AN ABSTRACT OF THE THESIS OF

Claude Gary Ross for the M.S. in Farm Crops
(Degree)

Date thesis is presented June 10, 1966

Title INFLUENCE OF SOIL MOISTURE ON THE MOVEMENT OF BROMACIL IN SOIL

Abstract approved [redacted]
(Major professor)

In previous research, bromacil gave good performance when it was applied in early fall with fairly dry soil conditions and before the fall germinating weeds had started growth. On the other hand, if bromacil was applied in late November, December, or January on nearly saturated soil with weeds that had grown for one or two months, weed control was quite noticeably reduced. Field and greenhouse studies were conducted at Corvallis, Oregon, to determine the influence of soil moisture and time of herbicide application on bromacil movement and performance.

In one field trial, two or six acre-inches of water were applied by sprinkler irrigation at intervals following herbicide treatment. Intervals used were one day, two, four, or eight weeks following herbicide application on dry soil. Field bioassay with rape, wheat, oats, annual bluegrass, sugar beets, and winter field peas indicated that the performance of bromacil applied to dry soil was not affected by

differences in irrigation levels or by the time interval between application and irrigation. Bioassay of core segments taken from the top six inches of soil showed no difference due to treatment and indicated that bromacil was not leached below three inches regardless of irrigation treatment. Of the bromacil found in the top three inches, approximately half of it was in the 0-1 inch segment.

Difficulty in duplicating fall conditions appeared to have a definite effect on results of field studies. Extensive loss of soil moisture due to evaporation was probably the main factor causing deviation from the desired conditions.

Another field trial included 0-, 1.5-, 3-, and 6-inch sprinkler irrigation rates on an annual bluegrass stand which had been treated with either pre- or post-emergence applications of bromacil. Irrigations were applied immediately after the post-emergence treatment. Both pre- and post-emergence applications of bromacil gave good control of annual bluegrass regardless of subsequent post-emergence irrigation. However, total precipitation during the first month was only 0.25 inches and where there was no irrigation, bromacil did not give adequate control.

Greenhouse leaching studies with soil columns did not give satisfactory results. Consistent patterns of leaching throughout replications could not be accomplished. When bromacil movement was determined by the use of soil columns and subirrigation with 1.5 inches of water, there was no difference in movement whether it was applied to water-saturated or dry soil. A preliminary experiment with a shorter subirrigation period, however, resulted in less movement of the bromacil applied to dry soil.

Bromacil movement in soil by subirrigation is not the same as leaching downward. Water moving through soil from subirrigation occurs through all except the very large pores; whereas in downward leaching, water primarily moves by gravity through the large pores once the small pores are filled.

INFLUENCE OF SOIL MOISTURE ON THE MOVEMENT OF BROMACIL IN SOIL

by

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A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1967

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Date thesis is presented June 10, 1966

Typed by Kay Smith

ACKNOWLEDGMENT

I am grateful to Dr. Arnold P. Appleby for his patience and guidance throughout my graduate program, and for his critical reading and correction of the manuscript.

My appreciation is expressed to Dr. W. R. Furtick for his guidance and critical reading of the manuscript.

Gratitude is also expressed to Dr. William W. Chilcote, who served on my graduate advisory committee.

Special thanks go to Larry Burrill, Floyd Colbert, and Allen Fechtig for their valuable assistance in research.

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INFLUENCE OF SOIL MOISTURE ON THE MOVEMENT OF BROMACIL IN SOIL

INTRODUCTION

Bromacil is a soil-active herbicide that has been used commercially as a soil sterilant and in research on a variety of crops. Early fall applications of this compound in western Oregon have given better weed control than applications in late fall or winter. This has been noted over a range of soils and is not thought to be characteristic of a particular soil type. The Willamette Valley has a Mediterranean type climate with relatively dry soil conditions prevailing until early to mid-October. Rainfall gradually increases through November, December, and January reaching an average total of 12.6 inches during the latter two months, then decreases in the spring.

The difference in herbicidal activity may be due to increased leaching when this compound is applied to moist soil and subjected to the heavy and continual winter rainfall. When the bromacil is applied to dry soil or damp soil that is allowed to dry the leaching effect appears to be markedly retarded.

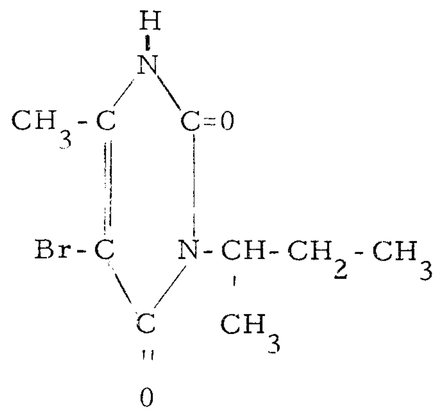
Another possibility might be the growth stage that the weeds are in at the time of bromacil application. A pre-emergence or early post-emergence application might be significantly more effective in weed control than an application when the weeds have already grown to some extent.

The objective of this thesis was to determine what influence the timing of rainfall or irrigation and timing of bromacil application would have on this compound's performance.

LITERATURE REVIEW

Properties of Bromacil

Bromacil (5-bromo-3-sec butyl-6-methyl uracil) is a member of a recently discovered class of herbicides, the substituted uracils. The structural formula is:



Information from E. I. DuPont de Nemours & Co. (7) indicates that pure bromacil is an odorless, white crystalline solid with a melting point of 158 to 159°C. It is soluble in water at room temperature to the extent of 815 parts per million and to a much greater degree in the presence of a strong base. Tests in which bromacil was exposed to elevated temperatures and direct sunlight indicated that losses from soil because of volatilization or photodecomposition were negligible with this compound. Bromacil does not ionize to any great extent when it is in solution (7).

DuPont (6) has found this compound to be highly active against a broad spectrum of grasses and broadleaf weeds. Bromacil, in its wettable powder formulation, is intended to be dispersed in water and applied as a spray to the soil surface. Here it is carried by rainfall into the soil where it can be taken up by the roots of weeds. Bromacil is activated with a very small amount of rainfall. Since breakdown of this compound by heat and light is negligible, it will persist on the soil surface until precipitation occurs. Persistence has been quite high under fairly dry conditions (6).

In many instances, bromacil has been applied alone or in combination for soil sterilant purposes (18). Other uses have also been reported. Foy and Gibson (9) reported excellent weed control in established alfalfa at one pound per acre, but some alfalfa injury resulted. Lee (16) reported that bromacil at rates from 0.5 to 1.5 pounds per acre were very effective in controlling downy brome and that Merion bluegrass was not injured at these rates.

Herbicide Movement in Soil

Effectiveness of soil-applied herbicides has been strongly influenced by the extent of their movement in soil (13). Two factors which seem to be generally recognized as important in affecting movement of a herbicide in the soil are soil type and the amount of precipitation. Ogle and Warren (17) in their work with the fate and activity of herbicides in soil, showed that there was an interaction of herbicides and soil type in relation to herbicide movement and retention. They worked with a sandy soil, a silt loam, and a muck soil and found that 2, 4-D was readily leached in the mineral soils but was resistant to movement in muck. Upchurch and Pierce (22) found that the organic matter content of soil had a large effect upon the leaching of monuron. As the average organic matter in the 0 to 8 inch layer of a soil column was increased from 0. 87 to 1. 44 percent, the amount of monuron retained after leaching was increased from 35 to 95 percent. Holstun and Loomis (14) altered the leaching characteristics of soils; adding manure decreased the mobility of dalapon and adding sand increased its mobility.

The amount of leaching has been shown to be directly dependent on the amount of rainfall (17). In soil column studies Upchurch and Pierce (21) found that four inches of simulated rainfall applied in eight increments at one-half hour intervals leached 72 percent of a 40 pound per acre application of monuron below two inches and eight percent below 24 inches. Twelve inches of simulated rainfall applied in a similar manner on soil columns leached 89 percent of the monuron below two inches and 51 percent below 24 inches.

Adsorption

The relationship between leachability and adsorption is not clearly known (2). There are too many exceptions to the general rules that have been given. Upchurch and Pierce (22) stated "at least two processes determine the leachability of a herbicide, entrance of the compound into solution and adsorption". However, in his later discussion on the behavior of herbicides in soil, Upchurch (20) indicated that most of the thinking on this has been on the basis of delay in herbicide movement due to adsorption. Hance's (10) work with the adsorption of urea and some of its derivatives showed no relationship between adsorption and water solubility.

There are two basic types of adsorption, chemical and physical (2). Adamson (1) stated that chemical adsorption is distinguished from physical adsorption in that some degree of specific chemical interaction between the adsorbate and the adsorbent is involved and the strength of the adsorption is quite strong, comparable to that of a chemical bond formation.

Bailey and White (2) indicated that physical adsorption from solution to soil occurs as a result of non-specific forces of attraction between the solid and the adsorbate, such as van der Waals forces, and that chemical bonds as such are not involved. The energies involved are comparable to those of liquification of water vapor (1). Prutton (19) stated that the molecular forces at the surface of a liquid are in a state of unbalance or unsaturation. The same is true of the surface of a solid, where the molecules or ions in the surface of a crystal do not have all their forces satisfied by union with other particles. As a result of this unsaturation, these solid surfaces tend to satisfy their residual forces by attracting and retaining on their surfaces, gases or dissolved substances with which they come in contact (19).

Adsorption Competition

Bailey and White (2) indicated that adsorption on a solid surface is a selective or competitive process, with a given solute adsorbed in competition with other solutes and with the solvent. The adsorption of both solute and solvent by the soil colloid is quite evident. The main point is, to what extent each is adsorbed. Brey (4) made the point that, in general, the greater the solubility of the solute in the solvent, the less the extent of its adsorption. For a particular soil colloid, preferential adsorption of either the solute or solvent is a function of the relative strength of the forces acting between the surface of the solid and the molecules of the solute and solvent, as well as the interaction between solute and solvent (2).

Adsorption from solution is a readily reversible process (4). If an adsorbent is brought into contact with a concentrated solution of material which can be adsorbed, an adsorption-desorption equilibrium between soil and solution is attained. When the solution is diluted with more solvent, however, an increased portion of the adsorbate is taken into solution. The same amount is finally adsorbed as if the diluted solution had been treated directly with the solid (4).

Deming (5) found that under some circumstances the volatility response of CDAA to temperature was reversed to give a decreasing loss with increasing temperature. The volatility-temperature relationship was found to be strongly influenced by the amount of water present on the soil colloid, with increasing amounts of water accelerating CDAA volatility loss. The mechanism for this reaction appeared to involve competition between water and CDAA for adsorption sites; therefore, the more competition for adsorption sites, the more CDAA is available for volatilization. This factor, however, was not differentiated from removal of CDAA from soil by simple solubilization in water with subsequent steam distillation.

Fang, et al. (8) have obtained results with EPTC similar to those of Deming above. Their study of the volatile EPTC showed that loss from dry soil was much less than from wet soils. This evidence suggested that the persistence was due to the ability of soil particles to adsorb this chemical in the absence of water.

Hance (11) demonstrated this competition for adsorption sites with a non-volatile type herbicide, diuron. He showed that adsorption of diuron was much lower on hydrophillic materials such as cellulose, chitin, aluminum oxide and a soil mineral fraction than on the less hydrophilic ion exchange resins, lignin, carbon and a soil organic fraction. This does not disprove the theory that, in general, the amount of the solute in solution is dependent upon the amount of solvent present, but it does emphasize the point that a fairly soluble compound in low concentration in the soil water has very little opportunity to become adsorbed until the water content of the soil has been decreased to a great extent.

FIELD LEACHING STUDY

Methods and Materials

A field trial was established in July, 1965 to determine the influence of time interval between application and rainfall upon leaching of bromacil. Since no significant rainfall occurs in July, August, and September, sprinkler irrigation was the only source of leaching moisture introduced in the trial. A split-split-plot design with four replications was used. The intervals of one day, two weeks, four weeks, and eight weeks between bromacil application and irrigation made up the main plots; the sub-plots consisted of irrigation levels of two inches and six inches; and rates of 0, 0.2, 0.4, 0.8, and 1.2 pounds of active bromacil per acre made up the sub-sub-plots. The main plots were 30 x 60 feet, the sub-plots 30 x 30 feet, and the sub-sub-plots 6 x 30 feet. Three-foot alleys separated sub-plots to make irrigation less exacting and allow less chance for water to flow from one sub-plot to the next.

Table 1. Chemical and mechanical analysis of Woodburn surface soil from the experimental area.

Soil pH	CEC meq/100g.	% o. m.	Sand %>.05mm	Wilt %.05-.002	Clay %<.002mm
5.6	17.1	4.14	9.86	69.9	20.2

The sub-sub-plots of bromacil rates were applied as a wettable powder in water by means of a one-wheeled, compressed-air plot sprayer. Each sub-plot was irrigated separately by setting a "Rainbird" quarter-circle sprinkler in each corner of the plots. This gave fairly even distribution of the irrigating water.

The study area had been previously leveled and the soil tilled. Four days before chemical treatments were applied on July 24, the plot area was irrigated with approximately one inch of water by means of overhead sprinklers. Due to hot dry conditions, however, the surface of the soil was dry at the time bromacil was applied. On the day following application, the first irrigations were started. Each individual sub-plot had its total amount of irrigation within a 48-hour period, but not all of them could be irrigated at the same time. Due to difficulty in manipulating irrigation facilities, four days were required to irrigate all sub-plots. At the 2-week 4-week, and 8-week intervals, remaining sub-plots were irrigated.

As soon as the last irrigation was completed and the soil dried, core samples to a depth of 24 inches were taken. The core sampler was a hydraulic apparatus mounted on the back of a pickup. Cores obtained were 1.25 inches in diameter and were divided into segments of 0-1, 1-3, 3-6, 6-12, and 12-24 inches in depth. These were taken from the 0.4 and 1.2 pound rates of bromacil. Four core samples were taken from each sub-sub-plot at 8-foot intervals, starting three feet in from the end of each plot. In order to obtain sufficient soil for bioassay purposes, a hand sampler was used to take additional 2.5 inch diameter cores at the 0-1, 1-3, and 3-6 inch depths. All samples from each depth within each sub-sub-plot were bulked, dried, and bioassayed.

On October 18, 1965, after core samples were taken, six test species, rape, wheat, oats, annual bluegrass, sugar beets, and winter field peas, were planted in five-foot strips across bromacil treatments. From results of previous screening trials, the first four species were considered most sensitive and the latter two, least sensitive. With winter rainfall beginning, no irrigation was required for the seeds to germinate and grow.

Visual evaluations of stand densities in treated sub-sub-plots as compared to no bromacil treatment were made on January 18, 1966, when maximum effects of treatments could be seen.

Density of each of the treated sub-sub-plots was estimated, considering the no-bromacil treatment as a 100 percent density. These density estimates were made independently by two evaluators. Their estimates were averaged and these figures averaged for the four replications.

Results

Of the six test species selected for the field bioassay, only four were evaluated. The stand of sugar beets was very poor and the effect of bromacil treatments was impossible to distinguish. There was a very good stand of winter field peas, but this species was so tolerant to the rates of bromacil that no differences between treatments could be seen. The remaining species (rape, wheat, oats, and annual bluegrass) were visually evaluated in each sub-sub-plot. Original data are in the Appendix, Tables 1-4. Densities in the four rates of bromacil were graphed in relation to time interval between bromacil application and leaching by irrigation. Results for each species are given in Figures 1-4.

To reiterate, the purpose of this trial was to simulate fall conditions with irrigation and determine the effect of time interval between bromacil application and irrigation on the performance of this herbicide.

Graphs of each of the bioassay species show no apparent effect of either amount of irrigation or of the time interval. Very low levels of soil moisture at the time of bromacil application may have eliminated differences. Had it been possible to keep the soil more moist throughout the experiment, time interval between application and irrigation could well have caused differences in bromacil adsorption and subsequent performance.

Figure 1. Field bioassay of leaching study using wheat as a test species.

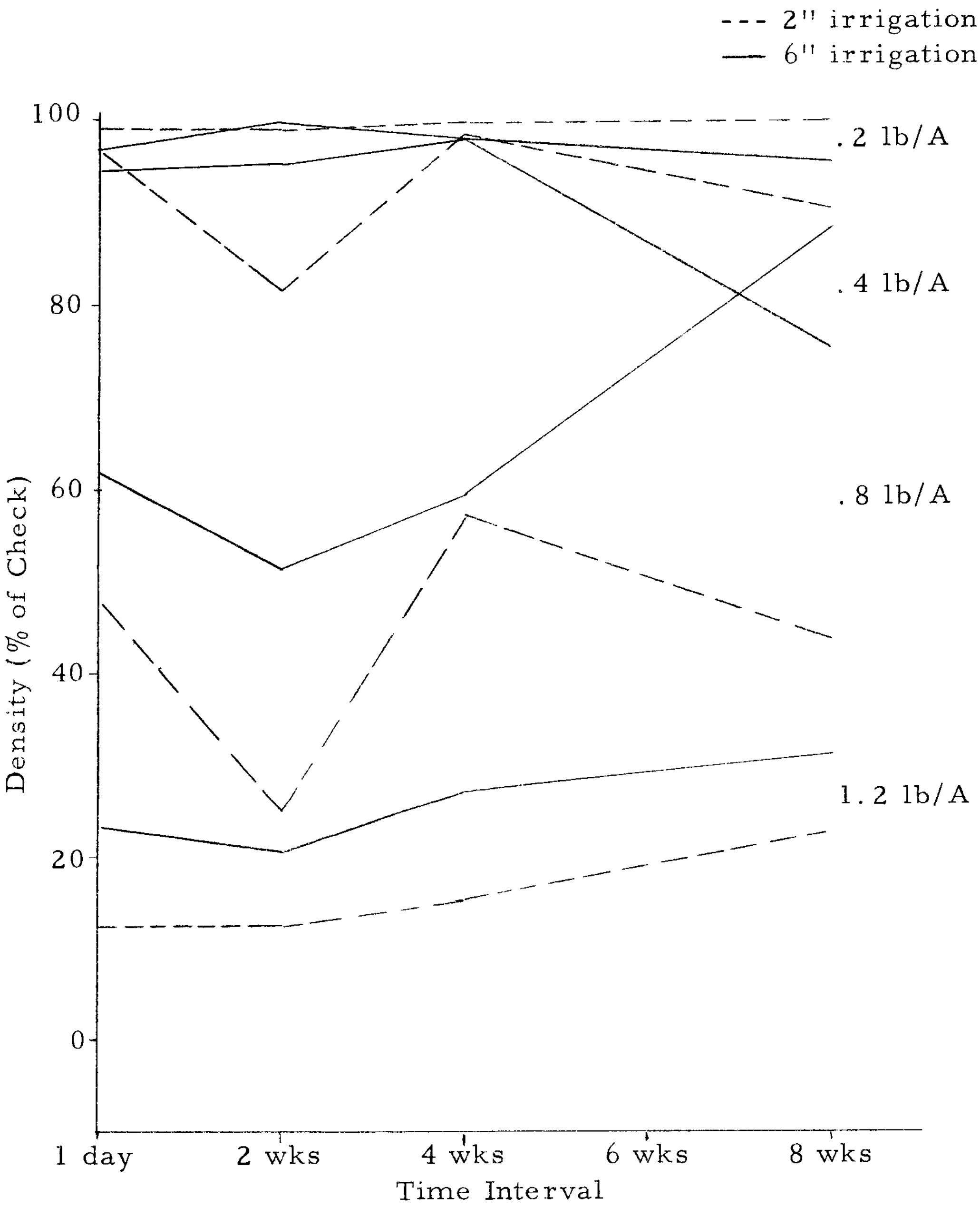


Figure 2. Field bioassay of leaching study using annual bluegrass as the test species.

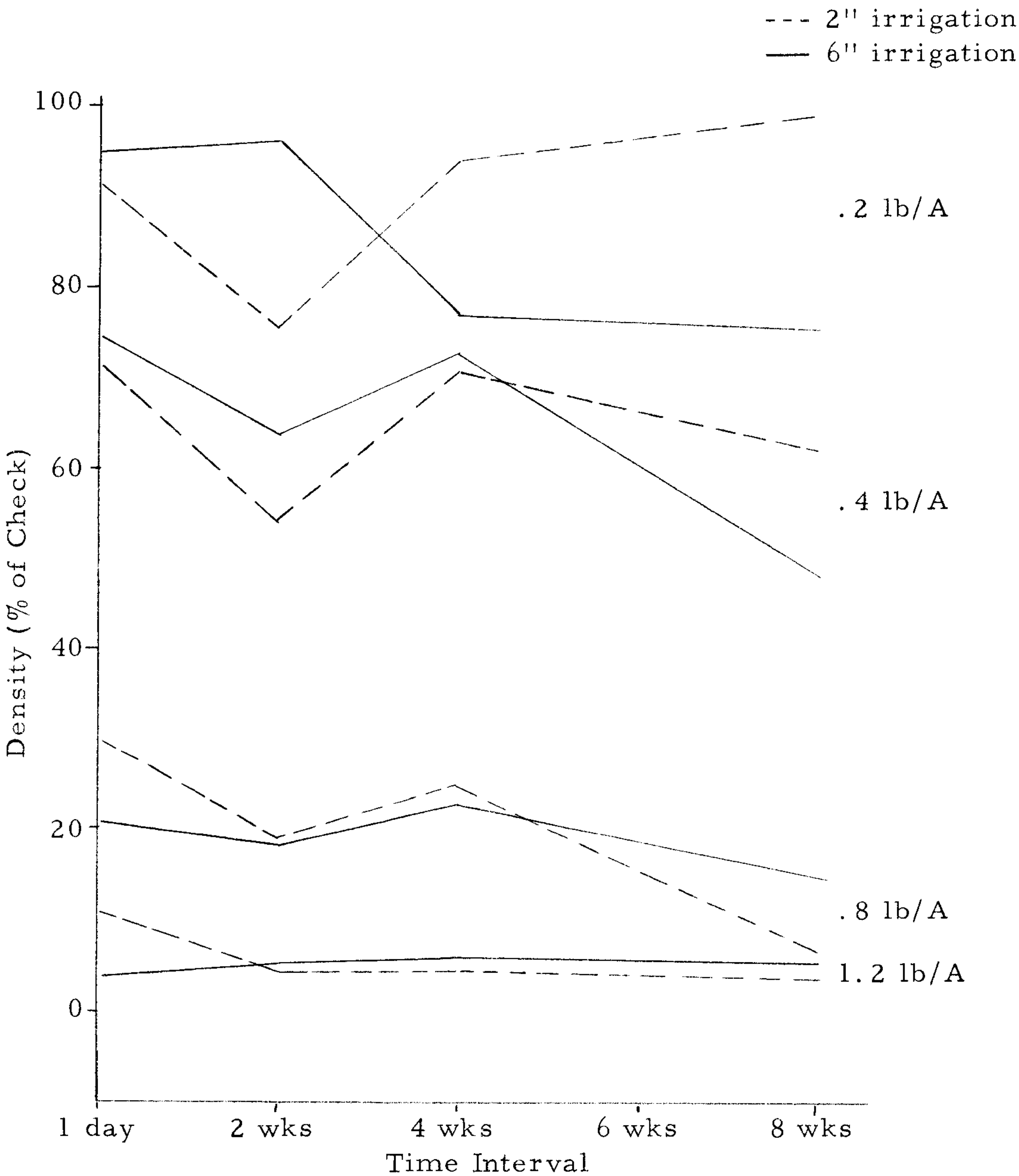


Figure 3. Field bioassay of leaching study using oats as the test species.

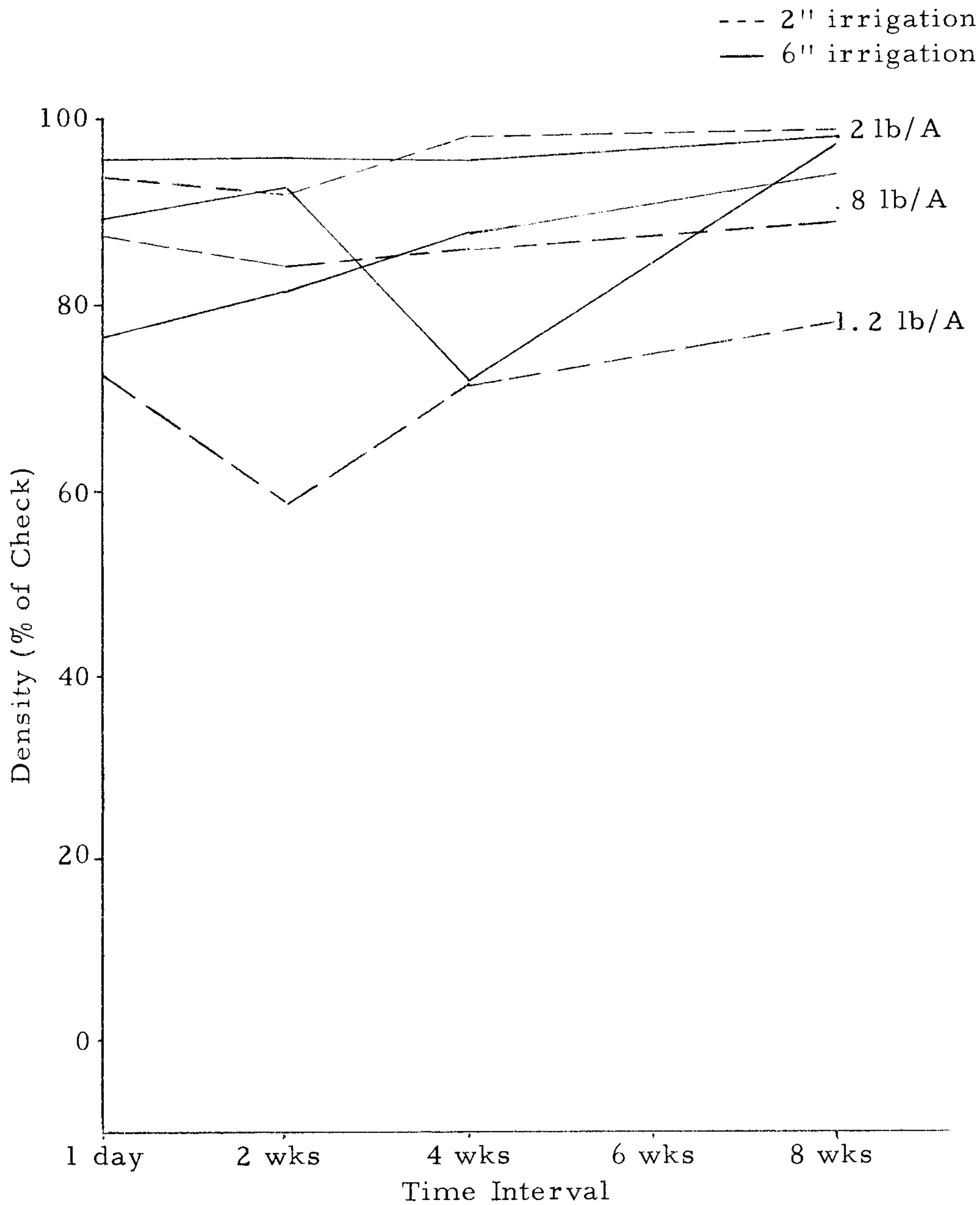
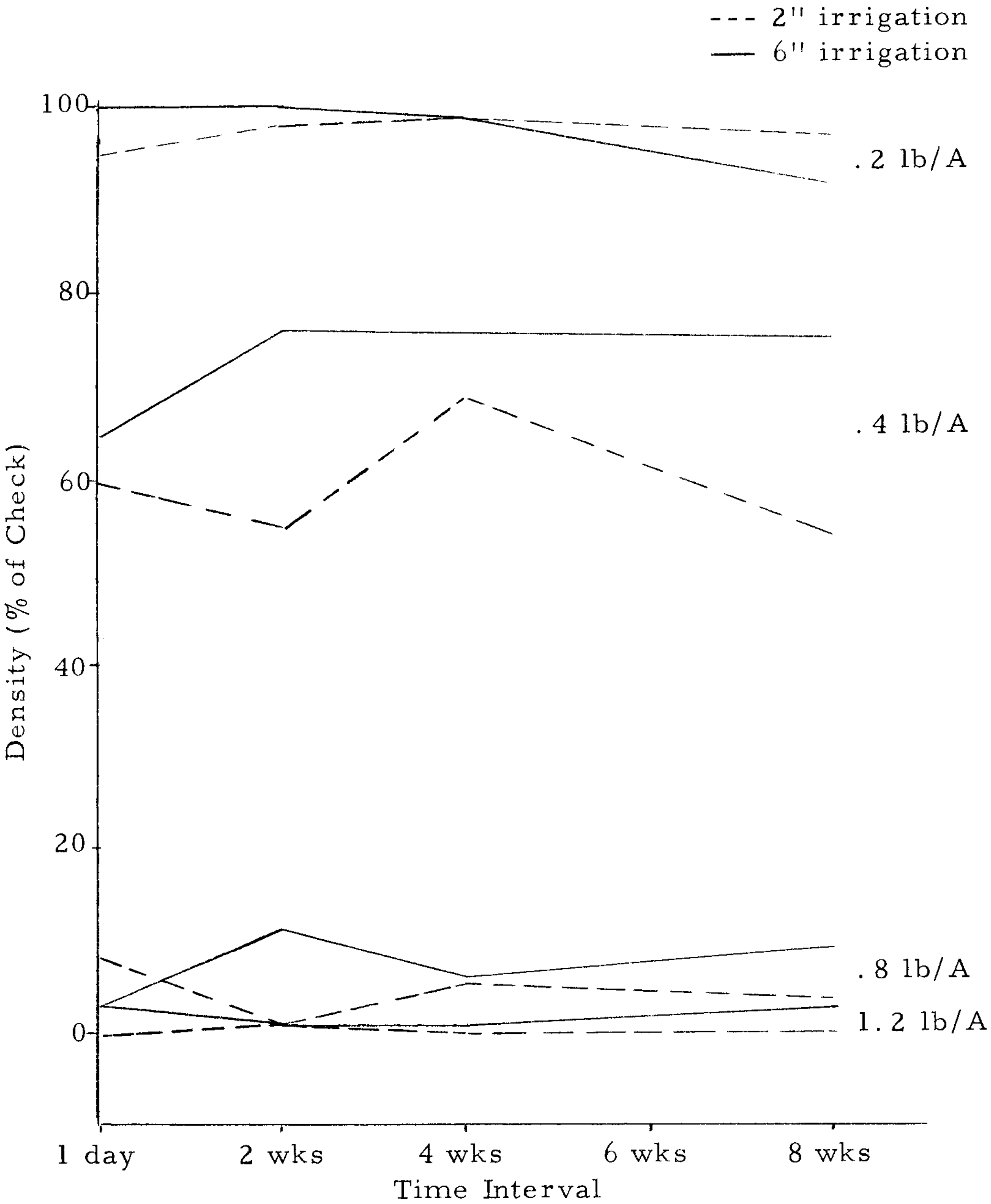


Figure 4. Field bioassay of leaching study using rape as the test species.



BIOASSAY OF FIELD LEACHING STUDY

Methods and Materials

Since a relatively quick and easy method of determining amounts of bromacil in soil was necessary, the bioassay best suited this purpose. Only core samples from 0-1 inch, 1-3 inches, and the 3-6 inch depth of the .4 lb/A and 1.2 lb/A rates of bromacil were bioassayed. Soil samples were mixed well and placed in 2.5 x 2.5 x 2.5 inch plastic pots. Twelve oat seeds were planted 1/4 to 1/2 inch deep in each pot. Oat seedlings were later thinned to 10 plants per pot. The pots were placed at random in watering trays and watered by sub-irrigation. White fluorescent lights plus incandescent bulbs were used to provide a uniform light intensity of 500-700 foot-candles for a 14-hour period each day. The temperature of the greenhouse was approximately 70°F. during the day and 60°F. at night. Pots were rotated every four to five days during bioassays to obtain more uniformity. At 2.5 to 3 weeks after oat emergence, visual evaluations were made, the plants harvested, and green weights determined.

To know approximately how much bromacil was present in the samples, oats were also grown in soils with uniform concentrations of 0, 0.5, 1.0, and 1.5 parts per million bromacil. By comparing green weights as well as visual observations of standards and samples, an estimate of the unknown bromacil concentration in the samples could be made. Standards were prepared by mixing the proper amount of bromacil, in sprayable suspension, with a measured weight of soil. A soil tumbler was used to facilitate the mixing.

The visual evaluations, again made by two investigators, were based on a rating system of 1 to 10 where 1 shows no injury and 10 is complete kill. The ratings 1, 3, 5, and 7 correspond to 0, 0.5, 1.0, and 1.5 parts per million respectively. Stages of injury above a rating of 7 or 1.5 ppm were estimated in degree of injury up to the rating of 10. Ratings given by the two evaluators were averaged and then averages for weights as well as ratings were taken for the four replications. These averages were plotted against the bromacil application-irrigation interval and are shown in Figures 5-9.

Results

These graphs indicate that a large percentage of bromacil remained in the top three inches of soil and about half of this in the top inch. In relating parts per million to pounds per acre applied on sub-sub-plot surfaces, one pound per acre evenly incorporated in the top three inches of soil is approximately equal to one ppm in the soil. Visual ratings of the 0-1 inch segment bioassay of 1.2

Figure 5. Green weights from bioassay of field core samples--0-1 inch depth.

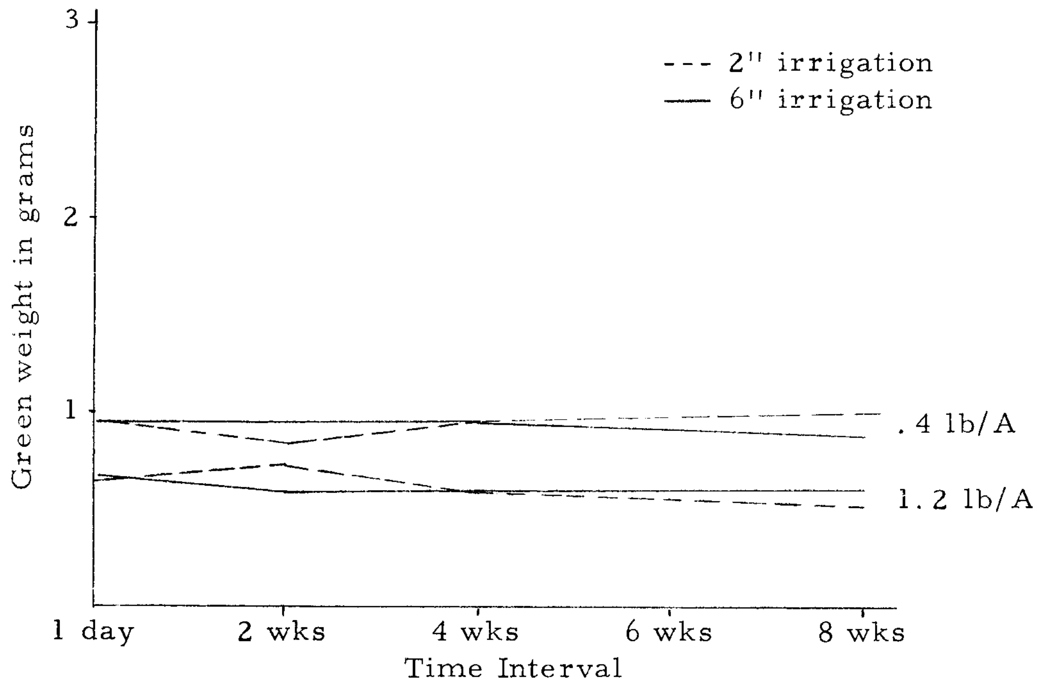


Figure 6. Visual ratings from bioassay of field core samples--0-1 inch depth.

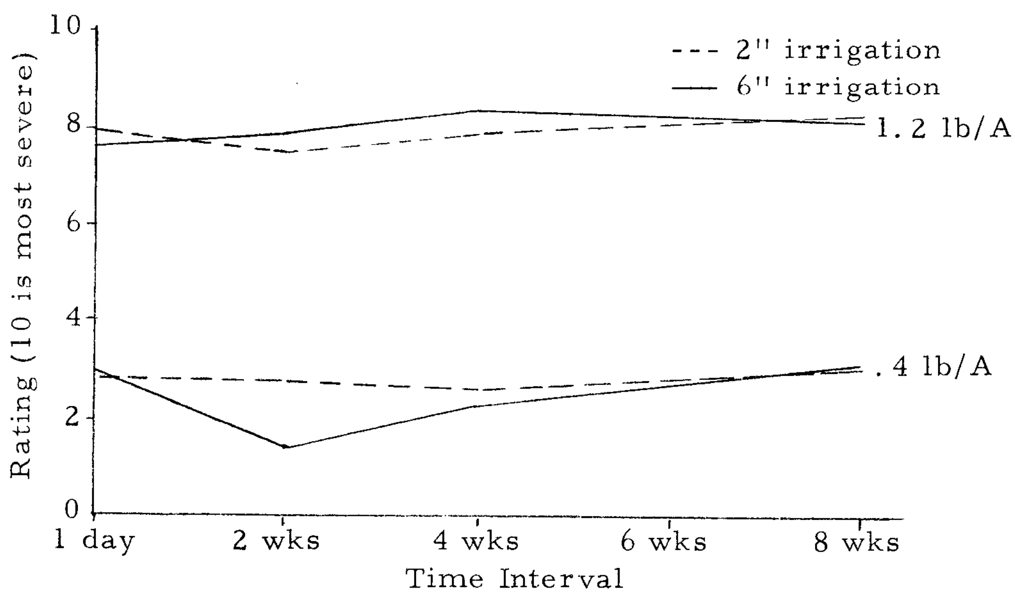


Figure 7. Green weights from bioassay of field core samples --1-3 inch depth.

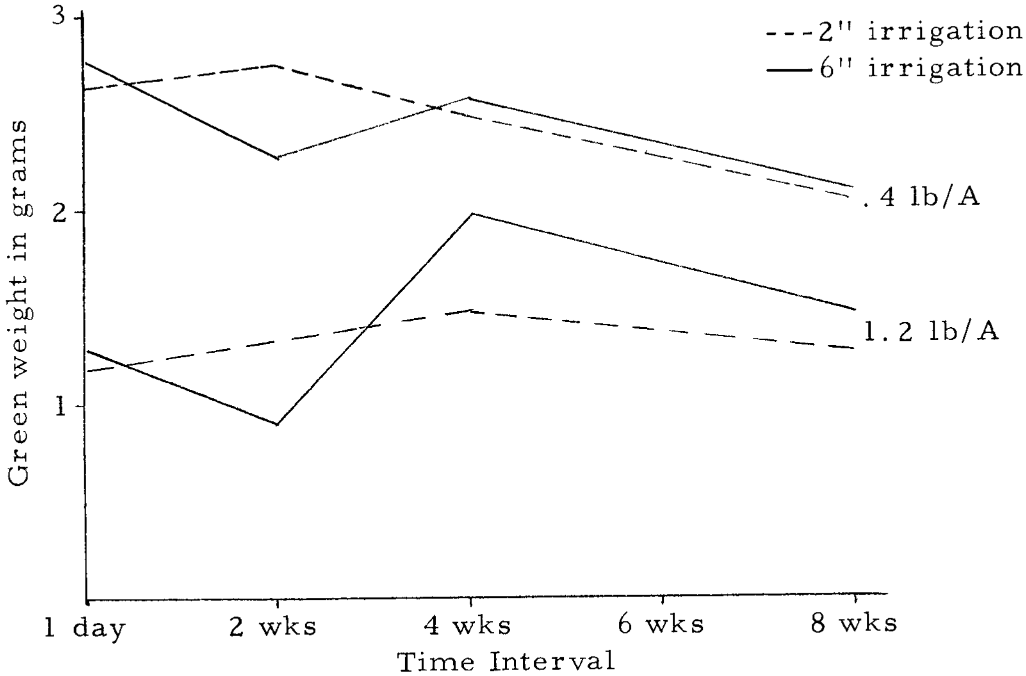


Figure 8. Visual ratings from bioassay of field core samples--1-3 inch depth.

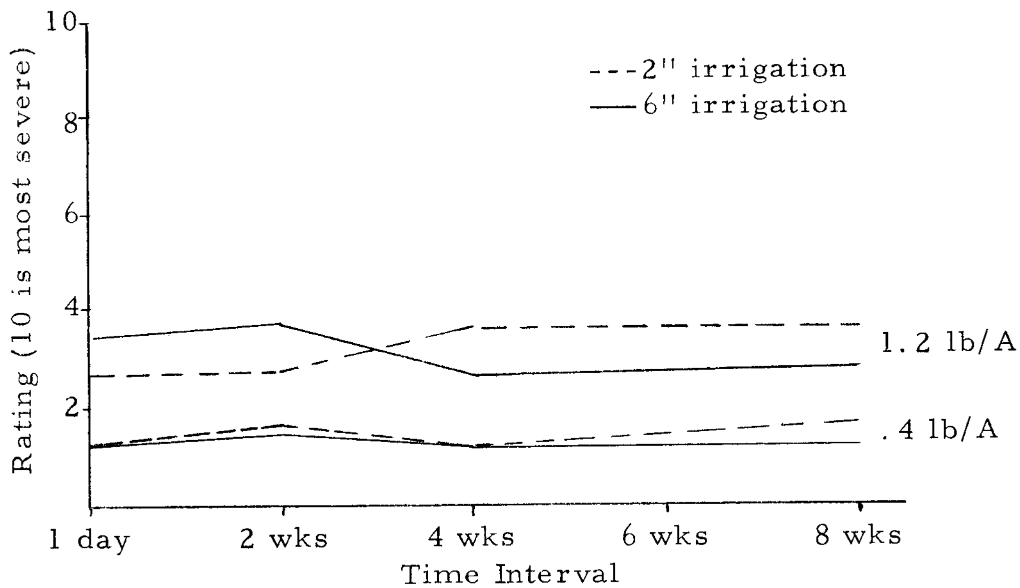
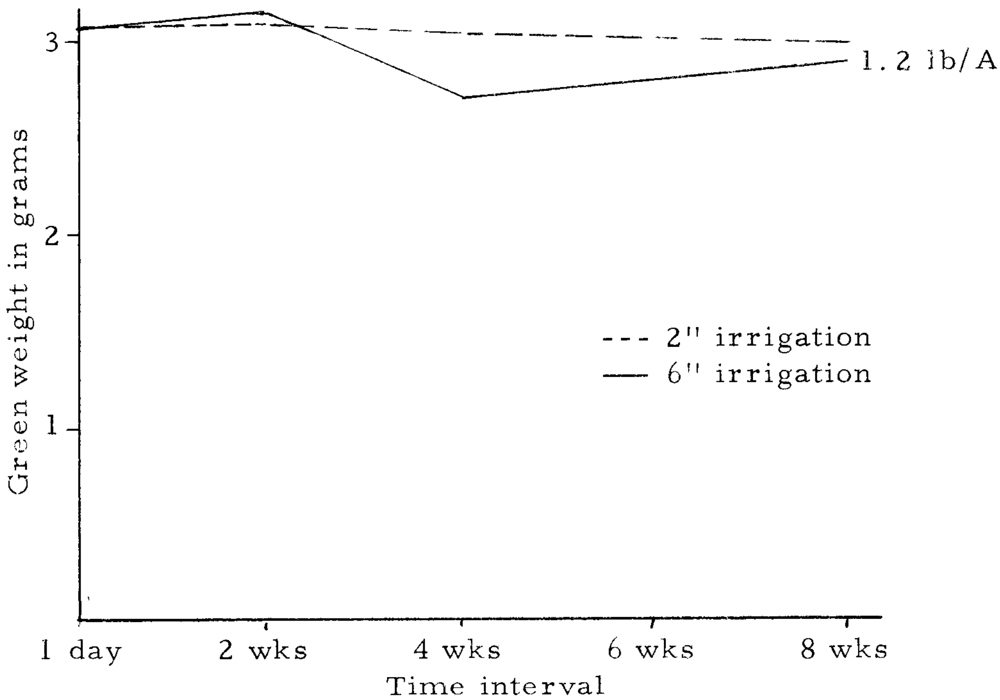


Figure 9. Green weights from bioassay of field core samples--3-6 inch depth.



pound per acre sub-sub-plots indicated that the concentration of bromacil was slightly greater than 1.5 ppm throughout the plots with different time intervals between irrigations. This same segment of the cores from .4 pound per acre sub-sub-plots indicated a concentration of approximately .5 ppm. In the 1-3 inch segment, the 1.2 and .4 pound per acre sub-sub-plots had approximately .5 and .2 ppm respectively. Total bromacil concentration in the surface three inches of soil then is approximately three-fourths of the total applied, the top inch of soil containing about one-half of the total. No toxicity symptoms were observed in core samples from the 3-6 inch segment. This indicated that neither rate of irrigation moved detectable levels of bromacil down in the soil deeper than three inches. These bioassays also support the results obtained in the field bioassay, that there were no differences in movement of bromacil when time of leaching irrigations was varied.

A point of interest in comparing the field bioassay with greenhouse bioassay is that a more definite effect of bromacil should have been seen in the field. Since half of the total bromacil is concentrated in the top one inch of soil, it is quite likely that at least the larger seeded species such as wheat and oats were planted below this high concentration. If the roots of these plants avoid the main concentration of bromacil, this could account for the decreased effect in the field.

PRE- VS POST-EMERGENCE *POA ANNUA* TRIAL

In previous research, a September application of bromacil applied pre-emergence to *Poa annua* gave much better control than a post-emergence application in December. An experiment was designed to determine if the difference in control was a result of the herbicide being applied pre-emergence versus post-emergence to annual bluegrass, or if differences were caused by varied amounts of rainfall following application.

Methods and Materials

This trial was also arranged in a split-split-plot design. The main plots were pre-emergence and post-emergence applications of bromacil, the sub-plots were irrigation levels of 0, 1.5, 3, and 6 inches of water, and the sub-sub-plots were bromacil rates of 0, 0.2, 0.4, 0.8, and 1.2 pounds of active bromacil per acre. The main plots were replicated four times. Main plots were 30 x 120 feet, sub-plots were 30 x 30 feet, and sub-sub-plots were 6 x 30 feet. Spraying of sub-sub-plots and irrigation of sub-plots were handled exactly as in the previous field trial.

The plot area had been previously leveled and tilled. It was irrigated with approximately 2.5 inches of water and then planted as soon as possible with annual bluegrass by means of a seven-inch disc drill. Two days after planting, it was rolled, sprayed with the pre-emergence bromacil treatments, and then irrigated with 1/4 inch of water. Twelve days later the annual bluegrass was in the 3-leaf stage and bromacil post-emergence treatments were applied. On the following day, irrigation of sub-plots began. Because of difficulties in manipulating irrigation equipment, it took five days to complete all of them. After irrigation, the annual bluegrass was allowed to grow. Occasional showers provided enough moisture for growth without irrigation. Visual evaluations and density counts were completed on September 29 and October 21 respectively. At this time, two strips ten feet wide were sprayed in block fashion across sub-sub-plots. The application contained diquat and paraquat applied at 1/2 pound of each active material per acre. This mixture killed all top growth without leaving any toxic residue in the soil. Then on October 29, each strip was seeded with either winter wheat or winter field peas, so that each sub-sub-plot would then contain 10 feet of the old annual bluegrass plus 10 feet of each newly seeded species.

Visual evaluations of this trial were based on percentage control of *Poa annua* rather than percentage of density as in the previous field trial. Percentage of control is comparable to percentage of density when the latter is subtracted from 100 or vice versa. The evaluations were made by one person and these were averaged for the four replications. Percentage control of *Poa annua* under the different conditions of pre- versus post-emergence bromacil application and varied irrigation levels was plotted against application rates of bromacil (see Figure 10).

Four density counts were also taken in each plot. These were taken at eight-foot intervals starting three feet in from the end of the plots and included the annual bluegrass plants present in a four-inch segment of a row at each interval. Counts were averaged for individual sub-sub-plots and percentage of density as compared to no bromacil treatment was determined for each. These were then averaged for the four replications and plotted against rates of bromacil (see Figure 11).

Results

Both of the graphs indicate that control of annual bluegrass was comparable when bromacil was applied pre- or post-emergence. The rate of irrigation after application of bromacil made no apparent difference in control. One line on the graphs that does not follow the same general path of the others is that derived from post-emergence application of bromacil followed by no irrigation. There may have been insufficient moisture from the limited rainfall to move the bromacil into the root zone of the annual bluegrass in sufficient concentration to obtain control comparable to the irrigated sub-plots.

Figure 10. Control of annual bluegrass by pre- and post-emergence applications of bromacil as influenced by four rates of irrigation following the last application.

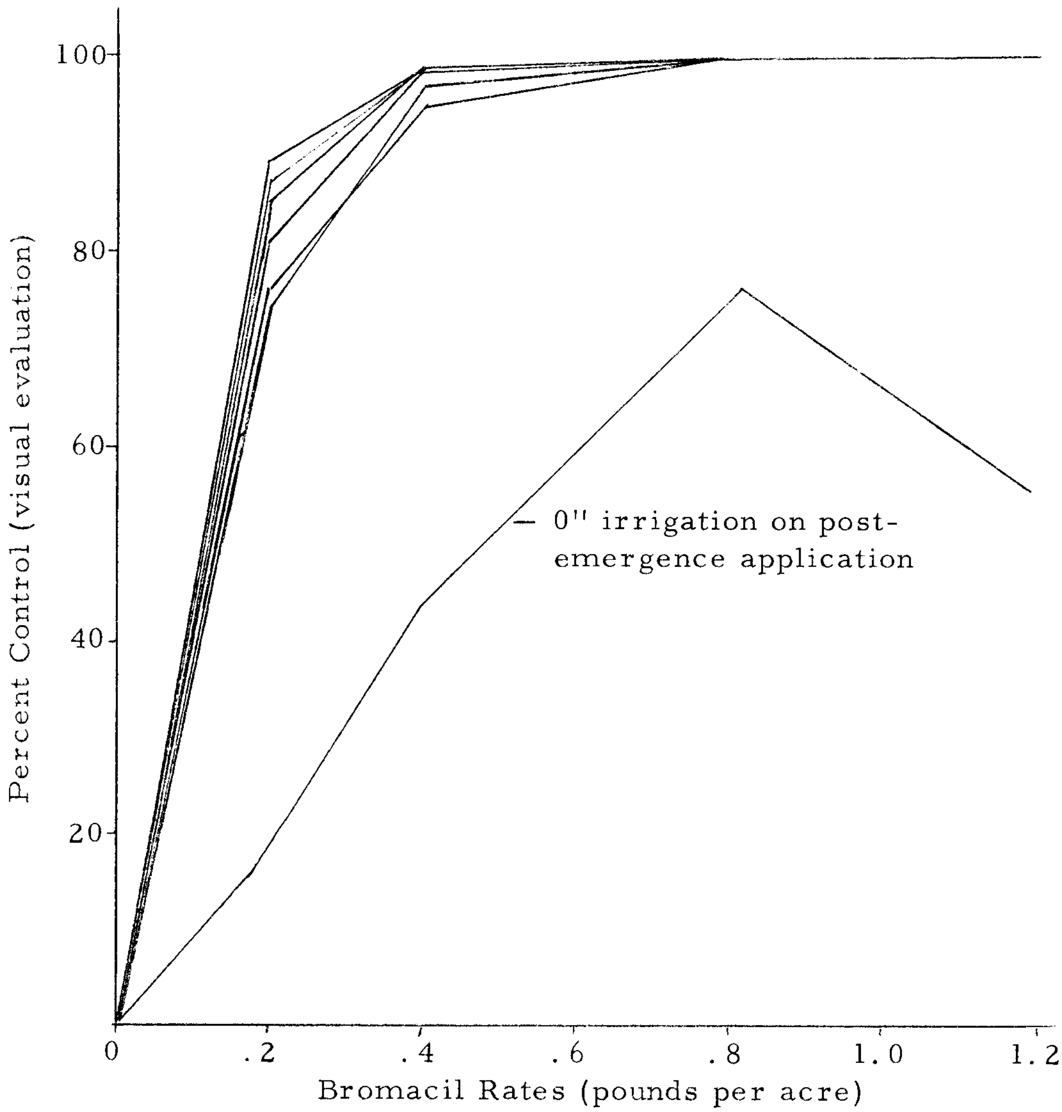
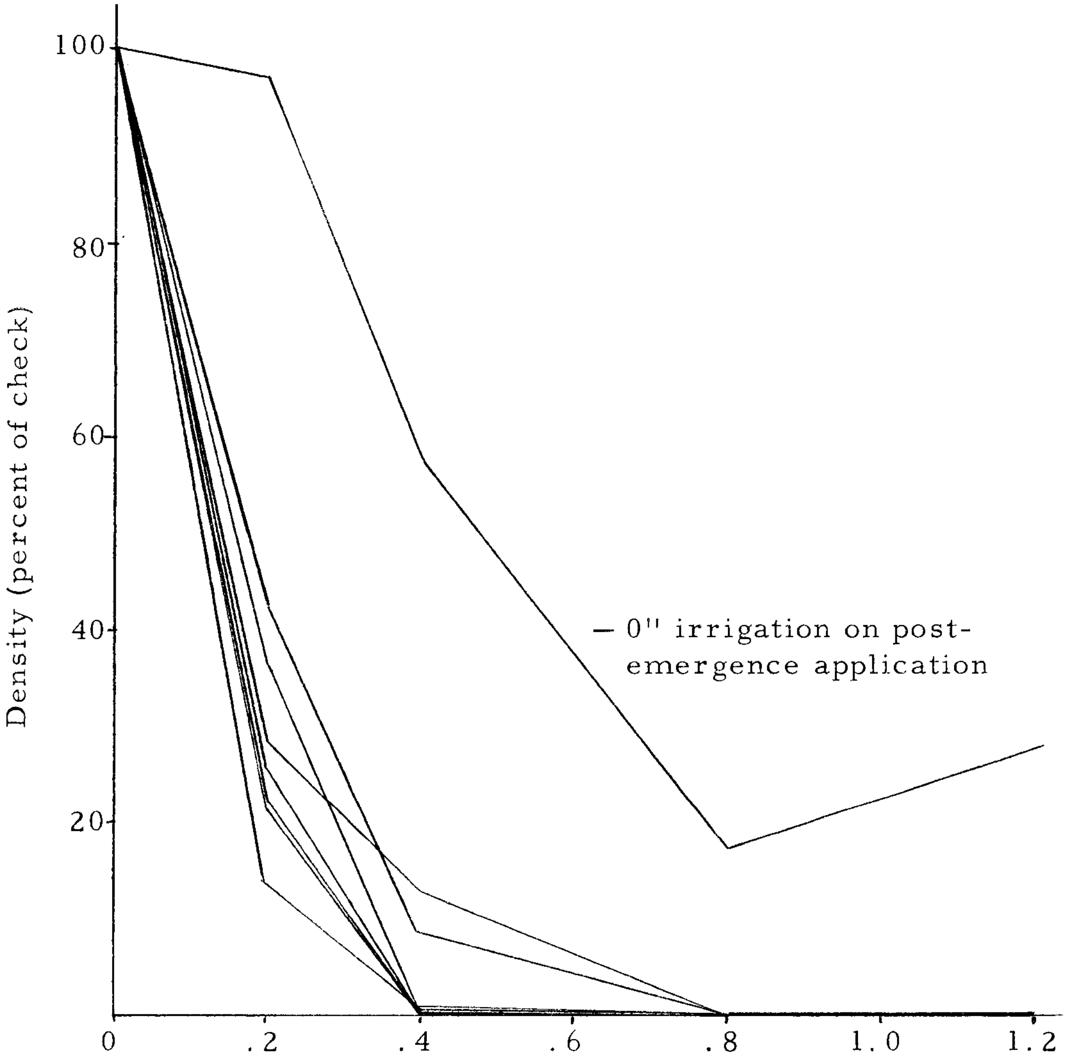


Figure 11. Control of annual bluegrass by pre- and post-emergence applications of bromacil as influenced by four rates of irrigation following the last application.



Results of this trial indicate that the difference between pre- and post-emergence control of annual bluegrass seen in earlier research was not due to changes in tolerance at different growth stages. Irrigation level after post-emergence application did not effect bromacil performance. The results of the field bioassay with winter wheat and winter field peas did not prove to be of value. Neither species showed any apparent toxicity from bromacil.

COLUMN LEACHING STUDY

Methods and Materials

An experiment was established in the greenhouse involving downward leaching in soil columns in an attempt to simulate early winter rainfall conditions. The study included three moisture levels in the surface soil at the time of spray application, one rate of bromacil, two dates of bromacil application, and one quantity of water for leaching. Treatments were replicated four times, giving a total of 24 columns.

Columns were 18 inches high and were made up of two 3-inch upper sections and two 6-inch lower sections of 3-inch diameter drain pipe. Plastic electrical tape was used to seal the column sections together. Lids made to fit soft drink cups three inches in diameter were used as bottoms for the columns after holes were punched in them to allow drainage. Soil was dry and had been screened through a 2-millimeter sieve before being packed in the columns. To fill columns with soil, a .75-inch diameter glass tube with a funneled top was first placed in the column and filled with soil. With a circular motion, the soil filled tube was slowly raised in the column, allowing the soil to be deposited with the least amount of disturbance. Packing or settling the soil was accomplished by running a vibrating tool up and down the column sides.

Studies by the Oregon State University Soils Department have shown that this type packing will most closely simulate field conditions. To vary soil moisture on the soil surface at the time of bromacil application, the top six inches of two treatments were packed after the columns had been saturated with water and allowed to drain for 24 hours. This gave one treatment with the soil surface at field capacity when bromacil was applied, another had the top six inches packed with soil at approximately 20 percent moisture, and the third treatment had the top six inches packed with air dry soil. Saturating the lower soil was thought to provide more uniform leaching when equal amounts of water were applied. The surface soil was sprayed with bromacil in suspension by means of an accurate greenhouse sprayer calibrated to deliver 633 gallons per acre when passed over the column tops five times. The two dates of bromacil application were (a) two weeks before leaching and

Table 2. Chemical and mechanical analysis of the Chehalis surface soil used in greenhouse studies.

Soil pH	CEC meq/100g.	% o. m.	Sand %>.05mm	Silt %.05-.002mm	Clay %<.002mm
5.8	38.7	6.65	2.8	61.8	35.4

(b) immediately before leaching. This variable was used to determine if time of application had any effect on adsorption and subsequent leaching of bromacil. After spraying, a two-inch section of drain pipe was added to the top of each column to act as a reservoir. Before leaching, a layer of spun glass was placed on top to protect the soil from disturbance when applying water. Eight inches of water were added in one-inch increments so that as one inch had disappeared from the top of all columns, the next inch increment was added. When all movement of water had ceased and column segments dried to a workable texture, the soil in each segment was bioassayed by the procedure mentioned earlier.

Results

The bioassay showed no consistent patterns of bromacil leaching. There was such a wide variation between replications that no conclusions could be drawn.

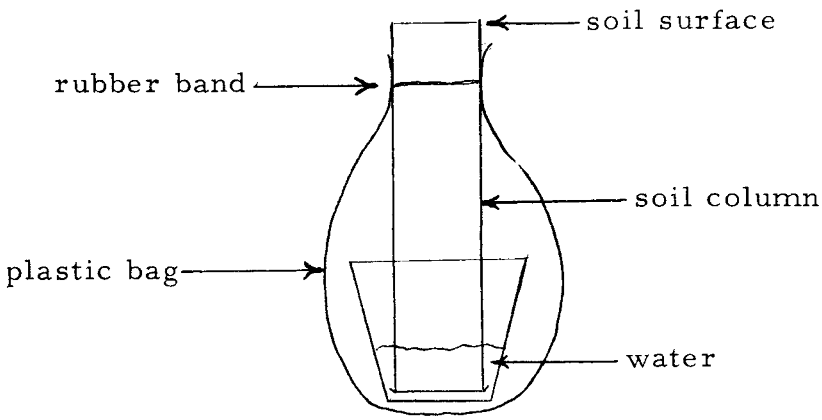
Uniform leaching appeared to be difficult to attain since some columns drained quite rapidly and others slowly. The fast draining columns may have had channels formed along the sides of the column or within the soil mass itself. The procedure may have been the problem, or this approach may not simulate field conditions well enough for this purpose.

SUBIRRIGATION AND CAPILLARY MOVEMENT STUDIES

Methods and Materials

Due to difficulty in obtaining leaching conditions similar to field leaching conditions, the technique was changed from leaching downward to movement upward in the column by subirrigation and capillary movement. This experiment was similar to the studies conducted by Harris (12, 13). Two-inch segments of drain pipe were used to form columns eight inches high and lids with holes were used for bottoms. Bromacil application was made two inches from the bottom of each column. The soil in these bottom two-inch segments was at three moisture contents at the time of bromacil application: saturated, 20 percent, and air dry. Bromacil was applied as before and after adding the rest of the column, soil at 20 percent moisture was packed in on top by the method given before.

Figure 12. Soil column-subirrigation apparatus.



The columns were set in water until all had drawn water to the surface. At this time, the columns were put in individual containers of water and the system closed by means of a plastic bag and rubber band so that water loss could only take place from the soil surface. The whole system was then weighed. Additional water added to each system was measured and each column was allowed to lose approximately 1.5 inches of water. Evaporation loss was accelerated by means of a fan blowing on the systems at all times.

As soon as the subirrigation-evaporation period was finished, columns were broken apart and lids with holes in them put on the bottoms. Oats were then planted directly into the segments. The same bioassay conditions were maintained in this experiment as in those mentioned previously. The oats were allowed to grow for approximately two weeks after they first emerged. They were then visually evaluated, harvested, and the green weights measured. Green weights were plotted against column segments arranged in order of increasing height. The oats were visually evaluated on a 1-10 rating scale with one indicating no bromacil symptoms and 10 complete kill. Ratings were made by two researchers and the averages of their ratings were plotted against column segments.

Two experiments of this type were carried out. The first, a preliminary trial, was completed without the measurement of the amount of water evaporating from the top of the columns. The subirrigation period was 36 hours shorter than the period for the second trial.

Results

The preliminary trial indicated that there was reduced upward movement of bromacil when it was applied on dry soil as compared to application on saturated soil. Visual ratings show that the oats in segment "c" of the columns that had dry soil when bromacil was applied had much less injury than those in the same segment of columns that had saturated soil at the time the herbicide was applied. Green weights verified these results, with averages of 1.64 and .44 grams of oats per "c" segment of the respective treatments (see Figures 13 and 14). No bromacil was indicated above segment "c".

The second and more refined trial with 1.5 inches of water evaporating from the column tops, however, did not show this difference. Movement of bromacil upward in the columns was quite uniform. This was shown by both visual ratings and green weights of the bioassay (see Figures 15 and 16).

Figure 13. Preliminary subirrigation--bromacil movement.

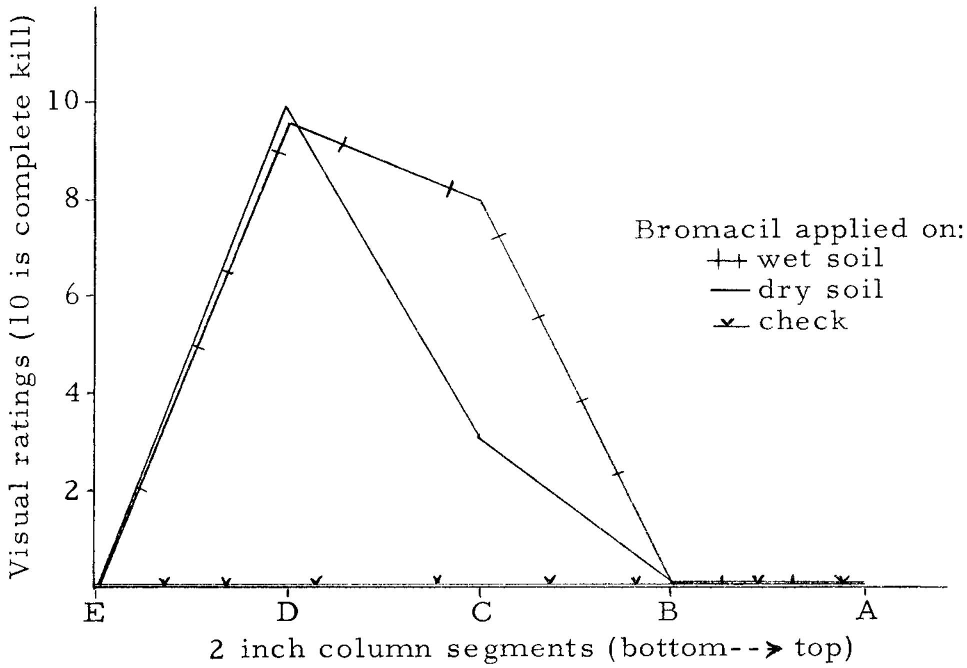


Figure 14. Preliminary subirrigation--bromacil movement.

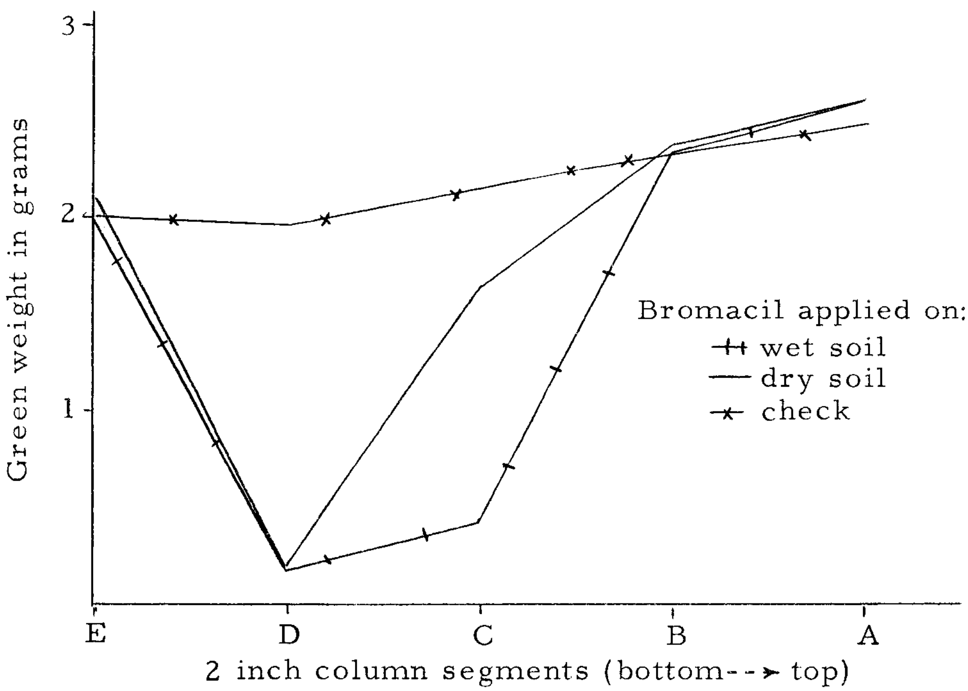


Figure 15. Subirrigation--bromacil movement.

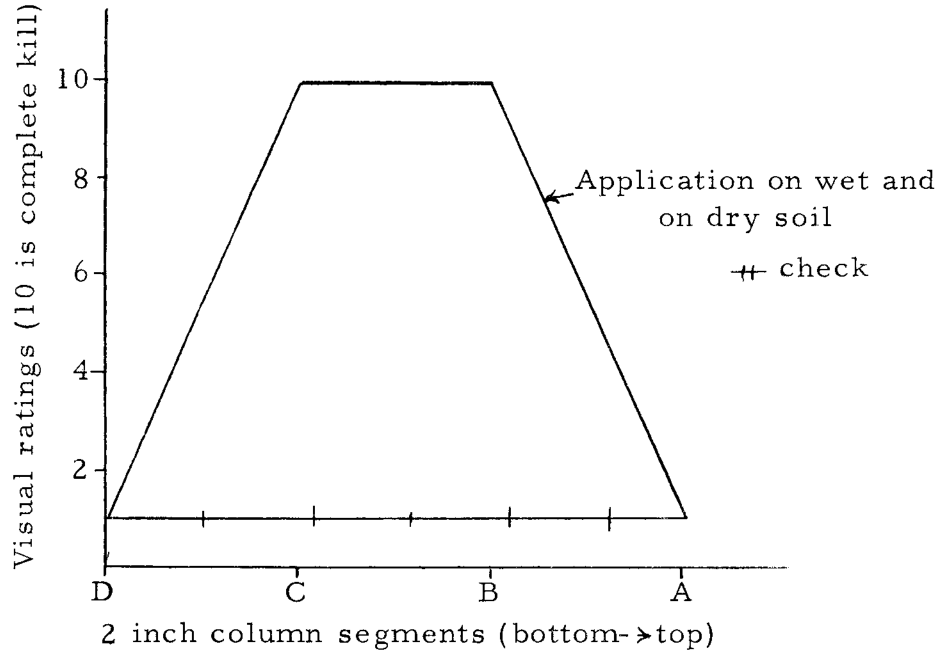
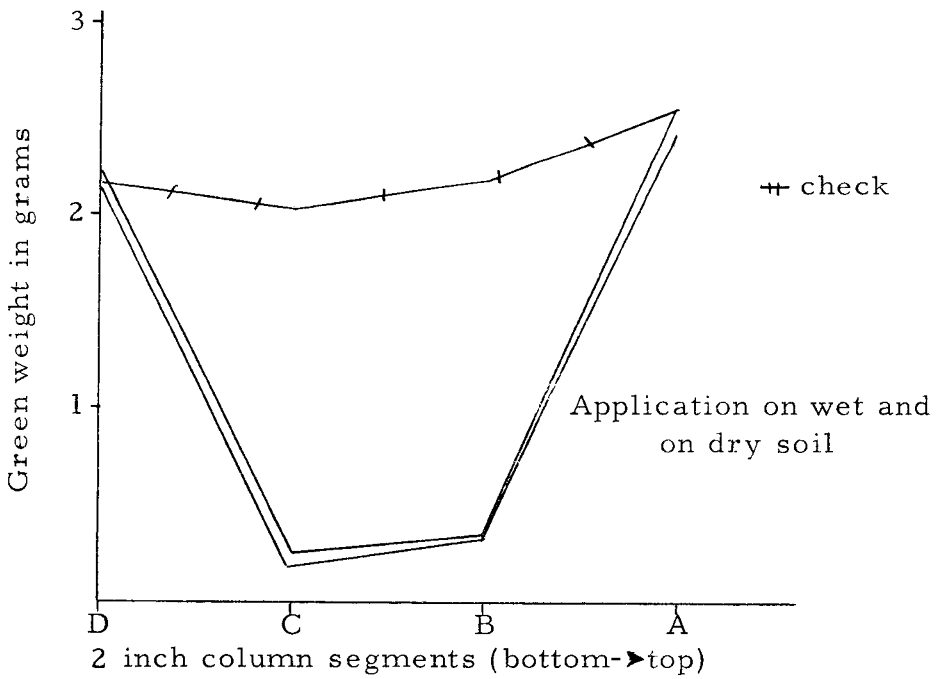


Figure 16. Subirrigation--bromacil movement.



CONCLUSIONS

In previous research, bromacil gave good performance when it was applied in early fall with fairly dry soil conditions and before the fall germinating weeds had started growth. On the other hand, if bromacil was applied in late November, December, or January on nearly saturated soil with weeds that had grown for one or two months, weed control was quite noticeably reduced.

At the start of this thesis study, there were two main questions: (1) was the difference in bromacil performance due to the necessity of a certain time interval between application and leaching rainfall, or (2) was it due to the early fall application being pre-emergence to the weed population as opposed to post-emergence with the late fall-early winter application?

The first study attempted to determine whether the time interval between application and leaching rainfall was a pertinent factor. The soil was dry when bromacil was applied. No effect of time interval could be seen.

The second field study was conducted to determine if there would be a difference in bromacil performance when applied pre- and post-emergence to annual bluegrass and followed by varied amounts of sprinkler irrigation. Both pre- and post-emergence applications gave equal annual bluegrass control, regardless of irrigation level.

Since neither the time interval between application and irrigation nor the pre- versus post-emergence application affected bromacil's performance, the differences observed in the field between applications on dry soil early in the fall compared to wet soil in late November and December was not explained.

Moisture moving into relatively dry soil might carry the bromacil into the small pore spaces first and cause a greater retention. In wet soil, the small pores would have already been filled by moisture containing no herbicide and the percolating solution containing bromacil would have been largely excluded from the adsorption sites of these small openings. Attempts to prove this hypothesis failed. Fall soil conditions could not be duplicated by greenhouse studies primarily because of inadequate techniques. Downward leaching in soil columns proved faulty in that true leaching conditions could not be accomplished. Some columns drained quite rapidly and others slowly. The fast draining columns were thought to have channels formed along the sides of the column or within the soil mass itself. Bromacil movement by subirrigation showed no noticeable differences in movement after extensive leaching, probably because capillary movement takes place through all pores. Accessibility to adsorption sites would be equal in both cases. The difference in movement seen in the preliminary subirrigation experiment may have been due to the greater time required for desorption of bromacil when it was completely adsorbed to the dry soil. Complete adsorption would not occur in wet soil.

Further data to support the above hypothesis might be obtained by use of a timing trial. Bromacil could be applied at definite intervals from October to January with soil samples for bioassay determinations taken in the spring. This would indicate whether differential leaching of bromacil had occurred.

Much more research is necessary in the area of soil adsorption of organic molecules and in the initial wetting and subsequent leaching of water through soil. A more complete knowledge of these two factors would make it possible to understand, in theoretical terms, why differences in bromacil performance have been seen.

SUMMARY

Two experiments were designed to provide data on the effects of time of application and rates of sprinkler irrigation on bromacil applied to dry soil and the efficiency of pre- and post-emergence applied bromacil in annual bluegrass control. Movement of bromacil in soil columns by subirrigation and gravity leaching was tested by bioassay.

The following results were obtained:

1. The herbicidal performance of bromacil applied to dry soil was not affected by irrigation rates or by the time intervals between herbicide application and irrigation. Field bioassay species responded uniformly across all treatments. No differences in bromacil leaching could be detected and bioassay indicated no bromacil below three inches in soil depth. Approximately half of the amount found in the top three inches was located in the 0-1 inch layer.

2. Both pre- and post-emergence applications of bromacil gave good control of annual bluegrass except in the post-emergence treatments that received no irrigation. Apparently not enough precipitation was received on the latter treatments to move the herbicide into the annual bluegrass root zone.

3. Greenhouse leaching studies with soil columns were inconclusive, because consistent patterns of leaching throughout

replications were not obtained.

4. Upward movement of bromacil by subirrigation and capillary action of 1.5 inches of water gave no differences whether the herbicide was applied on water-saturated or dry soil. Subirrigation for a shorter period of time resulted in less movement of the bromacil applied to dry soil.

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APPENDIX

Table 1. Influence of two rates of irrigation applied at four different dates on four rates of bromacil on stand density of wheat.

Time of irrigation	Rate of irrigation	.2#/A Rep I	Rep II	Rep III	Rep IV	Ave.	.4#/A Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	100	97.5	95	95	96.88	100	100	92.5	85	94.38
	2"	97.5	97.5	100	100	98.75	97.5	95	97.5	95	96.25
2 weeks	6"	97.5	97.5	100	100	99.38	100	90	92.5	100	95.63
	2"	100	100	95	100	98.75	90	62.5	85	90	81.88
4 weeks	6"	92.5	100	100	97.5	97.5	95	95	100	100	97.5
	2"	100	97.5	100	100	99.38	100	100	92.5	95	98.13
8 weeks	6"	97.5	95	100	87.5	95.0	100	95	100	60	75.25
	2"	100	100	97.5	100	99.38	100	90	80	90	90.0

Time of irrigation	Rate of irrigation	.8#/A Rep I	Rep II	Rep III	Rep IV	Ave.	1.2#/A Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	40	95	22.5	90	61.88	32.5	15	25	20	23.13
	2"	22.5	25	65	77.5	47.5	20	5	15	10	12.5
2 weeks	6"	25	30	55	95	51.25	5	5	52.5	20	20.63
	2"	10	17.5	32.5	40	25.0	5	5	30	10	12.5
4 weeks	6"	30	70	50	87.5	59.38	15	25	47.5	22.5	27.5
	2"	50	75	45	60	57.5	12.5	7.5	32.5	10	15.63
8 weeks	6"	87.5	77.5	90	97.5	88.13	17.5	20	67.5	20	31.25
	2"	10	45	45	72.5	43.13	5	17.5	60	7.5	22.5

Table 2. Influence of two rates of irrigation applied at four different dates on four rates of bromacil on stand density of annual bluegrass.

Time of irrigation	Rate of irrigation	.2#/A					.4#/A				
		Rep I	Rep II	Rep III	Rep IV	Ave.	Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	100	97.5	95	87.5	95.0	95	95	92.5	15	74.38
	2"	100	100	100	65	91.25	90	100	92.5	25	71.25
2 weeks	6"	95	90	100	100	96.25	90	75	5	85	63.75
	2"	100	85	17.5	100	75.63	97.5	37.5	37.5	45	54.38
4 weeks	6"	100	100	75	32.5	76.88	87.5	92.5	10	100	72.5
	2"	100	97.5	77.5	100	93.75	95	100	60	27.5	70.63
8 weeks	6"	90	97.5	85	27.5	75.0	40	85	55	12.5	48.13
	2"	95	100	100	100	98.75	92.5	95	50	10	61.88
		.8#/A					1.2#/A				
1 day	6"	17.5	35	25	5	20.63	5	10	0	0	3.75
	2"	15	60	40	5	30.0	15.	10	17.5	0	10.63
2 weeks	6"	10	27.5	7.5	27.5	18.13	7.5	5	0	0	5.0
	2"	10	27.5	5	35	19.38	5	5	0	7.5	4.38
4 weeks	6"	20	60	2.5	7.5	22.5	17.5	15	0	0	5.63
	2"	27.5	60	5	7.5	25.0	7.5	10	0	0	4.38
8 weeks	6"	30	17.5	0	10	14.38	5	12.5	0	2.5	5.0
	2"	7.5	10	0	7.5	6.25	5	5	0	2.5	3.13

Table 3. Influence of two rates of irrigation applied at four different dates on four rates of bromacil on stand density of oats.

Time of irrigation	Rate of irrigation	.2#/A Rep I	Rep II	Rep III	Rep IV	Ave.	.4#/A Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	100	87.5	100	97.5	96.25	87.5	95	100	92.5	93.75
	2"	92.5	100	97.5	92.5	95.63	92.5	100	92.5	95	95.0
2 weeks	6"	90	97.5	100	97.5	96.25	92.5	87.5	95	92.5	91.88
	2"	90	100	85	100	93.75	77.5	77.5	100	87.5	95.63
4 weeks	6"	85	100	100	97.5	95.63	97.5	100	97.5	97.5	98.13
	2"	95	95	100	100	97.5	92.5	95	100	97.5	96.25
8 weeks	6"	100	95	100	97.5	98.13	100	95	100	97.5	98.13
	2"	100	97.5	97.5	100	98.75	92.5	100	92.5	85	92.5
		.8#/A					1.2#/A				
1 day	6"	95	90	77.5	95	89.38	70	80	80	77.5	76.88
	2"	85	95	85	85	87.5	72.5	77.5	70	70	72.50
2 weeks	6"	85	95	92.5	97.5	92.5	77.5	80	87.5	80	81.25
	2"	80	75	92.5	90	84.38	40	42.5	85	65	58.13
4 weeks	6"	90	95	92.5	100	71.88	85	90	85	90	87.5
	2"	75	85	92.5	92.5	86.25	50	65	87.5	82.5	71.25
8 weeks	6"	100	92.5	100	95	96.88	92.5	85	100	97.5	93.75
	2"	85	90	82.5	95	88.13	80	82.5	77.5	70	77.5

Table 4. Influence of two rates of irrigation applied at four different dates on four rates of bromacil on stand density of rape.

Time of irrigation	Rate of irrigation	.2#/A Rep I	Rep II	Rep III	Rep IV	Ave.	.4#/A Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	100	100	100	100	100	92.5	97.5	55	17.5	65.25
	2"	95	90	100	97.5	95.63	45	67.5	90	37.5	60.0
2 weeks	6"	100	100	100	100	100	57.5	95	60	92.5	76.25
	2"	95	100	97.5	100	98.13	62.5	10	52.5	95	55.0
4 weeks	6"	100	100	95	100	98.75	67.5	80	55	100	75.63
	2"	100	97.5	100	97.5	98.75	77.5	72.5	60	65	68.75
8 weeks	6"	97.5	92.5	97.5	77.5	91.25	87.5	87.5	97.5	25	74.38
	2"	100	100	92.5	95	96.88	72.5	72.5	22.5	45	53.13

Time of irrigation	Rate of irrigation	.8#/A Rep I	Rep II	Rep III	Rep IV	Ave.	1.2#/A Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	0	10	0	5	3.75	5	2.5	5	0	3.13
	2"	0	7.5	20	5	8.13	0	0	0	0	0
2 weeks	6"	2.5	5	5	35	11.88	0	0	0	5	1.25
	2"	0	0	0	5	1.25	0	0	5	0	1.25
4 weeks	6"	5	12.5	2.5	5	6.25	0	5	0	0	1.25
	2"	10	7.5	5	0	5.63	0	0	0	0	0
8 weeks	6"	10	7.5	7.5	12.5	9.38	0	5	5	0	2.50
	2"	0	10	0	5	3.75	0	0	0	0	0

Table 5. Influence of two rates of irrigation applied at four different dates on the downward movement of bromacil applied at four rates.

Bioassay of the 0-1" segments of field core samples

Time of irrigation	Rate of irrigation	Ratings (1-10)* Rep I	Rep II	Rep III	Rep IV	Ave.	Wet wt. of oats** Rep I	Rep II	Rep III	Rep IV	Ave.
						.4 lb/A					
1 day	6"	2	4	2	4	3	1.04	.92	.78	1.10	.96
	2"	3	3	3	2.5	2.88	1.02	1.05	.74	1.01	.96
2 weeks	6"	2	1	1	2	1.5	.97	1.00	1.04	.88	.97
	2"	2	3	3	3	2.75	.92	.77	.94	.79	.86
4 weeks	6"	2	2	2	2.5	2.13	1.08	.98	.94	.86	.97
	2"	2.5	2	3	3	2.63	.97	1.24	.95	.68	.96
8 weeks	6"	3	3	4	2.5	3.13	1.00	.86	.62	1.05	.88
	2"	3	3	3	3	3	.98	.93	.96	1.06	.98
						1.2 lb/A					
1 day	6"	7.5	7.5	7.5	9	7.88	.84	.73	.76	.41	.69
	2"	7	7.5	8	8.5	7.75	.74	.64	.66	.54	.65
2 weeks	6"	8	8.5	5	8.5	7.5	.66	.51	.72	.53	.61
	2"	7.5	8	8	8	7.88	.67	.71	.59	.95	.73
4 weeks	6"	8.5	7	8	8	7.88	.52	.70	.61	.68	.63
	2"	8	7.5	8	10	8.38	.69	.75	.47	.37	.57
8 weeks	6"	7.5	9	7.5	9	8.25	.81	.38	.61	.52	.58
	2"	6.5	8	9	9	8.13	.59	.69	.44	.40	.53

Table 5. (continued)

		Bioassay of the 1-3 inch segment of field core samples									
		.4 lb/A									
Time of	Rate of	Ratings (1-10)*					Wet wt. of oats**				
irrigation	irrigation	Rep I	Rep II	Rep III	Rep IV	Ave.	Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	1.5	1	1	1.5	1.25	3.03	2.88	2.23	2.96	2.78
	2"	1.5	1.5	1	1	1.25	2.76	3.32	2.03	2.45	2.64
2 weeks	6"	1	1	1	3	1.50	2.57	2.09	2.09	2.82	2.39
	2"	2.5	1	1.5	1.5	1.63	3.22	1.76	2.76	3.28	2.76
4 weeks	6"	1.5	1.5	1	1	1.25	2.72	3.39	1.97	2.28	2.59
	2"	1	1	1.5	--	1.17	2.41	2.23	2.81	--	2.48
8 weeks	6"	1	2	1	1	1.25	2.12	2.20	2.27	1.85	2.11
	2"	2.5	1	1.5	--	1.67	2.37	1.74	2.01	--	2.04
		1.2 lb/A									
1 day	6"	4	4	3	3	3.5	.56	.52	2.42	1.72	1.31
	2"	3	3.5	1	3.5	2.75	1.39	.96	2.01	.52	1.22
2 weeks	6"	3.5	4	3.5	4	3.75	1.27	.31	1.60	1.88	.91
	2"	2	3.5	1	4.5	2.75	2.26	.73	1.92	.39	1.33
4 weeks	6"	2.5	2.5	2	4	2.75	2.29	2.17	2.20	1.21	1.97
	2"	4	4	3	3.5	3.63	1.69	.40	2.54	1.24	1.47
8 weeks	6"	3	1.5	3.5	3.5	2.88	1.76	2.20	.76	1.12	1.46
	2"	4	4	3	3.5	3.63	.77	1.23	2.10	1.03	1.28

Table 5. (continued)

Time of irrigation	Rate of irrigation	Bioassay of the 3-6 inch segment of field core samples 1.2 lb/A — Ratings (1-10)* Rep I	Rep II	Rep III	Rep IV	Ave.	Wet wt. of oats** Rep I	Rep II	Rep III	Rep IV	Ave.
1 day	6"	1	1	1	1	1	3.23	3.18	2.74	3.13	3.07
	2"	1	1	1	1	1	3.28	2.89	2.93	3.17	3.07
2 weeks	6"	1	1	1	1	1	3.21	3.19	3.10	3.14	3.16
	2"	1	1	1	1	1	3.58	2.91	2.78	3.12	3.10
4 weeks	6"	1	1	1	1	1	2.71	2.62	2.53	2.99	2.71
	2"	1	1	1	1	1	3.36	2.78	3.22	2.82	3.05
8 weeks	6"	1	1	1	1	1	2.69	2.71	2.98	3.09	2.87
	2"	1	1	1	1	1	2.95	2.70	3.21	3.01	2.97

* Injury ratings were given on a 1-10 scale; 1 indicates no injury and 10 the most severe injury. Ratings of 1, 3, 5, and 7 are comparable to oat injury obtained in standards of 0, .5, 1, and 1.5 ppm respectively. Ratings are given as the average of two independent evaluators.

** Oats were used for the bioassay.

Table 6. Control of annual bluegrass by pre- and post-emergence applications of bromacil as influenced by four rates of irrigation following the last application.

Treatment	Amount of irrigation	Percent control					Density counts expressed as percent of check				
		0#/A	.2#/A	.4#/A	.8#/A	1.2#/A	0#/A	.2#/A	.4#/A	.8#/A	1.2#/A
Pre-emergence	0"	0	93	99	100	100	100	20.30	0	0	0
		0	93	99	100	100	100	4.17	0	0	0
		0	94	99	100	100	100	20.62	0	0	0
		0	75	99	100	100	100	11.63	3.10	0	0
	Total	0	355	396	400	400	400	56.72	3.10	0	0
	Average	0	89	99	100	100	100	14.18	0.78	0	0
	1.5"	0	80	98	100	100	100	1.14	1.14	0	0
		0	88	99	100	100	100	103.53	0	0	0
		0	80	100	100	100	100	25.56	0	0	0
		0	93	99	100	100	100	17.30	0	0	0
	Total	0	341	396	400	400	400	147.53	1.14	0	0
	Average	0	85	99	100	100	100	36.88	0.28	0	0
	3"	0	95	99	100	100	100	9.49	0	0	0
		0	85	99	100	100	100	36.23	0	0	0
		0	80	99	100	100	100	27.10	3.87	0	0
		0	93	99	100	100	100	17.01	0	0	0
	Total	0	353	396	400	400	400	89.83	3.87	0	0
	Average	0	88	99	100	100	100	22.48	0.97	0	0
	6"	0	96	99	100	100	100	3.74	0	0	0
		0	80	99	100	100	100	44.09	0	0	0
		0	75	99	100	100	100	13.33	0	0	0
		0	96	100	100	100	100	25.33	0	0	0
	Total	0	347	397	400	400	400	86.49	0	0	0
	Average	0	87	99	100	100	100	21.62	0	0	0

Table 6. (continued)

Treatment	Amount of irrigation		Percent control 0#/A	.2#/A	.4#/A	.8#/A	1.2#/A	Density counts expressed as percent of check 0#/A	.2#/A	.4#/A	.8#/A	1.2#/A
Post-emergence	0"		0	35	60	90	65	100	130.23	55.04	3.10	22.48
			0	5	30	35	40	100	137.41	85.03	48.30	44.22
			0	15	25	100	70	100	30.35	47.02	0.0	10.12
			0	10	60	80	50	100	88.46	46.15	19.23	35.57
		Total	0	65	175	305	225	400	386.45	233.24	70.63	112.39
		Average	0	16.25	43.75	76.25	56.25	100	96.61	58.31	17.66	28.10
	1.5"		0	40	98	100	100	100	24.31	0	0	0
			0	80	98	100	100	100	106.86	0	0	0
			0	80	90	98	99	100	31.87	35.16	0	0
			0	96	100	100	100	100	8.74	0	0	0
		Total	0	296	386	398	399	400	171.78	35.16	0	0
		Average	0	74	97	100	100	100	42.94	8.79	0	0
	3"		0	45	97	100	100	100	57.26	0.48	0	0
			0	90	98	99	100	100	23.91	2.72	0	0
			0	94	100	100	100	100	7.19	0	0	0
			0	95	99	100	100	100	14.610	0	0	0
		Total	0	324	394	399	400	400	102.97	3.20	0	0
		Average	0	81	99	100	100	100	25.74	.80	0	0
	6"		0	50	85	100	99	100	34.42	52.60	0	0
			0	80	99	100	100	100	45.90	0	0	0
			0	80	98	100	100	100	31.25	0.57	0	0
			0	93	99	100	100	100	1.80	0	0	0
		Total	0	303	381	400	399	400	113.37	53.17	0	0
		Average	0	76	95	100	100	100	28.34	13.29	0	0

Table 7. A preliminary study on the movement of bromacil by subirrigation as influenced by herbicide application on dry and saturated soils.

Treatment***	Rating (1-10)*				Green wt. of oats**			
	Rep I	Rep II	Rep III	Ave.	Rep I	Rep II	Rep III	Ave.
A. Dry soil	0	0	0	0	2.82	2.60	2.47	2.63
B. " "	0	0	0	0	2.67	2.29	2.20	2.39
C. " "	2.5	0	7.5	3.3	2.12	2.31	.48	1.64
D. " "	10	10	10	10	.19	.27	.27	.24
E. " "	0	0	0	0	2.08	2.17	2.07	2.11
A. Wet soil	0	0	0	0	2.53	2.63	2.69	2.62
B. " "	0	0	0	0	2.29	2.33	2.46	2.36
C. " "	8	8	7.5	7.9	.42	.44	.46	.44
D. " "	10	9	10	9.7	.19	.23	.24	.22
E. " "	0	0	0	0	2.00	1.82	2.10	1.97
A. Check	0	0	0	0	2.30	2.57	2.63	2.50
B. "	0	0	0	0	2.30	2.49	2.29	2.36
C. "	0	0	0	0	2.21	2.12	2.09	2.14
D. "	0	0	0	0	2.00	1.92	2.00	1.97
E. "	0	0	0	0	2.00	2.08	2.01	2.03

* An injury rating system from 1-10 was used; a rating of one indicating no injury and 10 indicating complete kill.

** Oats was used as the bioassay species.

*** Columns were labelled starting with "A" at the top two-inch section.

Table 8. The movement of bromacil by subirrigation as influenced by herbicide application on dry and saturated soils.

Treatment	Rating (1-10) Rep I	Rep II	Rep III	Rep IV	Ave.	Green wt. of oats Rep I	Rep II	Rep III	Rep IV	Ave.
Application on:										
A. Dry soil	1	1	1	1	1	2.53	2.41	2.42	2.67	2.51
B. " "	10	9.5	10	10	9.9	.33	.47	.21	.36	.34
C. " "	10	10	10	10	10	.25	.37	.26	.33	.30
D. " "	1	1	1	1	1	2.18	2.33	2.09	2.20	2.20
Application on:										
A. 20% moisture	1	1	1	1	1	2.43	2.45	2.48	2.29	2.41
B. " "	10	10	10	10	10	.32	.29	.38	.31	.33
C. " "	10	10	10	10	10	.27	.28	.28	.29	.28
D. " "	1	1	1	1	1	2.12	2.06	2.17	2.11	2.12
Application on:										
A. Sat. soil	1	1	1	1	1	2.60	2.50	2.61	2.48	2.55
B. " "	9.5	10	10	10	9.9	.40	.28	.30	.26	.31
C. " "	10	10	10	10	10	.25	.26	.30	.22	.26
D. " "	1	1	1	1	1	2.21	2.17	2.92	2.21	2.22
A. Check	1	1	1	1	1	2.56	2.49	2.49	2.61	2.54
B. "	1	1	1	1	1	2.15	2.12	2.13	2.30	2.18
C. "	1	1	1	1	1	1.98	2.06	1.92	2.21	2.04
D. "	1	1	1	1	1	2.07	2.17	2.09	2.29	2.16