The Surface of a New s-Triazine Herbicide from Treated Cropland and its Environmental Effects

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THE SURFACE MOVEMENT OF A NEW S-TRIAZINE HERBICIDE FROM TREATED CROPLAND AND ITS ENVIRONMENTAL EFFECTS

by

Zeldon A. Nelson

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

MASTER OF SCIENCE

in

Plant Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1972
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ABSTRACT

The Surface Movement of a New s-Triazine Herbicide from Treated Cropland and its Environmental Effects

by

Zeldon A. Nelson, Master of Science
Utah State University, 1972

Major Professor: Dr. John O. Evans
Department: Plant Science

Six days following the application of 1.5 and 3.0 lb/A of 2-methoxy-4-sec.-butylamino-6-ethylamino-s-triazine (GS-14254) to established plots of alfalfa, water samples were collected at several distances from the plots and analyzed for herbicide residues with a Beckman DB-G grating spectrophotometer. The data indicate that GS-14254 is transported in small amounts but that the concentrations in the runoff water decline rapidly with increased distance from the treated areas and time.

GS-14254 produced no visual injury symptoms of leaf chlorosis or plant stunting on alfalfa at the two rates used. However, some initial injury has been reported by other workers.

This study indicates that oats are very sensitive to GS-14254 and that they would be a good bioassay for detecting different concentrations of this chemical in soil.

The data indicate that the green alga, Chlorella, is a very sensitive test organism. However, all herbicide concentrations and incubation periods examined were found to be algistatic.
Indications are that concentrations of this chemical transported in irrigation or precipitation runoff water when used at recommended rates, would likely not be hazardous to plant and animal life.
INTRODUCTION

A new s-triazine herbicide has recently been released that demonstrates excellent potential for weed control in alfalfa (Medicago sativa L.) and small grains of Utah and the United States. In Utah there are presently 471 thousand acres planted to alfalfa and approximately half that planted to small grains. The potential use of this material on a national and international level is obvious.

Chemicals are now available which can adequately control most annual grassy and broadleaved weeds in some agronomic crops. GS-14254 (2-methoxy-4-sec-butylamino-6-ethylamino-s-triazine) might be classed with this type of chemical. It can eliminate many species of annual grassy and broadleaved weeds from established alfalfa. In this respect GS-14254 might be considered an ideal type herbicide for established alfalfa.

There has been growing concern over possible contamination of water systems from runoff of treated agricultural and watershed lands. Runoff from these and other treated areas offer a potential hazard to the health of both animal and plant life. If GS-14254 finds wide acceptance, the questions as to its movement in soil and water, effects on other crops, and environmental effects must be answered. The continued use of the material may also depend on the answers to these questions.

The movement of GS-14254 in irrigation or precipitation runoff is an area that has not been extensively studied. The contamination of runoff from treated areas may result in serious reductions to the stand and yield of susceptible crops and aquatic plants. This problem would
be most pronounced when runoff immediately followed application or when it is not diluted by more water. An understanding of the lateral movement of GS-14254 in water from treated areas will enable us to make more appropriate use of this compound on different ecological areas and to enjoy greatest benefits with the least amount of risk.

A review of the literature on GS-14254 reveals most of the work done with this compound deals with its control of weeds in agronomic crops. Little attention has been paid to its movement from treated areas to nearby fields and water systems. Attempts have been made in this study to elucidate the lateral movement of GS-14254 from a field of established alfalfa, with some mention of the possible inhibitory effects on other plant life.
LITERATURE REVIEW

There has been growing concern expressed lately by scientists and others over the possible contamination of water systems from the runoff of agricultural and watershed areas (36, 52). Mullison (36) stated that drainage from watersheds and other herbicide treated areas offer a potential hazard by possibly causing harmful effects to the health of domestic animals, wildlife, aquatic invertebrates and vertebrates as well as man. A publication (51) of the National Academy of Sciences indicated that herbicides may be carried from their point of application to unsprayed areas in surface-water drainage. It also pointed out that when excess rainfall or irrigation water drains from fields, herbicide molecules may be carried in solution or in the adsorbed phase on suspended soil particles and become deposited along the path of the flowing water. Allan (2) stated that herbicides are not known to be accumulated by plankton or aquatic fauna and water pollution by runoff from treated land at present is not a problem. However, existing and new herbicides must be examined periodically with the express purpose of preventing environmental contamination. White, Barnett, Wright, and Holladay (52) conducted a study on the losses of atrazine from fallow land caused by runoff and erosion. In their study, atrazine was applied to the surface of a fallow field at 3 lb/A and simulated rainfall was used to produce runoff. A simulated rainfall of 2.5 inches in 1 hour applied 96 hours after the herbicide application, caused 7.3% or 0.24 lb/A of the atrazine to be lost. They mentioned that a storm of this intensity comes only about once in 10 years and that the losses from this type of storm would be considerably greater than the normal storm
encountered in the area. They reported that a common size storm (0.5 inch) for the area simulated 96 hours after herbicide application resulted in 0.06 lb/A or only 25% as much herbicide loss as the 2.5 inch simulated rainfall. It was stated that the concentration of atrazine in the soil fraction of the washoff was higher than in the water fraction but that most of the atrazine transported was associated with the water fraction due to the larger amounts of water lost as compared with soil. Their study also showed that the average concentration of atrazine in the runoff decreased with increase in storm size.

GS-14254 is a member of the \( \text{\textit{s-}} \)triazine herbicides, which are known for their persistence in the soil (52). Work began on this group of herbicides in 1952 when the first \( \text{\textit{s-}} \)triazine derivatives were synthesized and screened in the laboratories of J. R. Geigy, Basle, Switzerland (30). Since that time, three major classifications of \( \text{\textit{s-}} \)triazines have developed: the chlorotriazines, methoxytriazines, and methylthiotriazines. All three classes of \( \text{\textit{s-}} \)triazines interfere in a similar way with photosynthesis so that it is possible to make a generalization that all active \( \text{\textit{s-}} \)triazines have the same or a similar mode of action (25). For this reason, and due to the lack of work done with GS-14254, the author is comparing this chemical with the other \( \text{\textit{s-}} \)triazines.

Simazine (2-chloro-4,6-bis(ethylamino)-\( \text{\textit{s-}} \)triazine) and atrazine (2-chloro-4-ethylamino-6-isopropylamino-\( \text{\textit{s-}} \)triazine) are two widely known chlorotriazines that have found considerable use in woody perennials and corn respectively (20). Simazine shows a greater margin of safety in woody perennials than does atrazine, mainly due to its lower water solubility. On the other hand, atrazine shows better weed control in
corn due to its greater water solubility and postemergence activity (20).

Due to its wide use and relatively high water solubility, several studies (51, 52) have been conducted with atrazine to measure its lateral movement and possible injury to nearby crops. In southeastern United States it was reported (51) that intense rain showers moved atrazine from sprayed corn fields to nearby fields where it caused injury to sensitive crops.

GS-14254 belongs to the methoxytriazine class of s-triazines which is characterized by having a relatively high water solubility and leaf and soil activity (20). These characteristics make this class of compounds, especially atratone (2-methoxy-4,6-bis(isopropylamino-s-triazine) and prometone (2-methoxy-4,6-bis(isopropylamino-s-triazine), excellent as general herbicides for industrial uses (20). Gysin (25) stated that it is probably the higher solubility of the methoxytriazines which allows them to penetrate established vegetation more readily than the chlorotriazines but that this is also the probable reason for its decreased crop selectivity. GS-14254 has a water solubility of 620 ppm (23) or about nine times that of atrazine. For this reason, possible concern might also be expected about its movement from treated areas.

The methylthiotriazines show the greatest amount of variability among the s-triazine derivatives (20). For example, prometryne (2-methylthio-4,6-bis(isopropylamino-s-triazine) can be applied on cotton, peas, beans, soybeans, sunflowers, leek, onions, parsnips, artichokes, peppers, rice, carrots, celery, broad beans, and peanuts depending on soil type and climatic conditions. Part of the reason for their greater variability is their shorter period of soil activity. However, due to their relatively high vapour pressure, the methylthiotriazines are known to cause phytotoxicity problems under high
temperature conditions (20).

Most of the work done with GS-14254 deals with its control of weeds in agronomic crops (10, 11, 12, 13, 14, 18, 28, 29, 34, 35, 38, 39, 40, 41). However, some work has been done with its control of weeds in horticultural crops (1, 15, 19, 43), metabolism by dairy cows and goats (7), influence on some enzymes of carbohydrates and nitrogen metabolism in pea (Pisum sativum L.) leaves and sweet corn (Zea mays L.) (54), subherbicidal dose on bush beans (Phaseolus vulgaris L.) (44), and influence on delta-aminolevulinic acid dehydratase of pea seedlings (55).

GS-14254 demonstrates excellent potential for the alfalfa and small grain areas of the west (11, 12, 13, 14, 18, 34, 35, 38). Roy and Gibson (18) stated that GS-14254 provided the most outstanding combination of broad spectrum weed control and crop safety of all compounds tested. Evans and Woods (11) established three experiments for the control of shepherdspurse (Capsella bursa-pastoris (L.) Medic.) and downy brome (Bromus tectorum L.) in irrigated alfalfa. They reported that of the herbicides tested, only terbacil (3-tert.-butyl-5-chloro-6-methyluracil) and GS-14254 gave satisfactory control of both weeds. In another study to control buttercup (Ranunculus testiculatus Crantz), shepherdspurse, snoweed (Veronica camphylopoda Boiss), and downy brome in established dryland alfalfa, Evans and Woods (12) stated that only GS-14254 gave satisfactory control of both broadleaved and grassy weeds at all locations. They also stated that GS-14254 and terbacil were the most promising compounds tested, based on crop safety and longevity, for full season weed control. Of the herbicides tested for control of snoweed and bur buttercup in dryland wheat, Evans and
Woods (13) reported that only terbutryn (2-tert.-butylamino-4-ethylamino-6-methylthio-s-triazine) and GS-14254 gave over 90% control of both species. They mentioned that some crop injury was noticeable shortly after applying GS-14254 but that it was not evident when the wheat reached the boot stage.

Bailey and White (6) indicated that adsorption, climatic conditions and the physical properties of the soil appear to affect the overall pesticide movement through the soil the most. Harris (27) reported that adsorption gives a better indication of herbicide resistance to movement than does solubility. He pointed out that prometryne (2-methylthio-4,6-bis(isopropylamino)-s-triazine), having a water solubility of 48 ppm, is nearly 10 times more soluble than simazine yet prometryne moved much less in the soils tested. Prometone (750 ppm water solubility), the most soluble of the herbicides studied, appeared to move less in Wehadkee silt loam than all other herbicides examined except prometryne.

Frissel and Bolt (19) reported that adsorption processes are pH-dependent and that s-triazines are adsorbed as positively charged ions in acidic solutions and as neutral molecules in neutral and basic environments. Weber (42) reported that the substituent in the 2-position on 13 s-triazines has the greatest effect on the ionization constant and basicity of these compounds. Generally with like substituents in the 4- and 6-positions, these compounds had the following order of basicity: -OH > -OCH3 > -SCH3 > -CI. The basicity of these compounds was also affected by the number and type of alkyl groups present on the 4- and 6-positions. Weber (49) also reported that the maximum adsorption of each of the 13 s-triazines tested occurred near
its pKa. In a summary article on the adsorption of s-triazines by clay colloids, Weber (50) stated that more basic compounds are generally adsorbed in greater amounts than less basic compounds; but the key to the amount of adsorption is the molecular structure of the compounds. He indicated that decreased adsorption results as the 2-substituent is changed in the following order: \(-\text{SCH}_3\) > \(-\text{OCH}_3\) > \(-\text{OH}\) > \(-\text{Cl}\). He concluded by saying that the 2-substituent determines the primary adsorption mechanism and that changes in the alkyl groups in the 4- and 6-positions affect the basicity of the compounds and hence the amount of adsorption.

A study conducted by Talbert and Fletchall (46), on the adsorption of five s-triazines from the aqueous solutions on 25 soil types, four clay minerals and two peat soils, substantiates the summary conclusions made by Weber (50) above. They stated that in almost all cases, adsorption decreased in the following order: Prometryne > prometone > simazine > atrazine > propazine. They also indicated that adsorption of these compounds is not related to water solubility.

Harris (27) reported that the movement of s-triazine herbicides through soil columns by subirrigation was in reverse order of their adsorption. In other words, methoxytriazines and methylthiotriazines were adsorbed in greater amounts than chlorotriazines, and they also moved less with subirrigation. This report by Harris conflicts slightly with a report by Ashton (3) showing the lateral movement of three s-triazine herbicides. Ashton conducted an experiment to show the movement of simazine, atrazine and atratone in soil with simulated furrow irrigation. These three compounds, although similar in chemical structure, have water solubilities of 5, 70, and 1800 ppm respectively. He reported that the lateral movement of these compounds was in order of
their water solubilities for both surface and incorporated applications.

Wright (53) indicated that small concentrations of most herbicides reach soil and soil drainage water whether directly or indirectly following their application. He pointed out that it is therefore important that effects of these substances on non-target organisms be examined. Aquatic life would appear to represent the logical non-target organisms in many cases.

Kratky and Warren (32) reported 50% or greater inhibition of Chlorella (Chlorella pyrenoidosa Sorokin) by 1 ppm of each of the following triazines: ametryne (2-methylthio-4-ethylamino-6-isopropylamino-s-triazine), atratone, atrazine, prometone and simazine. They also showed that 50% inhibition of chlorophyll production or oxygen evolution in Chlorella could be achieved with 0.08 ppm of atrazine. In another study (31) by Kratky and Warren, the Chlorella bioassay was shown to be more sensitive than soybeans, equally as sensitive as cucumbers and oats, but less sensitive than sugar beets.

Walker (47) reported on the use of simazine, atrazine, propazine (2-chloro-4,6-bis(isopropylamino)-s-triazine) and prometone as aquatic herbicides in fish habitats. He obtained control of Potamogeton, Majas, Ceratophyllum, Heteranthera and Zannichellia with preemergence applications of granular formulations of simazine at 1 to 2 ppm. The control of Cladophora and Pithophora (filamentous algae) required higher rates. Atrazine gave similar control of Cladophora and Pithophora and three species of Potamogeton at concentrations of 0.5 to 1 ppm. Concentrations up to 3 ppm of propazine and prometone were unable to control submersed species. Walker (47) stated that no toxicity to the different species of fish was observed following application of s-triazines under field conditions. Field observations did not reveal
any serious reduction in the production of organisms living on the bottom of the ponds. However, the control of aquatic vegetation did affect bottom dwelling and weed clinging organisms. The destruction of plant cover would expose smaller forage fish to larger predator sport fish.

Behrens reported that oats (*Avena fatua* L.) have been the most frequently used plant species for conducting biological assays of soil for *s*-triazine herbicides. He also indicated that oats are relatively sensitive to the *s*-triazines and are often used to determine low concentrations of these herbicides. In work done by Burnside and Behrens (43) oats were used to detect simazine in soils at concentrations between .25 to 1 ppm. Grover (24) found that the addition of organic matter to soil treated with simazine reduced phytotoxicity to oats.
MATERIALS AND METHODS

GS-14254 (2-methoxy-4-sec.-butylamino-6-ethylamino-s-triazine) was used in this study.

![Chemical structure of GS-14254](image)

The experimental formulation of GS-14254 used in the field experiments was GS-14254-80W, consisting of 76 percent GS-14254, 4 percent related compounds and 20 percent inert ingredients. Technical GS-14254 with a purity of 97 percent was used in the greenhouse and laboratory experiments. The rates of GS-14254 reported herein refer to active ingredients.

Field Experiments

A well established, uniform stand of irrigated alfalfa was selected on the Utah State University South Farm for this study. The alfalfa was established with irrigation furrows in alternating rows to allow for irrigation as is commonly practiced in the area. The soil type is a Nibley clay loam. The characteristics of this soil can be found in Appendix B. The experiment consisted of two rates of herbicide, and a control. The treatments were arranged in a randomized block design with three replications. After the first cutting of
alfalfa was removed, the field was furrowed to prevent any crossover of irrigation water between rows. The field was then sprayed with Diazinon to control alfalfa weevil, followed by the staking of the plots. Each plot was 4 by 30 ft. GS-14254 was applied to the plots on July 2, 1971 at 1.5 and 3.0 lb/A with a bicycle sprayer having 8003 nozzle tips. It was applied at 35 psi pressure and equivalent to 19 gallons of water per acre. At the time of application, very few alfalfa stems had leaves. The plot area was sprinkled four days after herbicide application with approximately 0.25 inch of water over a 2.5 hour period to both fix and leach the chemical into the soil. During the four days while the chemical was laying on the surface of the ground, the minimum and maximum soil temperatures at the two cm depth were 12 and 40 °C respectively (5).

**Effect of furrow irrigation on the lateral movement of GS-14254 from treated cropland**

**Collection and storage of water samples.** The flow of water was regulated to permit it to run down the furrows at about 200 feet per hour. Water samples were collected in 110 ml sampling bottles from the first water reaching the sampling points at 0, 10, 50, and 120 feet below the end of the plots. A second sample was collected at the end of the plots after 10 minutes. Prior to the collection of samples, the sample bottles were washed with soap and rinsed four times with water. Collected samples were stored in a cooler at 4 °C until they were analyzed to prevent microbial degradation of the chemical (52).

**Quantitative Determination of GS-14254 in water samples.** The chemical extraction procedure used was a modification of a Geigy Agricultural Chemical extraction procedure (22) for extracting
chlorotriazines from water. A 50 to 100 ml sample of water was extracted three times with 13 ml portions of chloroform in a separatory funnel. The chemical was then converted from methoxytriazine to hydroxytriazine following the procedure outlined by Geigy Agricultural Chemical Corp. (21) for the hydrolysis of methylthiatriazine residues with several modifications. Following extraction, the chloroform was evaporated to dryness in 16 by 150 mm test tubes in a Buchler Rotary Evapo-Mix. Five ml of 1N H₂SO₄ was added to each test tube and placed in a boiling water bath for three hours. After the tubes had cooled to room temperature, the acid solution was transferred to a 250 ml separatory funnel and washed with 10 ml of 20% diethyl ether in chloroform. The organic layer was drained off and the aqueous layer was washed by shaking with 10 ml of diethyl ether. All extractions and washings followed one minute of vigorous shaking and a separation period. The aqueous layer was then transferred to a three ml silica cell and the adsorbancy was measured and recorded on a Beckman DB-G grating spectrophotometer at 225, 240 and 255 μ. The net absorbance (E) was then determined at 240 μ by using a baseline technique according to the following equation:

\[
E = A^{240} - \frac{A^{225} + A^{225}}{2}
\]

A standard curve was made by running known amounts of GS-14254 through the same hydrolysis procedure as the field samples. This standard curve was used for determining the ppm of GS-14254 in the water. Reagent
blanks were run simultaneously with the standards and samples.

**Effect of two rates of GS-14254 on the fresh weight yields of two cuttings of alfalfa**

As was mentioned previously, each plot was 4 by 30 ft and was covered with a well established even stand of alfalfa. Following regrowth of the alfalfa, a 3 by 30 ft quadrant of alfalfa was cut from the center of each plot for fresh weight yields. The succeeding crop was cut in like manner, and the fresh weight yields were recorded. An analysis of variance was performed on the fresh weights of the two cuttings following treatment using a split plot design. The analysis of variance can be found in Appendix A.

**Greenhouse and Laboratory Experiments**

The stock solution for the following experiments was made by dissolving 100 mg of GS-14254 in distilled water in a 1000 ml volumetric flask. The stock solution was kept refrigerated at 4°C when not in use. All dilutions were made by adding 10 ml of the higher concentration to 90 ml of distilled water and shaking vigorously 50 times.

**Concentration effect of GS-14254 on oats**

Two pound plastic cottage cheese containers were filled with 500 grams of a 3:1 mixture of Mibley clay loam and sand and were used as pots for growing the oats. Four rates of chemical, 1, 2, 3, and 4 lb/A, were added to the containers. The chemical rates were made by putting 5, 10, 15, and 20 ml of a 100 ppm stock solution with enough water to make a final solution of 45 ml. After dumping the chemical solution in the pots, the lids were put on and the soil and chemical were shaken up
vigorously until they were well mixed. Approximately 15 oat seeds were planted about 0.5 inch deep in each pot. A uniform number of plants were selected from each pot to be used in the experiment. Four replications were made of the four different rates of GS-14254 and a check. The pots were placed randomly in the greenhouse to avoid differences in treatments due to lighting and climatic conditions. The pots were watered daily with 40 ml of water. The average day and night temperatures were 80 and 65 °F ±10. After 14 days, the oats were harvested at soil level and dried in an oven for 24 hours at 100 °C. An analysis of variance was run on the dry weights to determine if there were significant differences due to the rates of chemical used.

**Concentration effect of GS-14254 on Chlorella**

**Growth.** *Chlorella pyrenoidosa* (strain 254) was selected as the test organism for this study. A stock culture of this organism was grown aseptically from a stock culture originally obtained from the Indiana University Algal Collection (45), Bloomington, Indiana. Both the test and stock cultures were grown in Bristol's medium (45) because it does not encourage the growth of bacteria, due to its complete lack of organic matter (see Appendix B for media preparation). To avoid contamination, all media was autoclaved and kept covered to avoid recontamination. To determine the tolerance of *Chlorella* to GS-14254, several dilutions of a stock solution (100 ppm GS-14254 in water) were prepared and following autoclaving, were added to the test tubes. Eight ml of the media were transferred into optically matched 18 by 150 mm test tubes. Following autoclaving one ml of 10 different dilutions of chemical were added to different tubes. The control received one ml of distilled water. Finally, one ml of exponentially growing algae from
the stock culture was added to each culture tube. The cultures were grown at 25 °C ± 1 with continuous illumination intensity of 350-400 ft-c. Growth was recorded as optical density at 700 μm at post inoculation intervals of 24 hours for the first two weeks and then every other day until the cultures leveled off. The readings were made on a Bausch and Lomb Spectronic 20 spectrophotometer set at 700 μm. Prior to inserting the culture tubes into the spectrophotometer, they were thoroughly stirred using a Vortex Jr. mixer. Myers (37) indicated that optical density is normally thought to be a reliable index of culture growth and relative cell numbers.

Regrowth. Cultures prepared in the same manner as those above, were incubated with the following concentrations of chemical for 1, 14, and 20 days to test for algistatic and algicidal activity: .5, 1, 5 and 10 ppm. A later group of cultures were tested in this same way for 24 hours using concentrations of 1, 5, 10, 25 and 50 ppm. At the end of each time period indicated, one culture of each concentration was centrifuged with an International Clinical Centrifuge and the liquid solution poured off. Fresh media was added to each tube and the tube contents were thoroughly stirred on a Vortex Jr. mixer. The tube contents were recentrifuged, the media solution poured off, and the algal pellet in the bottom of the tube placed in 10 ml of fresh media to test for regrowth.
RESULTS AND DISCUSSION

Field Experiments

Effect of furrow irrigation on the lateral movement of GS-14254 from treated cropland

The data show that the average levels of GS-14254 in the irrigation water declined rapidly with increased distance from the treated plots (Figures 1 and 2, Table 1). The irrigation return flow from the plots treated with 3.0 lb/A GS-14254 consistently had higher residue levels than that from the plots treated with 1.5 lb/A (Table 1). The differences in residue levels between treatments at equal distances from treated plots were significant at the 10% probability level (Table 8). The average GS-14254 concentrations in the irrigation water for the 1.5 lb/A treatment ranged from .272 ppm at the end of the treated plots to .005 ppm at 120 feet from the treated plots. For the 3.0 lb/A treatment, GS-14254 concentrations ranged from .487 ppm at the end of the plots to .035 ppm at 120 feet from the plots (Figure 2, Table 1).

Residue levels in the irrigation water dropped off rapidly with time. Figure 3 shows that the concentration of GS-14254 in the first flush of water was .272 ppm for the 1.5 lb/A rate and that it dropped off to .010 ppm in the water passing the same point 10 minutes later. It also shows that the concentration in the first flush of water was .487 ppm for the 3.0 lb/A rate and that it dropped off to .043 ppm after 10 minutes.

This data agree with the runoff studies conducted by White, et al. (52) on the losses of atrazine from fallow land. They found that losses
Figure 1. Average concentration of GS-lit254 in runoff water at several distances from treated areas. Curves A and B represent the average residue recovered from water running thru plots treated with GS-lit254 at 1.5 and 3.0 lb/A respectively.
Figure 2. Concentrations of GS-14254 in runoff water at several distances from end of treated area. Plots A and B were treated with 1.5 and 3.0 lb/A respectively.
Table 1. A comparison of the quantity of GS-14254 recovered in the runoff water from two treatments at different distances from the treated area

<table>
<thead>
<tr>
<th>Distance (feet)</th>
<th>Rate of GS-14254 applied (lb/A)</th>
<th>Concentration in runoff (ppm)\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.5</td>
<td>.272 a</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>.487 b</td>
</tr>
<tr>
<td>10</td>
<td>1.5</td>
<td>.122 c</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>.147 c</td>
</tr>
<tr>
<td>50</td>
<td>1.5</td>
<td>.013 d</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>.053 d</td>
</tr>
<tr>
<td>120</td>
<td>1.5</td>
<td>.005 d</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>.035 d</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Values followed by the same letter are not significantly different at the 5% level as determined by the L.S.D. test. Each value is the mean of three replications.
were highest during the early stages of runoff followed by a gradual tapering off.

Losses of GS-14254 due to erosion were not included in this study. It is estimated that the average water sample contained 1 to 2 gm of soil. White, et al. (52) stated that the concentrations of atrazine in the soil fraction were much higher than in the water fraction (the atrazine soil: water ratio was about 10 to 1). However, due to the greater amounts of water that were lost as compared to soil, there were about 10 times as much atrazine lost in the water as in the soil fraction. Although no measurement of the level of GS-14254 was made in the soil fraction of the water sample, a similar 1 to 10 ratio might be expected.

GS-14254, like atrazine, will move in irrigation or precipitation runoff. The concentration of GS-14254, however, drops off rapidly with increased distance from the treated areas (Figure 1). In areas where s-triazine sensitive crops are grown, phytotoxicity symptoms might occur on sensitive plants from runoff from treated areas.

**Effect of two rates of GS-14254 on the fresh weight yields of two cuttings of alfalfa**

No visual injury symptoms of leaf chlorosis or plant stunting was observed with either rate of herbicide. The average fresh weight data for the combined cuttings of alfalfa suggest that there was a significant reduction in yield due to both rates of GS-14254 (Figure 4). However, a comparison of the treatments using Scheffle's test did not show any significant difference at the 10% probability level (Table 2). Large field variations made it impossible to detect small yield changes that might have occurred as a result of the chemical treatment.
Figure 3. Concentration of GS-1425 lb in runoff water at two times. Bars A and C represent residue levels in first flush of water reaching the end of treated area. Bars B and D represent residue levels in water passing the end of treated area after 10 minutes.
Figure 4. The average fresh weight of two cuttings of alfalfa following application of two rates of GS-1425 to dormant alfalfa.
Table 2. A comparison of the effects of two concentrations of GS-14254 on the average fresh weight of two cuttings of alfalfa

<table>
<thead>
<tr>
<th>Treatment (lb/A)</th>
<th>Fresh weight (T/A) a</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.76 a</td>
</tr>
<tr>
<td>1.5</td>
<td>5.08 a</td>
</tr>
<tr>
<td>3.0</td>
<td>4.50 a</td>
</tr>
</tbody>
</table>

aValues followed by the same letter are not significantly different at the 10% level as determined by Scheffle's test. Each value is the mean of three replications.

Evans and Woods (11) reported that GS-14254 caused some initial injury to irrigated alfalfa when applied in the spring before the alfalfa broke dormancy, but that it did not cause a significant reduction to any of the cuttings. Hastings and Kust (28) also reported some initial injury due to GS-14254 when it was applied in September. However, little injury was noticeable after five weeks and no significant reduction in alfalfa yield occurred the following spring. It appears that GS-14254 will cause some initial leaf chlorosis or stunting depending on time and rate of application, but that no significant reductions in yield due to the chemical treatment are likely. GS-14254, therefore, offers promise as a herbicide in alfalfa because it effectively controls most broadleaved and grassy weeds in alfalfa (12) without causing a significant reduction in yield.

Greenhouse and Laboratory Experiments

Concentration effect of GS-14254 on oats

Oats were grown in Nibley clay loam treated with known concentrations of GS-14254 to demonstrate the effects of this herbicide on sensitive
Figure 5. The effect of several concentrations of GS-14254 on the dry weight of oats grown in greenhouse pots.
crops. All concentrations of GS-14254 used showed significant reductions in dry weight (Figure 5, Table 3). The lack of significance between dosage levels of the herbicide indicate that oats are too sensitive to detect differences among concentrations of GS-14254 greater than 1 or 2 ppm in the soil.

Table 3. A comparison of the effects of several concentrations of GS-14254 on the dry weight of oats

<table>
<thead>
<tr>
<th>Concentration (ppmw)</th>
<th>Dry weights (mg/10 plants) a</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>135 a</td>
</tr>
<tr>
<td>1</td>
<td>76 b</td>
</tr>
<tr>
<td>2</td>
<td>70 b</td>
</tr>
<tr>
<td>3</td>
<td>63 b</td>
</tr>
<tr>
<td>4</td>
<td>59 b</td>
</tr>
</tbody>
</table>

Values followed by the same letter are not significantly different at the 5% level as determined by Newman-Keuls multiple range test. Each value is the mean of 4 replications.

Oats are relatively sensitive to triazine herbicides and are often used as bioassays to detect triazines in soil. Burnside and Behrens (9) used oats to detect differences in concentrations of simazine in soil ranging from 0.25 to 1.0 ppm. It appears that oats are about as sensitive to GS-14254 as they are to simazine. Therefore, oats would also be a good bioassay for detecting differences in concentrations of GS-14254 in soils between 0.25 and 1.0 ppm.

Concentration effect of GS-14254 on Chlorella

The growth of Chlorella incubated in several concentrations of GS-14254 for 25 days is shown in Figure 6. There was no growth
stimulation effect produced by the lowest concentration (.01 ppb) of herbicide used (Figure 6). Figures 7, 8, 9 and 10 show the growth of Chlorella in the different concentrations as percent of the control for 5, 10, 15 and 21 days post inoculation respectively. Tables 4, 5, 6 and 7 give growth comparisons between the algal cultures incubated in the different concentrations of GS-14254 at three levels of significance for 5, 10, 15 and 21 days post inoculation. Figures 7, 8, 9 and 10 show 50% inhibition of growth resulting from 100 ppb after 5, 10, 15 and 21 days post inoculation respectively. Figures 8, 9 and 10 show 90% inhibition of growth resulting from 500 ppb after 10, 15 and 21 days post inoculation respectively. When maximum growth was achieved (21 days post inoculation), there was a significant difference in the growth of algal cultures incubated in concentrations of .01 and .1 ppb at the 99.9% confidence level (Table 7). Chlorella appears to be a very sensitive test organism that could possibly be used for determining GS-14254 residue levels in runoff water.

From an ecological standpoint, whether the algae are dead (algicidal effect) or merely prevented from growing (algistatic effect) in the presence of the herbicide would be of greater importance than a measure of algal growth (15). Figure 11 shows that all cultures were algistatic for all incubation concentrations and time periods examined. Brief exposure to the concentrations of GS-14254 found under field conditions would appear to have little if any effect on the growth of Chlorella (Figure 12). The regrowth curves on Tables 12, 13 and 14 show that Chlorella cultures, even after 20 days of incubation in concentrations as high as 10 ppm achieved growth nearly equal to that of the control when the two were placed in fresh media and were grown for 25 days. Fitzgerald (17) stated that there was some minimum exposure
time necessary for organisms to take up a lethal dose of a toxicant and that there was some minimum concentration that can be tolerated indefinitely. No such minimum exposure time was found with Chlorella necessary to take up a lethal dose of GS-14254 at the concentrations tested (Figure 11). It appears (Figure 5) that concentrations of GS-14254 between .1 and .5 are the maximum concentrations that can be tolerated for extended periods of time.

Ashton, et al. (4) reported that atrazine hindered all development and cell division. The highest concentrations in Figure 6 (1 and 5 ppm) indicate no growth or cell division. In time these concentrations would probably prove algicidal because of the constant need of energy to support life processes. When Ashton, et al. (4) added an atrazine-glucose mixture (the mixture contained 70 ppm atrazine) to Chlorella vulgaris, the algal cells exhibited more growth than did the control. The Chlorella was able to use the glucose as an exogenous energy source to carry on living processes. It is also likely that algae in an aquatic environment would be able to tolerate concentrations higher than were demonstrated in this study due to the presence of tremendous amounts of microscopic particulates that would provide an adsorptive surface for the removal of the compound from solution.
Figure 6. Effects of several concentrations of GS-14254 on the growth of Chlorella. Curves represent growth of algal cultures incubated for 25 days.
Figure 7. Effects of several concentrations of GS-14254 on the growth of Chlorella. Bar heights represent algal growth as percent of control 5 days post inoculation.
Table 4. A comparison of the effects of several concentrations of GS-14254 on Chlorella 5 days post inoculation

<table>
<thead>
<tr>
<th>Concentration (ppb)</th>
<th>Levels of significance(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Control</td>
<td>ab</td>
</tr>
<tr>
<td>0.01</td>
<td>a</td>
</tr>
<tr>
<td>0.1</td>
<td>ab</td>
</tr>
<tr>
<td>1.</td>
<td>ab</td>
</tr>
<tr>
<td>10.</td>
<td>ab</td>
</tr>
<tr>
<td>100.</td>
<td>bc</td>
</tr>
<tr>
<td>500.</td>
<td>cd</td>
</tr>
<tr>
<td>1000.</td>
<td>d</td>
</tr>
<tr>
<td>5000.</td>
<td>d</td>
</tr>
</tbody>
</table>

\(^a\)Treatments followed by the same letter did not produce results that were different at the various alpha levels as determined by the L.S.D. test. This experiment was replicated four times.
Figure 8. Effects of several concentrations of GS-14254 on the growth of Chlorella. Bar heights represent algal growth as percent of control 10 days post inoculation.
Table 5. A comparison of the effects of several concentrations of GS-14254 on Chlorella 10 days post inoculation

<table>
<thead>
<tr>
<th>Concentration (ppb)</th>
<th>Levels of significance&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Control</td>
<td>a</td>
</tr>
<tr>
<td>0.01</td>
<td>a</td>
</tr>
<tr>
<td>0.1</td>
<td>ab</td>
</tr>
<tr>
<td>1.</td>
<td>c</td>
</tr>
<tr>
<td>10.</td>
<td>d</td>
</tr>
<tr>
<td>50.</td>
<td>e</td>
</tr>
<tr>
<td>100.</td>
<td>f</td>
</tr>
<tr>
<td>500.</td>
<td>g</td>
</tr>
<tr>
<td>1000.</td>
<td>g</td>
</tr>
<tr>
<td>5000.</td>
<td>g</td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatments followed by the same letter did not produce results that were different at the various alpha levels as determined by the L.S.D. test. This experiment was replicated four times.
Figure 9. Effects of several concentrations of GS-14254 on the growth of Chlorella. Bar heights represent algal growth as percent of control 15 days post inoculation.
Table 6. A comparison of the effects of several concentrations of GS-14254 on Chlorella 15 days post inoculation

<table>
<thead>
<tr>
<th>Concentration (ppb)</th>
<th>Levels of significance&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Control</td>
<td>a</td>
</tr>
<tr>
<td>0.01</td>
<td>a</td>
</tr>
<tr>
<td>0.1</td>
<td>b</td>
</tr>
<tr>
<td>1.</td>
<td>b</td>
</tr>
<tr>
<td>10.</td>
<td>c</td>
</tr>
<tr>
<td>50.</td>
<td>d</td>
</tr>
<tr>
<td>100.</td>
<td>e</td>
</tr>
<tr>
<td>500.</td>
<td>f</td>
</tr>
<tr>
<td>1000.</td>
<td>fg</td>
</tr>
<tr>
<td>5000.</td>
<td>g</td>
</tr>
</tbody>
</table>

<sup>a</sup>Treatments followed by the same letter did not produce results that were different at the various alpha levels as determined by the L.S.D. test. This experiment was replicated four times.
Figure 10. Effects of several concentrations of GS-14254 on the growth of Chlorella. Bar heights represent maximum growth of cultures as compared to percent of control 21 days post inoculation.
Table 7. A comparison of the effects of several concentrations of GS-14254 on Chlorella 21 days post inoculation

<table>
<thead>
<tr>
<th>Concentration (ppb)</th>
<th>Levels of significance(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Control</td>
<td>a</td>
</tr>
<tr>
<td>0.1</td>
<td>a</td>
</tr>
<tr>
<td>1.</td>
<td>b</td>
</tr>
<tr>
<td>10.</td>
<td>b</td>
</tr>
<tr>
<td>50.</td>
<td>c</td>
</tr>
<tr>
<td>100.</td>
<td>d</td>
</tr>
<tr>
<td>500.</td>
<td>e</td>
</tr>
<tr>
<td>1000.</td>
<td>f</td>
</tr>
<tr>
<td>5000.</td>
<td>g</td>
</tr>
</tbody>
</table>

\(a\) Treatments followed by the same letter did not produce results that were different at the various alpha levels as determined by the L.S.D. test. This experiment was replicated four times.
Figure 11. The regrowth of Chlorella following incubation in several concentrations of GS-14254 for varying periods of time. Algal cultures were washed and put in fresh media following 1, 14 and 20 day incubation periods. Cultures showing regrowth were marked with a plus and those showing no regrowth with a minus. All cultures showed regrowth.
Figure 12. Regrowth of Chlorella incubated in several concentrations of GS-14254 for one day. Curves represent regrowth of algal cultures that were washed and put in fresh media after incubation period.
Figure 13. Regrowth of Chlorella incubated in several concentrations of GS-1425 for 14 days. Curves represent regrowth of algal cultures that were washed and put in fresh media after incubation period.
Figure 14. Regrowth of Chlorella incubated in several concentrations of GS-l4:25h for 20 days. Curves represent regrowth of algal cultures that were washed and put in fresh media after incubation period.
Attempts were made in this study to elucidate the lateral movement of GS-14254 from a field of established alfalfa, with some mention of possible inhibitory effects on other plant life.

The results of the lateral movement study indicate that small but significant amounts of GS-14254 are transported in irrigation runoff from a stand of alfalfa established in Mibley clay loam. The concentration of GS-14254 in the irrigation water declined rapidly with increased distance from the treated plots and with time. Oats and other sensitive crops planted adjacent to and receiving irrigation water from GS-14254 treated areas would possibly sustain some injury within 5 to 10 ft of the treated areas.

GS-14254 produced no visual injury symptoms of leaf chlorosis or plant stunting on alfalfa at 1.5 and 3.0 lb/A. The average alfalfa fresh weight data indicated a reduction in yield due to both rates of GS-14254. However, a comparison of the treatments using Scheffle's test showed no significance at the 10% probability level. An initial alfalfa injury is likely to occur and has been observed by other workers.

Oats are very sensitive to GS-14254 and would be a good bioassay for detecting differences in concentrations of this chemical in soil. Precautions should be taken when growing oats on other crops sensitive to GS-14254 that runoff water from treated areas is diluted below toxic levels before reaching the crops.

Chlorella appears also to be a very sensitive test organism that could possibly be used for determining GS-14254 residue levels in runoff water. The data show that 50% inhibition of growth was given by 100 ppb
after 5, 10, 15 and 21 days. Algal growth showed an inverse relationship with herbicide concentration. There was no growth stimulation effect produced even by the lowest concentration (0.01 ppb) of herbicide used. Brief exposure to the concentrations of GS-14254 found under field conditions would appear to have little if any effect on the growth of Chlorella. All herbicide concentrations and time periods examined proved to be algistatic for the test organism. It is likely that algae in aquatic environments would be able to tolerate concentrations of GS-14254 higher than was demonstrated in this study due to the presence of absorptive particulates capable of removing herbicide molecules from solution.

At recommended rates for alfalfa, the herbicide concentration in the runoff would likely not be hazardous to plant or animal life.
LITERATURE CITED


5. Austin, D. 1972. Graduate student doing soil studies covering the period of this experiment. Personal interview, April 23.


APPENDIXES
APPENDIX A

Table 8. Analysis of variance on the residue from two rates of GS-14254 in the runoff water at different distances from the treated area

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>1</td>
<td>0.03603</td>
<td>0.03603</td>
<td>8.0662***</td>
</tr>
<tr>
<td>Error (A)</td>
<td>4</td>
<td>0.01787</td>
<td>0.00446</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>3</td>
<td>0.49800</td>
<td>0.16600</td>
<td>61.5224***</td>
</tr>
<tr>
<td>Distance x Treatment</td>
<td>3</td>
<td>0.03798</td>
<td>0.01266</td>
<td>4.6929*</td>
</tr>
<tr>
<td>Error (B)</td>
<td>12</td>
<td>0.03237</td>
<td>0.00269</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>0.62228</td>
<td>0.02705</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.10
*** Significant at 0.05
**** Significant at 0.01
Table 9. Analysis of variance on the effects of two concentrations of GS-14254 on the fresh weight of two consecutive cuttings of alfalfa

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>2.21</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>2</td>
<td>72.43</td>
<td>36.21</td>
<td>4.44*</td>
</tr>
<tr>
<td>Error (A)</td>
<td>4</td>
<td>32.60</td>
<td>8.15</td>
<td></td>
</tr>
<tr>
<td>Cuttings</td>
<td>1</td>
<td>544.49</td>
<td>544.49</td>
<td>155.89**</td>
</tr>
<tr>
<td>Cuttings x treatment</td>
<td>2</td>
<td>0.37</td>
<td>0.18</td>
<td>0.05</td>
</tr>
<tr>
<td>Error (B)</td>
<td>6</td>
<td>20.95</td>
<td>3.49</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>673.08</td>
<td>39.59</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.10
** Significant at 0.01

Table 10. Analysis of variance on the efforts of several rates of GS-14254 on the dry weight of oats.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
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<td>0.003871</td>
<td>47.504*</td>
</tr>
<tr>
<td>Error</td>
<td>15</td>
<td>0.001222</td>
<td>0.000081</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>0.016709</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.01
Table 11. Regression analysis on the effects of several concentrations of GS-14254 on the growth of Chlorella

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>VAR</th>
<th>COEF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable 1</td>
<td>1</td>
<td>7.1469</td>
<td>664.93*</td>
<td>B(1)</td>
<td>0.01808</td>
</tr>
<tr>
<td>Variable 4</td>
<td>1</td>
<td>4.2600</td>
<td>396.34*</td>
<td>B(4)</td>
<td>-0.00438</td>
</tr>
<tr>
<td>Model</td>
<td>2</td>
<td>4.7580</td>
<td></td>
<td>RSQ</td>
<td>0.56</td>
</tr>
<tr>
<td>Error</td>
<td>677</td>
<td>0.0107</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>679</td>
<td>0.0247</td>
<td></td>
<td>B(0)</td>
<td>0.08198</td>
</tr>
</tbody>
</table>

*Significant at 0.01

Variable 1 = days
Variable 4 = days x concentration

Model: \[ Y = B_0 + B_1 D + B_4 DXC \]

\( Y = \) slope of data points for a given concentration

\( B_0 = 0.03198 \)

\( B_1 = 0.01808 \)

\( B_4 = -0.00438 \)

\( D = \) days

\( C = \) concentration
Table 12. Analysis of variance on the effects of several concentrations of GS-14254 on the growth of Chlorella

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>3</td>
<td>0.0802</td>
<td>0.02673</td>
<td>3.62*</td>
</tr>
<tr>
<td>Concentration</td>
<td>9</td>
<td>7.5836</td>
<td>0.84262</td>
<td>113.45**</td>
</tr>
<tr>
<td>Error (A)</td>
<td>27</td>
<td>0.2005</td>
<td>0.00742</td>
<td></td>
</tr>
<tr>
<td>Days</td>
<td>17</td>
<td>5.3913</td>
<td>0.33695</td>
<td>843.59**</td>
</tr>
<tr>
<td>Error (B)</td>
<td>480</td>
<td>0.1917</td>
<td>0.00039</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>679</td>
<td>16.7925</td>
<td>0.02473</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.05
** Significant at 0.01
APPENDIX B

Table 13. Nutrient solution composition for growth media of Chlorella pyrenoidosa (Bristol's solution (60) plus Provasoli and Pintner's (42) P IV trace metal mix)

Add the following amounts of stock solutions to 938 ml. of Pyrex-distilled water.

<table>
<thead>
<tr>
<th>No. of ml</th>
<th>Stock solution</th>
<th>Stock solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00</td>
<td>NaNO$_3$</td>
<td>10.0 g/400 ml</td>
</tr>
<tr>
<td>10.00</td>
<td>CaCl$_2$</td>
<td>1.0 g/400 ml</td>
</tr>
<tr>
<td>10.00</td>
<td>MgSO$_4$•7H$_2$O</td>
<td>3.0 g/400 ml</td>
</tr>
<tr>
<td>10.00</td>
<td>K$_2$HPO$_4$</td>
<td>3.0 g/400 ml</td>
</tr>
<tr>
<td>10.00</td>
<td>KH$_2$PO$_4$</td>
<td>7.0 g/400 ml</td>
</tr>
<tr>
<td>0.05</td>
<td>FeCl$_3$</td>
<td>1.0 g/400 ml</td>
</tr>
<tr>
<td>2.00</td>
<td>P IV metal solution</td>
<td>see below</td>
</tr>
</tbody>
</table>

Add the following amounts of chelating agent and metal salts to 500 ml of glass distilled water

- FeCl$_3$•6H$_2$O 0.097 g
- MnCl$_2$•4H$_2$O 0.041 g
- ZnCl$_2$ 0.005 g
- CoCl$_2$•6H$_2$O 0.002 g
- Na$_2$MoO$_4$ 0.204 g
- Na$_2$EDTA 0.750 g
Table 14. Characteristics of the soil used in this study (26)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage organic matter</td>
<td>3.2</td>
</tr>
<tr>
<td>Extractable phosphorus (P₂O₅) lb/A</td>
<td>125.0</td>
</tr>
<tr>
<td>Exchangeable potassium**</td>
<td>1.8</td>
</tr>
<tr>
<td>Percentage clay</td>
<td>35.5</td>
</tr>
<tr>
<td>Percentage silt</td>
<td>61.8</td>
</tr>
<tr>
<td>Percentage sand</td>
<td>2.7</td>
</tr>
<tr>
<td>Percentage moisture at 1/3 atm.</td>
<td>29.6</td>
</tr>
<tr>
<td>Percentage moisture at 15 atm.</td>
<td>14.4</td>
</tr>
<tr>
<td>Percentage available water</td>
<td>21.4</td>
</tr>
<tr>
<td>Cation exchange capacity*</td>
<td>23.7</td>
</tr>
<tr>
<td>pH</td>
<td>7.6</td>
</tr>
</tbody>
</table>

* Cation exchange capacity expressed in milliequivalents per 100 grams of oven dry soil.
**Potassium exchange capacity expressed in milliequivalents per 100 grams of oven dry soil.
VITA

Zeldon A. Nelson

Candidate for the Degree of

Master of Science

Thesis: The surface movement of a new s-triazine herbicide from treated cropland and its environmental effects

Major Field: Plant Science

Biographical Information:

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