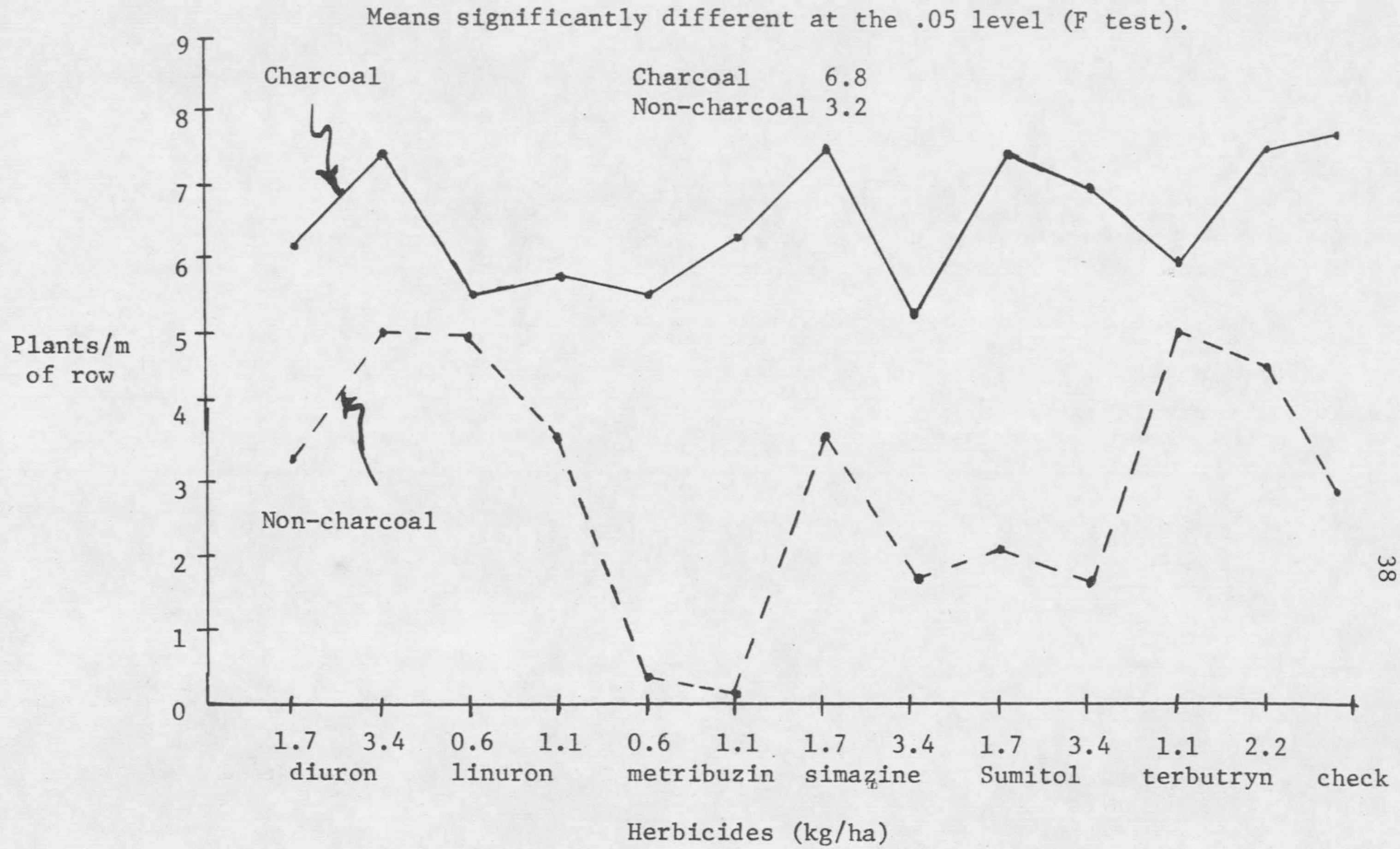

Figure 6. The effect of charcoal on herbicide injury to fall seeded <u>Agropyron elongatum</u> (fall plant count).

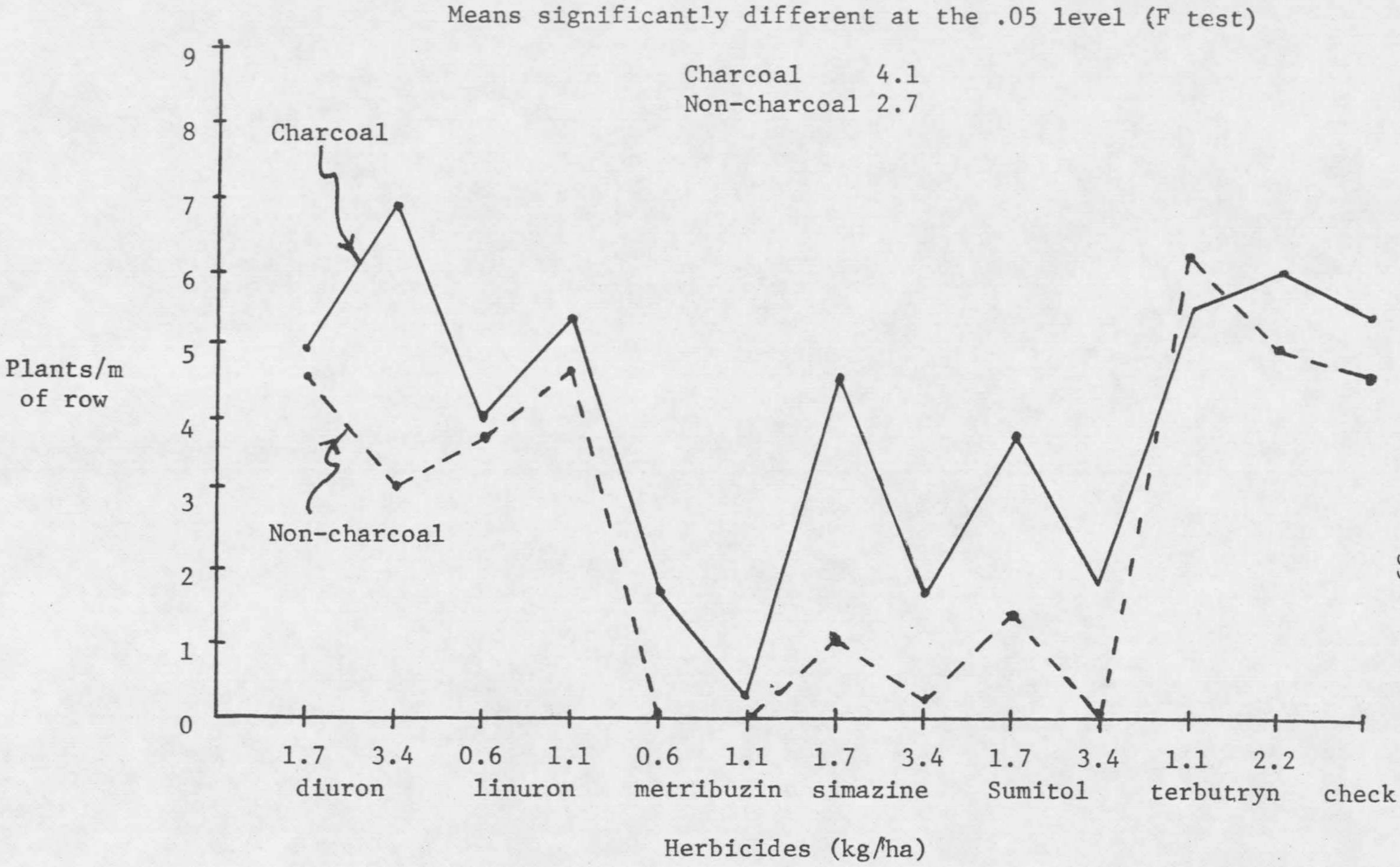

Figure 7. The effect of charcoal on herbicide injury to fall seeded Agropyron elongatum (spring plant count).

Few of the tested herbicides gave both good weed control and low A. elongatum damage. Terbutryn was the only effective treatment for A. sativa control which did not significantly reduce A. elongatum stand. Metribuzin and Sumitol provided good control of broadleaves, B. tectorum, and A. sativa. Some control of B. tectorum and broadleaves was obtained with simazine, but this material caused severe reductions in seedling A. elongatum stands.

Improved moisture storage due to snow trapping by the A. elongatum strips will increase the probability of harvesting a good crop. Limited competitive ability of the young A. elongatum plants together with susceptibility of the seedlings to many herbicides increases difficulty in establishment. Protection of A. elongatum seedlings from chemical injury by charcoal seems to be a workable solution. Further investigation is needed to determine charcoal rates necessary for Montana soils. Refinement of charcoal rates could resolve some of the charcoal x herbicide interaction in this study caused by variable protection of A. elongatum from some of the tested herbicides.

Established Agropyron elongatum. Five of the 20 treatments applied to one month old A. elongatum in the greenhouse resulted in significant dry weight reduction two months later (Table 8; Appendix Table 10). Dalapon at both rates was the only foliar application which significantly reduced yield. Yields were also reduced by soil applications of atrazine, atrazine + simazine, and terbacil.

Table 8. The effect of herbicides on one month old *Agropyron elongatum* in the glasshouse.

Treatment			
Herbicide	Rate (kg/ha)	Forage Yield 1/ (gm)	Stand Reduction Rating 1/ 2/
Foliar Application			
Barban	0.3	2.6 cde	0.0 c
Chlorbromuron	1.1	3.1 def	0.0 c
Dalapon	2.8	1.1 a	4.3 b
Dalapon	5.6	1.1 a	9.3 a
Linuron	0.6	3.5 f	0.0 c
MSMA	2.2	2.5 cd	0.0 c
Terbutryn	1.3	2.5 cd	0.0 c
Soil Application			
Atrazine	2.2	1.3 b	10.0 a
Atrazine+Simazine	0.6+2.7	1.1 a	9.7 a
Chlorbromuron	1.1	3.3 ef	0.0 c
Chlorbromuron	2.2	2.8 def	0.0 c
Diuron	1.7	2.7 cde	0.0 c
Linuron	0.6	3.0 def	0.0 c
Metribuzin	0.6	2.5 cd	0.0 c
Pronamide	0.6	1.9 bc	0.0 c
Simazine	2.2	2.5 cd	0.0 c
Sumitol	1.7	2.7 cde	1.7 c
Terbacil	0.6	1.2 a	10.0 a
Terbutryn	1.3	3.2 def	0.0 c
Trifluralin	0.6	2.9 def	0.0 c
Check	--	2.6 cde	0.0 c

1/ Means of 3 replications. Values in columns with letters in common are not significantly different at the .05 level using Duncan's Multiple Range Test.

2/ Visual rating. 0 = no damage, 10 = complete damage.

Ratings of A. elongatum injury taken after overwintering show dalapon, atrazine, the atrazine + simazine mixture, and terbacil to have caused severe stand reduction.

Of the materials which did not cause damage at either date, trifluralin (a,a,a-trifluro-2,6-dinitro-N,N-dipropyl-p-toluidine) would probably not be used because of the necessity of incorporation. Barban (4-chloro-2-butnyl-m-chlorocarbanilate) could be used for wild oat control, although interception by A. elongatum foliage might require the use of drop nozzles or higher application rates for effectiveness. Chlorbromuron, diuron, linuron, metribuzin, MSMA (monosodium methanearsonate), pronamide (3,5-dichloro-N-(1,1 dimethyl)-2-propyl benzamide), simazine, Sumitol, and terbutryn also did not cause injury.

Handweeding and the amitrole (3-amino-s-triazole) + 2,4-D treatment gave over 90% B. tectorum control in one year old A. elongatum snow barrier strips nine weeks after fall treatment (Table 9, Appendix Table 11). By the following spring, seven treatments (amitrole + 2,4-D, dalapon, the low rate of linuron, and the high rates of diuron, metribuzin, simazine, and terbacil) gave better than 70% weed control.

Six treatments caused 90% or greater control June 9: amitrole + 2,4-D, dalapon, the low rate of linuron; and the high rates of diuron, metribuzin, and terbacil. Control from the high rates of linuron, simazine, and Sumitol varied between 70% and 90%. Three materials gave less than a 50% B. tectorum control rating, while at the end of

Table 9. The effect of herbicides on Bromus tectorum in established Agropyron elongatum snow barriers.

Treatment		Weed Control Rating[1/]		
Herbicide	Rate (kg/ha)	Nov 16	May 9	June 9
Amitrole + 2,4-D	1.0 + 2.0	9.3 ab	10.0 a	9.7 a
Atrazine + Simazine	0.5 + 1.5	2.0 c	3.7 abcde	6.7 abc
Chlorbromuron	1.12	0.0 c	1.3 de	4.7 abc
	2.24	1.7 c	3.3 cde	5.0 abc
Dalapon	4.48	4.7 bc	10.0 a	9.7 a
Diuron	1.68	1.3 c	1.7 cde	2.3 c
	3.36	1.0 c	7.3 abcd	9.3 a
Linuron	0.56	2.7 c	9.3 ab	10.0 a
	1.12	1.3 c	6.7 abcd	7.7 abc
Metribuzin	0.56	0.7 c	4.7 abcde	5.7 abc
	1.12	2.3 c	7.7 abcd	9.3 a
Simazine	1.68	0.7 c	6.3 abcde	6.3 abc
	3.36	1.7 c	8.0 abc	8.7 ab
Sumitol	1.68	2.0 c	4.7 abcde	6.7 abc
	3.36	1.0 c	6.3 abcde	8.0 ab
Terbutryn	1.12	0.7 c	2.0 cde	3.3 bc
	2.24	1.3 c	3.0 bcde	5.3 abc
Terbacil	0.56	1.7 c	6.7 abcd	6.3 ab
	1.12	1.3 c	9.3 ab	9.3 a
Handweed	--	10.0 a	10.0 a	9.0 ab
Check	--	0.0 c	0.0 e	7.3 abc

1/ Means of 3 replications treated Sept 14. 0 to 10 visual rating. 0 = no control, 10 = complete control. Values in the same column followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

July no treatment gave less than 60% control. This probably is due to the fact that *B. tectorum* plants matured and dried as the season progressed.

Significant *A. elongatum* injury (Table 10; Appendix Table 12) nine weeks after treatment was limited to the amitrole + 2,4-D treatment. The following spring, amitrole + 2,4-D, dalapon, and the high rate of terbacil injured *A. elongatum* 70% or greater. Ratings in June and at harvest gave similar results, so are not reported. Forage dry weights show amitrole + 2,4-D, dalapon, the high rates of Sumitol and terbacil, and the low rate of diuron to have significantly lower yields than the handweeded check.

The best materials for *B. tectorum* control also caused severe *A. elongatum* injury. Diuron, linuron, metribuzin, simazine, Sumitol, and possibly a low rate of terbacil, controlled *B. tectorum* without serious injury to *A. elongatum*. The high level of Sumitol controlled *B. tectorum*, but *A. elongatum* yields were somewhat reduced.

Because *B. tectorum* stands were variable, it was not possible to determine how much *A. elongatum* yields were reduced by *B. tectorum* competition. *A. elongatum* yields were higher on the handweeded treatment, but not significantly so. Future work should probably include seeding of *B. tectorum* into the research plots to provide uniform stands. Investigation into the effect of *A. elongatum* injury

Table 10. The effect of herbicides on Agropyron elongatum in established snow barriers.

Treatment		A. elongatum Damage[1/]		
		Visual Rating[2/]		Forage Yield (gm/m of row)
Herbicide	Rate (kg/ha)	Nov 16	May 9	July 31
Amitrole + 2,4-D	1.00 + 2.0	8.3 a	7.0 ab	189 ab
Atrazine + Simazine	0.50 + 1.5	0.7 b	0.0 b	534 bcd
Chlorbromuron	1.12	0.0 b	0.3 b	554 cd
	2.24	0.3 b	0.3 b	635 cd
Dalapon	4.80	1.0 b	9.3 a	205 ab
Diuron	1.68	0.0 b	0.0 b	388 bc
	3.36	0.0 b	0.0 b	758 d
Linuron	0.56	0.0 b	0.3 b	572 cd
	1.12	0.0 b	0.3 b	568 cd
Metribuzin	0.56	0.0 b	0.3 b	740 d
	1.12	0.0 b	2.3 b	593 cd
Simazine	1.68	0.0 b	1.0 b	496 cd
	3.36	0.0 b	1.3 b	743 d
Sumitol	1.68	0.0 b	0.0 b	559 cd
	3.36	0.0 b	2.0 b	433 bc
Terbacil	0.56	0.0 b	0.0 b	655 cd
	1.12	0.0 b	8.0 ab	97 a
Terbutryn	1.12	0.0 b	0.0 b	589 cd
	2.24	0.0 b	0.0 b	760 d
Handweed	--	0.0 b	0.0 b	739 d
Check	--	0.0 b	0.0 b	671 cd

1/ Means of 3 replications treated Sept 14. Values in the same column followed by the same letter are not significantly different at the .05 level using Duncan's Multiple Range Test.

2/ 0 to 10 visual rating. 0 = no damage, 10 = complete damage.

on snow trapping might allow use of herbicides which cause some *A. elongatum* damage.

Solutions to the weed problems associated with the moisture conservation techniques of reduced tillage annual cropping and *A. elongatum* snow barrier strips appear possible. Herbicides are available which make limited tillage feasible, leaving standing stubble to increase moisture storage by trapping snow. Label registration for use of glyphosate on cropland is expected soon. Charcoal protection of *A. elongatum* seedlings appears to be a practical approach for herbicide use in snow barrier strip establishment, although application rates need clarification. New selective wild oat herbicides are being developed that may be of use in established *A. elongatum*. Glyphosate should be investigated as a treatment in dormant *A. elongatum* for control of *B. tectorum*.

LITERATURE CITED

Bibliography

1. Ahrens, J. J. 1964. Antidote for herbicides. Front. Pl. Sci. 17:5-7.

2. _______. 1965. Improving selectivity in horticultural crops with activated carbon. Proc. N. E. Weed Cont. Conf. 19:366-367.

3. _______. 1966. Persistance in soil of dichlobenil and EPTC applied for quackgrass control in ornamentals. Proc. N. E. Weed cont. Conf. 20:630-631.

4. Anderson, A. H. 1968. The deactivation of simazine and linuron in soil by charcoal. Weed Res. 8:58-60.

5. Anonymous. 1972. Weed control guide. Coop. Ext. Serv. Mont. State Univ.

6. Bell, A. R. and J. D. Nalewaja. 1968. Competition of wild oats in wheat and barley. Weed Sci. 16: 505-508.

7. Black, A. L. and F. H. Siddoway. 1971. Tall wheatgrass barriers for soil erosion control and water conservation. J. of Soil and Water Cons. 26:107-111.

8. _______, _______, and R. W. Saulmon. 1971. Wheatgrass barriers stop snow blowing, trap water. Mont. Farmer-Stockman 58(16):6-10.

9. Bleak, A. T. and W. Keller. 1972. Germination and emergence of selected forage species following preplant seed treatment. Crop Sci. 12:9-13.

10. Bosley, D. 1969. Bill Reed--the man who got summer-fallow off the ground. Mont. Farmer-Stockman 56(8):17-18.

11. Brenchley, R. G. 1968. Charcoal, a means of protecting crops in Oregon. Proc. W. Soc. Weed Sci. 22:10-11.

12. Brown, P. L. 1971. Water use and soil water depletion as affected by nitrogen fertilization. Agron. J. 63:43-46.

13. _______ and H. Ferguson. 1973. Crop and soil management for possible control of saline seeps in Montana. <u>In</u> Alberta Dryland Soil Salinity Workshop Proc., Lethbridge, Alta. pp. 77-92.

14. _______ and _______. 1973. Saline seep Preliminary possible control practices. Coop. Ext. Serv. Mont. State Univ. Folder 148.

15. Burr, R. J., W. O. Lee, and A. P. Appleby. 1972. Factors affecting use of activated carbon to improve herbicide selectivity. Weed Sci. 20:180-183.

16. Chepil, W. S. 1946. Germination of weed seeds. Sci. Agric. 26:307-346.

17. Clark, C. O. 1971. Saline seep development on nonirrigated cropland. In Proc. Saline Seep-Fallow Workshop. Great Falls, Mont. Sponsored by Highwood Alkali Cont. Assoc., Highwood, Mont.

18. de Brichament, G. Perrin. 1970. Similarities and differences in worldwide dryland farming. In Int. Conf. on Mech. Dry Farming. (ed) W. C. Burrows, R. E. Reynolds, F. C. Stickler, and G. E. Van Riper. John Deere and Co., Moline, Ill. pp. 20-24.

19. DeTar, W. R. 1971. Tomato seed wafers--a progress report. Amer. Soc. of Ag. Eng. 1971 Ann. Meet. Paper 71-102.

20. ______ and R. E. Johnson. 1973. Seed water research 1971-1973. Amer. Soc. of Ag. Eng. 1973 Ann. Meet. Paper 73-101.

21. Evans, R. A., H. R. Holbo, R. E. Eckert, Jr., and J. A. Young. 1970. Environment of Bromus tectorum in relation to establishment of Agropyron intermedium. Weed Sci. 18:154-162.

22. Ferguson, H. 1971. Saline seep--a serious agricultural problem. Now 7(4):3-5.

23. ______, P. L. Brown, and M. R. Miller. 1972. Saline seeps on nonirrigated lands of the northern plains. In Seminar: Control of Ag. Related Pollution in the Great Plains. Water Resources Comm., Great Plains Ag. Council Pub. 6, Lincoln, Neb.

24. Friesen, G. L., H. Shebeski, and A. D. Robinson. 1960. Economic Losses caused by weed competition in Manitoba grain fields. II. Can. J. Pl. Sci. 40:652-658.

25. Gerstner, J. 1972. Charcoal prevents herbicide damage. The Furrow. Sept-Oct pp. 26-27.

26. Greb, B. W. and A. L. Black. 1971. Vegetative barriers and artificial fences for managing snow in the central and northern plains. In Proc. Snow and Ice in Relation to Wildlife and Recreation Symposium. (ed) A. O. Haugen. Ames, Iowa. pp. 96-111.

27. Hulbert, L. C. 1955. Ecological studies of Bromus tectorum and other annual bromegrasses. Ecol. Mon. 25:181-213.

28. Jagschitz, J. A. 1968. Use of charcoal to deactivate herbicide residues in turfgrass seedbeds. Proc. N. E. Weed Cont. Conf. 22:401-408.

29. Johnson, L. P. V. 1935. General preliminary studies on the physiology of delayed germination in Avena fatua. J. Res. (C) 13:283-300.

30. Johnson, P. E., C. G. Haugh, G. F. Warren, G. E. Wilcox, and B. A. Kratky. 1969. Seed wafers, a new concept for seeding vegetables. Amer. Soc. Ag. Eng. 1970 Ann. Meet. Paper 69-667.

31. _______, _______, _______, and B. A. Kratky. 1972. Herbicide resistant seed carrier and process for manufacture thereof. U. S. Patent. 3, 648, 409.

32. Jordan, P. D. and L. W. Smith. 1971. Adsorbtion and deactivation of atrazine and diuron by charcoal. Weed Sci. 19:541-544.

33. Klemmendson, J. O. and J. G. Smith. 1964. Cheatgrass (Bromus tectorum L.). Bot. Rev. 30:226-262.

34. Krall, J. L. 1969. Changes in dryland farming and tillage methods. Mont. Farmer-Stockman 56(10):8-16.

35. Kratky, B. A. and G. F. Warren. 1971. Activated charcoal-vermiculite mixtures for increasing herbicide selectivity. Weed Sci. 19:79-81.

36. Leopold, A. C., P. van Schaik, and M. Neal. 1960. Molecular structure and herbicide adsorbtion. Weeds 8:48-54.

37. Linscott, P. L. and R. D. Hagin. 1967. Protecting alfalfa seedlings from a triazine with activated charcoal. Weed Sci. 15:304-306.

38. Lucas, E. H. and C. L. Hamner. 1947. Inactivation of 2,4-D by adsorbtion on charcoal. Sci. 105:240.

39. Martin, J. H. and W. H. Leonard. 1967. Principles of field crop production. 2nd ed. The Macmillan Co. New York, N. Y.

40. Massee, T. W., F. W. Siddoway, H. C. McKay, and S. J. Meche. 1966. Moisture conservation for wheat production in the upper Snake River dry-farming area. USDA-ARS Cons. Res. Rpt. 10.

41. Miller, M. R. 1971. Hydrology of saline-seep spots in dryland farming areas--a preliminary evaluation. In Proc. Saline Seep--Fallow Workshop. Great Falls, Mont. Sponsored by Highwood Alkali Control Assoc. Highwood, Mont.

42. Quail, P. H. and O. G. Carter. 1968. Survival and seasonal germination of seeds of *Avena fatua* and *A. ludoviciana*. Aust. J. Ag. Res. 19:721-729.

43. Ripper. W. E. 1956. A new method of selective weed control for related plants, in particular, broadleaf weeds in beets. Proc. Brit. Weed Cont. Conf. 3:225-230.

44. Robinson, D. W. 1965. The use of adsorbants and simazine on newly planted strawberries. Weed Res. 5:43-51.

45. Rydrich, D. J. 1974. Competition between winter wheat and downy brome. Weed Sci. 22:211-214.

46. Sexsmith, J. J. 1967. Varietal differences in seed dormancy of wild oats. Weeds 15:252-255.

47. ______. 1969. Dormancy of wild oat seed produced under various temperature and moisture conditions. Weed Sci. 17:405-407.

48. Siddoway, F. H. 1970. Barriers for wind erosion control and water conservation. J. of soil and Water Cons. 25:180-184.

49. Smika, D. E. and C. J. Whitfield. 1966. Effect of standing wheat stubble on storage of winter precipitation. J. of Soil and Water Cons. 21:138-141.

50. Steinbauer, G. P. and B. H. Grigsby, 1957. Field and laboratory studies on the dormancy and germination of the seeds of chess (*Bromus secalinus* L.) and downy bromegrass (*Bromus tectorum* L.). Weeds 5:1-4.

51. Thurston, J. M. 1966. Survival of seeds of wild oat (*Avena fatua* L. and *Avena ludoviciana* Dur.) and charlock (*Sinapi arvensis* L.) in soil under leys. Weed Res. 6:67-80.

52. Vogelsand, P. 1954. Herbicide resistant coated seed. U. S. Patent 2, 671, 985.

53. Walker, P. L., Jr. 1962. Carbon--an old but new material. Amer. Sci. 50:259-293.

54. Warden, R. F. 1954. Why that north slope alkali. Mont. Farmer-Stockman 42(1):1, 17.

55. Weed Sci. Soc. of Amer. 1970. Herbicide Handbook. WSSA Monograph 3. 2nd ed. W. F. Humphrey Press. Geneva, N. Y.

56. Young, J. A., R. A. Evans, and R. E. Eckert, Jr. 1969. Population dynamics of downy brome. Weed Sci. 17:20-26.

APPENDIX

Table 1. Some characteristics of herbicides tested (55).

Common Name	Manufacturer	Registered Trademark	Chemical Group	Mode of Application[1/]	Characteristics in soil	Persistance in soil
atrazine	CIBA-Geigy	Aatrex	triazine	Soil (t)	Adsorbed & desorbed. generally stays in top 30 cm.	Less than 12 mo.
amitrole	Amchem American Cyanimid	Amizol Amino Triazole Weed Killer	triazole	Foliar (t)	--	2-4 weeks
barban	Gulf	Carbyne	carbamate	Foliar (t)	Adsorbed and held	3 weeks
chlorbromuron	CIBA-Geigy	Maloran	substituted urea	Soil and foliar directed (t)	--	--
2,4-D	--	--	phenoxy acid	Foliar and soil (t)	Adsorbed	1-4 weeks
dalapon	Dow	Dowpon	propionic acid	Foliar (t)	Leaches rapidly	2-4 weeks
dinoseb	Dow	Dow General Weed Killer	dinitro-phenol	Foliar (c)	Leaches, partial adsorbtion	2-4 weeks
diuron	duPont	Karmex	substituted urea	Soil (t)	Some adsorbtion, little leaching	1 season
glyphosate	Monsanto	Roundup	glycine	Foliar (t)	No known soil activity	--

Table 1. (Con't)

Common Name	Manufacturer	Registered Trademark	Chemical Group	Mode of Application[1]	Characteristics in soil	Persistance in soil
GS-14254	CIBA-Geigy	Sumitol	triazine	Soil (t)	No leaching, strongly adsorbed	4-6 mo.
linuron	duPont	Lorox	substituted urea	Soil, foliar with surfactant	Not much adsorbtion	4 mo.
metribuzin	Chemagro	Sencor	triazine	Soil (t)	--	--
MSMA	Ansul Amchem	Ansar Trans-Vert	arsenical	Foliar (t)	Inactivated by adsorb- tion & ion exchange	very little
paraquat	Chevron	Ortho Paraquat	bipridinum salt	Foliar (c)	Rapid deactivation, long persistence	long
pronamide	Rohm & Haas	Kerb	amide	Soil (t)	--	--
simazine	CIBA-Geigy	Princep	triazine	Soil (t)	Some adsorbtion, stays in top 5 cm	1 year
terbacil	duPont	Sinbar	substituted uracil	Soil (t)	--	Half-life 5-6 mo.
terbutryn	CIBA-Geigy	Igran	triazine	Foliar and soil (t)	adsorbed and desorbed	3-10 weeks

Table 1. (Con't)

Common Name	Manufacturer[2]	Registered Trademark[2]	Chemical Group	Mode of Application[1]	Characteristics in soil	Persistance in soil
trifluralin	Elanco	Treflan	toluidine	Soil, pre-emergence incorperated (t)	Adsorbed, no leaching	4-6 mo.

[1] t = translocated, c = contact

Table 2. ANOVA tables for the effect of herbicides on *Bromus tectorum* in wheat stubble (Text Table 1).

Oct 6 Rating

Source	d.f.	M.S.
Total	27	--
Treatments	6	13.43
Blocks	3	0.57
Error	18	0.24

Coefficient of Variation 0.26

May 9 Rating (Regrowth)

Source	d.f.	M.S.
Total	35	--
Treatments	8	3.44
Blocks	3	0.22
Error	24	0.41

Coefficient of Variation 0.23

May 9 Rating (Seedling)

Source	d.f.	M.S.
Total	35	--
Treatment	8	5.72
Blocks	3	0.37
Error	24	0.39

Coefficient of Variation 0.27

Table 3. ANOVA table for the effect of charcoal and herbicides on *Agropyron elongatum* seedlings in the glasshouse (Text Tables 3 and 4).

Source	d.f.	M.S.
Total	701	--
Blocks	2	21.90
Treatments	(233)	42.97
Dates	12	213.92
Herbicides	17	319.27
D x H	104	19.40
Error	566	2.97
Coefficient of Variation	0.41	

Table 4. ANOVA tables for the effect of herbicides on weeds in spring seeded *Agropyron elongatum* (Text Table 5).

Oat
July 9 Rating

Source	d.f.	M.S.
Total	55	--
Treatments	13	4.77
Blocks	3	0.02
Error	39	0.22
Coefficient of Variation 0.22		

Oat
Sept 7 Rating

Source	d.f.	M.S.
Total	55	--
Treatments	13	2.70
Blocks	3	2.91
Error	39	0.69
Coefficient of Variation 0.36		

Broadleaf
July 9 Rating

Source	d.f.	M.S.
Total	55	--
Treatments	13	3.48
Blocks	3	0.30
Error	39	0.39
Coefficient of Variation 0.24		

Broadleaf
Sept 7 Rating

Source	d.f.	M.S.
Total	55	--
Treatments	13	4.97
Blocks	3	0.21
Error	39	0.38
Coefficient of Variation 0.28		

Table 5. ANOVA tables for the effect of herbicides on *Bromus tectorum* in fall seeded *Agropyron elongatum*, fall rating (Text Table 6).

Oct 6 Rating

Source	d.f.	M.S.
Total	51	--
Treatments	12	3.59
Blocks	3	1.76
Error	36	0.38

Coefficient of Variation 0.25

Nov 13 Rating

Source	d.f.	M.S.
Total	51	--
Treatments	12	107.40
Blocks	3	64.12
Error	36	28.27

Coefficient of Variation 0.63

Table 6. ANOVA table for the effect of herbicides on _Bromus tectorum_ in fall seeded _Agropyron elongatum_, spring rating (Text Table 6).

June 12 Rating

Source	d.f.	M.S.
Grand Total	104	--
(Herbicide ANOVA)		
Total	51	--
Treatment	12	261.21
Blocks	3	44.23
Error A	36	15.04
Coefficient of Variation	0.59	
(Charcoal ANOVA)		
Total	7	--
Treatment	1	0.61
Blocks	(3)	44.23
Error B	3	3.05
Coefficient of Variation	0.27	
(Interaction ANOVA)		
Total	104	--
C x H	12	3.05
Error C	36	2.07
Coefficient of Variation	0.22	

Table 7. ANOVA table for the effect of charcoal on herbicide injury to spring seeded Agropyron elongatum (Text Table 7, Figure 5).

Sept 9 Rating

Source	d.f.	M.S.
Grand Total	111	--
(Herbicide ANOVA)		
Total	55	--
Treatments	13	183.8
Blocks	3	146.2
Error A	39	39.2
Coefficient of Variation	0.64	
(Charcoal ANOVA)		
Total	7	--
Treatment	1	37.7
Blocks	(3)	146.2
Error B	3	74.6
Coefficient of Variation	0.88	
(Interaction ANOVA)		
Total	111	--
C x H	13	49.9
Error C	39	15.2
Coefficient of Variation	0.40	

Table 8. ANOVA table for the effect of charcoal on herbicide injury to fall seeded *Agropyron elongatum*, fall rating (Text Table 7; Figure 6).

Nov 30 Rating

Source	d.f.	M.S.
Grand Total	104	--
	(Herbicide ANOVA)	
Total	51	--
Treatments	12	55.0
Blocks	3	98.4
Error A	36	30.5
Coefficient of Variation	0.45	
	(Charcoal ANOVA)	
Total	7	--
Treatments	1	1929.9
Blocks	(3)	98.4
Error B	3	106.3
Coefficient of Variation	0.85	
	(Interaction ANOVA)	
Total	104	--
C x H	12	36.3
Error C	36	16.6
Coefficient of Variation	0.33	

Table 9. ANOVA table for the effect of charcoal on herbicide injury to fall seeded *Agropyron elongatum*, spring rating (Text Tables 7; Figure 7).

June 12 Rating

Source	d.f.	M.S.
Grand Total	104	--
(Herbicide ANOVA)		
Total	51	--
Treatments	12	213.85
Blocks	3	27.56
Error A	36	12.22
Coefficient of Variation	0.41	
(Charcoal ANOVA)		
Total	7	--
Treatments	1	304.65
Blocks	(3)	27.56
Error B	3	23.39
Coefficient of Variation	0.57	
(Interaction ANOVA)		
Total	104	--
C x H	12	21.59
Error C	36	5.86
Coefficient of Variation	0.28	

Table 10. ANOVA tables for the effect of herbicides on one month old *Agropyron elongatum* in the glasshouse (Text Table 8).

Dry Weight Reduction

Source	d.f.	M.S.
Total	62	--
Treatment	20	1.77
Blocks	2	0.01
Error	40	0.15

Coefficient of Variation 0.16

Spring Stand Reduction

Source	d.f.	M.S.
Total	62	--
Treatment	20	45.85
Blocks	2	2.33
Error	40	1.15

Coefficient of Variation 0.50

Table 11. ANOVA tables for the effect of herbicides in *Bromus tectorum* in established *Agropyron elongatum* snow barriers (Text Table 9).

Nov 16 Rating

Source	d.f.	M.S.
Total	62	--
Treatment	20	71.40
Blocks	2	68.87
Error	40	8.45

Coefficient of Variation 1.29

May 9 Rating

Source	d.f.	M.S.
Total	62	--
Treatment	20	29.49
Blocks	2	14.30
Error	40	11.17

Coefficient of Variation 0.58

June 9 Rating

Source	d.f.	M.S.
Total	62	--
Treatment	20	19.45
Blocks	2	16.00
Error	40	8.42

Coefficient of Variation 0.41

Table 12. ANOVA tables for the effect of herbicides on Agropyron elongatum in established snow barriers (Text Table 10).

Nov 16 Rating

Source	d.f.	M.S.
Total	62	--
Treatments	20	9.68
Blocks	2	0.29
Error	40	0.23

Coefficient of Variation 0.98

May 9 Rating

Source	d.f.	M.S.
Total	62	--
Treatments	20	24.29
Blocks	2	0.44
Error	40	1.26

Coefficient of Variation 0.73

July 31 Forage Yield

Source	d.f.	M.S.
Total	62	--
Treatments	20	398,484.66
Blocks	2	504,283.89
Error	40	77,225.71

Coefficient of Variation 0.26