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
Montana State University

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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Date August 5, 1974

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by

ALAN VONN TASKER

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

of

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in

Agronomy

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Bozeman, Montana

August, 1974

ACKNOWLEDGMENT

Thanks are due my major professor, Mr. L. O. Baker, for both physical help and mental encouragement. Members of my graduate committee: Drs. S. R. Chapman, K. C. Feltner, and J. M. Hodson were of great assistance. Drs. P. L. Brown and A. H. Ferguson contributed ideas from their expertise with the saline seep problem. Dr. L. E. Weisner aided with some helpful ideas about charcoal application. Mr. Norris Hanford of Fort Benton graciously contributed field space for the major part of this study. My wife, Linda, must also be commended for her patience and encouragement.

Services or materials were contributed by:

Amchem Products Inc.[1/]

Atlas Chem. Div. of ICI American

Bridger USDA Plant Materials Center

CIBA-Geigy Corp.

Chemagro Corp.

Chevron Chem. Co., Ortho Div.

The Dow Chem. Co.

E. I. duPont de Nemours & Co.

Elanco Products Div. of Eli Lilly & Co.

Gulf Oil Co., Agric. Chem. Div.

Monsanto Co., Agric. Div.

Montana State Grain Inspection Lab.

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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-

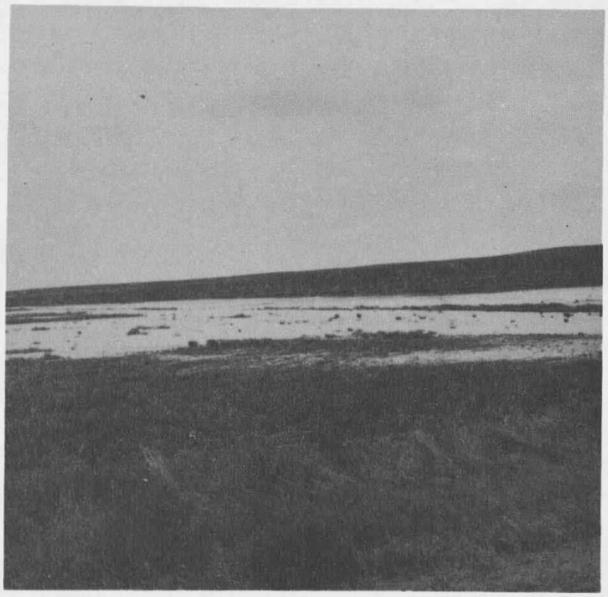

Figure 1. Typical saline seep in northern Montana cropland.

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.),

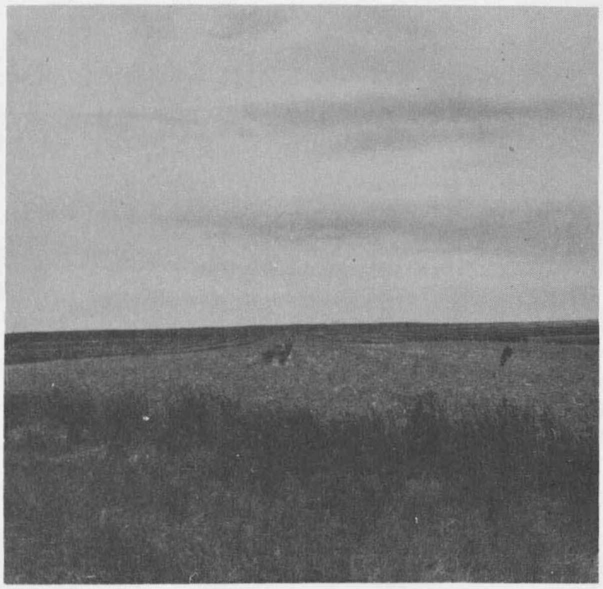

Figure 2. Agropyron elongatum snow barrier strips in northern Montana.

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 $11\frac{1}{2}$ 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^{o} C and weekly mean maximum temperature does not exceed 28^{o} 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 $6\frac{1}{2}$ 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