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ACTIVATED CARBON: ITS NEUTRALIZING EFFECTS
ON A PREEMERGENT HERBICIDE.

THE UNIVERSITY OF ARIZONA, M.S., 1982

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ACTIVATED CARBON: ITS NEUTRALIZING EFFECTS ON A PREEMERGENT HERBICIDE

by

Ramadjita Tabo

A Thesis Submitted to the Faculty of the

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DEDICATION

I dedicate this thesis to my dear mom, the late Marie N'Dodjam.

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ABSTRACT

The use of activated charcoal to neutralize the harmful effects of preemergent herbicides on plant species was investigated in this study.

Under laboratory conditions, activated carbon applied as a slurry on the surfaces of clay loam or sandy loam soils did not move downward in either one of the soil types. This resistance to leaching was observed in both plain water and in water treated with 0.1% of non-ionic wetting agent.

Greenhouse studies showed that blue panicgrass (*Panicum antidotale* Retz.) and twinberry (*Menodora scabra* Gray) were tolerant to Surflan, whereas Boer lovegrass (*Eragrostis curvula* (Schrad.) var. conferta Nees.) and Cochise lovegrass (*E. lehmanniana* Nees. x *E. trichophora* Coss. and Dur.) were sensitive. Activated carbon applied over the seeded rows of the plant species at 224 kg per ha provided adequate protection from subsequent applications of Surflan. An unexpected and unexplained reduction in seedling numbers occurred at 448 kg per ha of activated carbon.

CHAPTER 1

INTRODUCTION

Most of the problems related to establishing grass species in a cleared field are the invasion of weed plants. Mechanical control of these weed species is usually time consuming, labor intensive and costly. It is also usually impossible to remove selectively grass weeds because sometimes they are the same shape, size and density as the crop. Thus, chemical control (use of herbicide) is often substituted for mechanical control of weeds; however, the problem of selectively removing the weed species is still not completely solved since desirable plants are often injured by the herbicides. Herbicides having adequate selectivity between desirable plants and weeds species are usually not available. Even when weeds are removed by herbicides prior to the planting of desired species, there is frequently a residual toxicity to affect the desired crop. Consequently, more effective methods are needed to selectively eradicate undesirable plants.

The use of activated charcoal appears to be one method to inactivate some preemergent herbicides around the desired seeds to increase selectivity. It was initially used in experiments to adsorb and inactivate herbicide residues left in the soil after application to previous crops. But in many recent studies, activated carbon is used to protect crops before the application of the herbicide (Deutsch 1973).

Various techniques of applying activated charcoal to improve herbicide selectivity have been reported. Plants have been protected from preemergent herbicides by dipping their roots in activated charcoal. Some were also protected from herbicide injury by using a mixture of activated carbon and vermiculite in a hole 2 cm deep by 2.5 cm diameter (Kratky and Warren 1971). Pelleting seeds with activated carbon also proved to be an effective technique of improving herbicide selectivity.

In this study, a slurry of activated charcoal was applied directly over rows seeded with various species before Surflan, a preemergent herbicide, was sprayed on the field.

The objectives of this study were to:

1. Determine whether activated charcoal migrates into two different soil types (sandy and clay loam).
2. Determine the effects of preemergent herbicides (Surflan and Treflan) on four plant species--blue panicgrass (Panicum antidotale Retz.), Boer lovegrass (Erogrostis curvula (Schrad.) var. conferta Nees.), Cochise lovegrass (E. lehmanniana Nees. x E. trichophora Coss. and Dur.) and twinberry (Menodora scabra Gray).
3. Determine the amount of activated charcoal required to protect plants from various rates of Surflan.

CHAPTER 2

REVIEW OF LITERATURE

This review covers the characteristics and properties of activated carbon, the techniques of activated carbon application and the factors affecting the use of activated carbon and its effects on various chemicals.

Characteristics and Properties of Activated Carbon

Activated charcoal is obtained by heating material such as coal, wood and lignite in the absence of air. It is then activated by reheating it in air, steam or with any oxidizing agents which considerably increase the charcoal's adsorptive surface (Jagschitz 1979). Activated carbon is very porous and a very active adsorbent. Its surface adsorbs and retains substances coming into contact with it. Jagschitz (1979) reported as a general rule that activated carbon does not adsorb inorganic materials. Organic compounds, however, are adsorbed well by activated charcoal. As another general rule mentioned by Jagschitz (1979), the bigger the molecule to be adsorbed, the better the adsorption--the greater the water solubility of the material to be adsorbed, the poorer the adsorption.

Activated charcoal or activated carbon is a material widely used to remove impurities from various substances. It is often used in large amounts for municipal water treatment and sugar refining. Activated carbon can be a potential answer to most of the problems caused by chemical residues, contamination and misuse.

Activated carbon has wide usage in agriculture and is being studied for reclamation of land contaminated with phytotoxic chemicals. Bovey and Miller (1969) stated that activated carbon adsorbed from ten to over 100 times more of the herbicides studied than any other adsorbent tested. In tests done by Lee (1973); Rolston, Lee and Appleby (1979), the activated charcoal was a dry, finely divided powder called Gro-Safe--a product available throughout the United States. Gro-Safe is safe to handle and presents fewer hazards to the user than any other adsorbent agent. It can be applied to the soil dry or as a spray. Generally the spray form is used because it is easier to handle.

Techniques of Activated Carbon Application

Activated carbon can be used in various ways to either protect new seedlings from chemical toxicity or to remove impurities from various substances.

In the studies done by Naugju, Plucknett and Obien (1976), activated charcoal was applied as a slurry in a band directly over the row-seeded crop to protect susceptible species such as alfalfa (*Medicago sativa* L.) or Italian ryegrass (*Lolium multiflorum* Lam.) from herbicide toxicity. Linscott and Hagin (1967) found that narrow bands of activated charcoal sprayed on the soil surface directly over the rows seeded with alfalfa in the field protected the legume from damage by a broadcast application of G-36393[1]. They also determined that sugarbeets were protected from 13 kg/ha of Pyrazon[2] and 9 kg/ha of Propachlor[3] by 2.5 cm carbon band. Ripper (1956) placed activated carbon in subsurface bands in the soil by special equipment to intercept herbicide before they reach the roots of susceptible crops.

Arle, Leonard and Harris (1948) observed that good protection was obtained by dipping the roots of sweet potato (*Ipomoea batatas* (L.) Lam.) sprouts or strawberry (*Fragaria grandiflora* Ehrh.) runners in activated carbon powder or slurry before planting them in herbicide-treated soil. Linscott and Hagin (1967) reported that in European countries, roots of ornamental plants to be transplanted in soils that contain Triazine residues are treated with charcoal. Recent research done in the United States by Rolston, Lee and Appleby (1979) indicates that this practice may have merit for protecting ornamentals and crops such as cabbage (*Brassica oleracea* L., var. Danish Ballhead) and tobacco (*Nicotiana tabacum* L. var. Havana). Flagg and Bayer (1969) found activated charcoal to be of little value in protecting strawberries (*Fragaria chiloenis* L., var. Midway) from Simazine residues. On the other hand, Kratky, Coffey and Warren (1970) showed that excellent protection from Simazine injury at twice the dose needed for weed control was obtained by dipping the roots of strawberry (*Fragaria grandiflora* Ehrh.) in a 10% slurry of activated carbon before transplanting. Protection was greater when the roots were dipped in the slurry of activated carbon than when activated carbon was applied in the transplant water.

[1,2,3] Chemical nomenclature of compounds mentioned in the text are given in Appendix B.

Gibson (1964) concluded from his studies with roots of a variety of herbaceous plants that a species could be protected with activated carbon only if it contained some inherent resistance to the herbicide. Robinson (1965) pointed out that dipping roots in dry activated carbon resulted in retention of about 1 gram of activated carbon. Ahrens (1967) also dipped strawberry roots in dry activated carbon but did not obtain the same degree of protection as reported here; therefore, root dips in slurry may result in more protection with less activated carbon used. Also, handling slurries is easier than dry carbon. Kratky and Warren (1970) found that root dips of tomato transplants in slurries of activated carbon provided significant but not total protection from a 1.1 kg/ha simulated residue of Atrazine in the soil. Although activated carbon slurries did not damage roots, direct contact with the foliage caused severe injury. Tomato foliage appeared blackened and somewhat desiccated as a result of contact with an activated carbon slurry (Darco M).

Kratky and Warren (1971) developed another technique to prevent herbicide injury to cucumber (*Cucumis sativus* L.) and tomato (*Lycopersicum esculentum* Mill.). They placed a mixture of activated carbon and vermiculite in a hole 2 cm deep by 2.5 cm diameter over the seeds of the test crops. This technique was mechanized by making a wafer that contained activated carbon, vermiculite, seed and fertilizer. In some unsuccessful greenhouse trials, activated carbon was placed in a hole over the seed. The activated carbon became hard, making it difficult for the seedlings to emerge; however, when a mixture of activated carbon and vermiculite was placed in a hole over the seed, emergence of seedlings was not impaired and there was much less erosion of activated carbon.

Kratky and Warren (1971) suggested pelleting seeds with activated carbon or other materials as another possible method to protect direct seeded crops from herbicide toxicity. Numerous advantages and uses of seed pelleting have been reviewed by Plucknett (1971). The main advantages of seed pelleting are that the technique is relatively simple and cheap; several chemicals or substances can be pelleted on seeds to solve several problems during seedling establishment; and materials are in close proximity to emerging shoots and roots. The pelleting materials (adhesive and adsorbent) both affect the performance of pelleted seeds in puddled soil. Naugju, Plucknett and Obien (1976) gave a list of five adhesives usually used with this technique. The five adhesives are methyl cellulose, methyl ethyl cellulose, dry casein glue, gum arabic, and polyvinyl acetate. The adsorbent reported is activated carbon Darco G-60. Triple coating of activated carbon Darco G-60 gave better results than a single coating.

For planting in the greenhouse, rice (*Oryza sativa* L.) seeds were pelleted with activated carbon in a small beaker. The number of coating layers was increased to three by repeating the above procedure after the seeds were dried for at least 60 minutes. Resulting coating weight varied from 13 to 17 mg per seed. Application of liquid herbicide before planting (i.e., two days before sowing) could be either beneficial or detrimental to the survival of carbon-coated rice seeds depending on whether the herbicides were highly adsorbed on soil or were soluble and could leach down easily to the subsoil. Naugju, Plucknett and Obien (1976) also concluded that it was essential to apply the herbicides at least 24 hours before the emergence of the radicles and coleoptiles, so that the amount of herbicides around the coated seed can be reduced by adsorption and other means to a level which will not cause permanent injury to the young seedlings. Close spacings appeared to have induced rapid recovery of injured seedlings from coated seeds. Doubling the standard seeding rate (100-120 kg/ha) is not likely to reduce herbicide toxicity to direct-seeded rice. Adsorption capacity, coating quality and coating weight all determined the degree of protection afforded by carbon coating. The degree of protection also depends on time of flooding, method and rate of sowing, quality of activated carbon and rate and time of herbicide application.

Factors Affecting the Use of Activated Carbon and Its Effects on Various Chemicals

Coffey and Warren (1969) used a root bioassay to compare the adsorption of herbicides by activated carbon with that of muck soil, bentonite clay, a cation exchange resin and an anion exchange resin. The effectiveness of different adsorbents was determined by comparing the concentration of herbicide required to give 50% root inhibition of the test plant. Of eight herbicides used, six were more strongly adsorbed by activated carbon than by any of the other adsorbents. Paraquat, a strongly cationic and completely water soluble compound, was the only herbicide which was not adsorbed by activated carbon.

Plucknett (1971) classified several chemicals according to their effect on seedling growth in the presence of activated charcoal. Some chemicals required no charcoal, some could be detoxified by charcoal and some could not be deactivated by charcoal. The chemicals which did not inhibit seedlings and required no charcoal are Bentazon, cacodylic acid, Cyerquat, Dalapon, DSMA, gasoline, Glyphosate, Mefluidide, Metham, Paraquat, Siduron and sodium arsenite. The following herbicides inhibited grass seedlings but could be detoxified by activated carbon, resulting in improved grass stands: 2,4D, Amitrole, Bandane, Benefin, Butralin, Chlorofluerenol, DCPA, Dicamba, Endothall, Fluridamid, Mecroprop, Maleic hydrazide, Nitralin, Oxadiazon, Picloram, Profluralin, Proamide, Prosulfalin, Simazine, Silvex and Terbutol. Chemicals which inhibited seedlings and were not deactivated by activated carbon included diesel fuel, hydraulic fluid and tricalcium arsenate.

Bovey and Miller (1969) indicated that adequate crop protection by activated carbon following herbicide treatment depends on many factors such as crop species, soil type, herbicide type and rate, and activated carbon dosage. To illustrate the effects of some of these factors, Linscott and Hagin (1967) reported that charcoal suspended in water and applied at 27 to 54 kg per ha gave adequate protection to legumes from 1.6 kg per ha/G36393. Higher rates of charcoal, 112 kg per ha were necessary to protect legumes from a 3.2 kg per ha application. Activated carbon did not protect alfalfa (*Medicago sativa* L.) from 1.6 kg per ha of Atrazine. Harvey (1973) found that when exposed to alternate freezing and thawing, the ability of 0.4 g/kg of activated carbon to deactivate Atrazine was reduced causing increased oat (*Avena sativa* L.) injury. He also observed that certain plants, including corn (*Zea mays* L.), have the capability of detoxifying chlorotriazine herbicides. Under greenhouse conditions, cropping with a tolerant species such as corn can reduce Atrazine residues. Activated carbon, when mixed in the potting medium, reduces the rate of degradation of Atrazine residues and also decreases the amount of atrazine removed by corn plants. Rolston, Lee and Appleby (1979) concluded from their greenhouse studies that activated carbon at 150 and 300 kg/ha protected white clover (Trifolium repens L.) seedlings from Diuron applied preemergence at rates up to 2 and 4 kg/ha respectively. The ratio of activated carbon to herbicide that prevented a significant reduction in seedling numbers was 50:1 for Diuron and 200:1 for Atrazine and Simazine.

If the effective band becomes too narrow because of low carbon rates, high herbicide rates or a narrow application, crop injury may result, especially if the band is not precisely positioned above the seed row. Deutsch (1973) found that in the field, when single-spaced plants spread beyond the area of carbon protection onto soil treated with Diuron at 4 kg/ha, stolon length and fresh weight 40 weeks after establishment were reduced. He also observed that white clover (Trifolium repens L.) was severely injured in experiments established in the fall of 1977, particularly in those plots established when the soil surface was wet at the time of spraying. A possible explanation is that water molecules may compete with Diuron for adsorption sites on organic matter and clay colloids. When the soil surface is high in moisture, more Diuron would be available in the soil solution to interact with the emerging seedlings.

Deutsch (1973) also reported that carbon banding holds promise of economic potential for areas having widely varying soil conditions.

A streak of sandy, low adsorption soil in a field often may react quite differently to herbicide application than surrounding higher organic matter soil. The herbicide is tied up by the latter, but remains active in the former, adversely affecting certain crops. A protective carbon band would eliminate the variability by adsorbing the herbicide no matter what the soil conditions might be.

Burr, Lee and Appleby (1972) determined that activated carbon, applied as a slurry at the time of seeding, protected Italian ryegrass (Lolium multiflorum Lam.) seedlings from the toxicity of Diuron applied preemergence. Plants growing from seeds planted 1.3 cm deep received less protection from Diuron than plants growing from seeds planted 0.6, 1.9 or 2.5 cm deep. The reason for reduced protection for seedlings from seedlings from seeds planted 1.3 cm deep is not clear. They also reported that sandy loam soil required at least three times more activated carbon than a clay loam soil to obtain the same protection. Wetting agents added to aid in carbon wetting reduced the protective effect of activated carbon when added at 0.9 or 2.7% (V/V) but had only a slight effect on protection when added at 0.3% (V/V).

Ahrens (1965) found that activated carbon applied in water was less effective than that applied dry for inactivating Atrazine in soil. The wet application possibly attached the carbon particles more firmly to soil particles, making thorough mixing into the soil difficult. Although wet application of activated carbon may be less effective than dry application, it might have the advantage of avoiding the dusting problem in spreading the finely powdered, activated carbon.

Ahrens (1965) also reported that with the proper nozzle tips, it has been possible to spray suspensions containing 454 g of activated carbon per 3.78 to 5.67 liters of water.

Lee (1973) stated the difficulty in applying charcoal is getting it mixed properly. It takes longer to get it wet and mixed than to apply it. He recommends that the charcoal and herbicides be applied well before a rain. If it rains before the herbicide is applied, the charcoal soaks up soil organic matter and loses some of its ability to adsorb the herbicide. Lee (1973) also recommends applying the charcoal with corrosion-resistant centrifugal or diaphragm pumps because charcoal is very abrasive. He stated that liquid fertilizer works well as part of the charcoal carrier because charcoal does not tie up fertilizer or vice versa. In the process of applying charcoal as a slurry, proper nozzle tips and pressure should be used to put out the appropriate rates.

Weber, Perry and Upchurch (1965) found that all of the organic compounds they used were adsorbed by charcoal and each was influenced differently by temperature and exposure time. They mentioned that the organic cations were adsorbed by charcoal in small amounts at low temperature, but were adsorbed in increasing amounts with time at high temperature. The fate of organic compounds applied to the soil is becoming increasingly important as their use increases and because of the development of more persistent and more biologically active compounds. The disappearance of some of the pesticides by volatilization, leaching, chemical and biological decomposition, and the interactions with the various soil components is of interest because of the reduced efficiency of the compounds. The possibility of their accumulation in the soil, and the potential of increasing the selectivity between weeds and crops provides the basis for additional research on the beneficial effects of activated charcoal.

CHAPTER 3

METHODS AND PROCEDURES

Studies on the neutralizing effects of activated carbon on preemergent herbicides were conducted at the Tucson Plant Materials Center. They consisted of laboratory, greenhouse and field experiments. The laboratory and greenhouse experiments were designed to provide qualitative results and procedural information to establish a field study leading to quantitative data. Preliminary laboratory and greenhouse studies were done in the summer of 1980. Subsequent field and greenhouse studies were conducted in the summer of 1981.

Laboratory and Greenhouse Experiments of 1980 Summer

A series of five experiments was conducted from June 1980 to August 1980 to give more insight into the properties and problems related to the use of activated carbon. The first two experiments were to investigate the mobility of activated carbon when applied to the soil. For each one of these two laboratory studies, two 59 cm inside-diameter, glass tubes were filled with 58 cm sandy loam soil and two were filled with clay loam soil. The tubes were secured in a vertical position. A slurry of 1 gram of Gro-Safe and 10 ml of water was applied uniformly over the surface of the two soil types. In a second set of tubes, a slurry of Gro-Safe plus 0.1 percent surfactant in 10 ml of water was added to the soil. The tubes containing sandy loam soils were watered with 200 ml of water to bring to field capacity and 250 ml was required for the clay loam. These amounts of water were added to the soils in small quantities each day.

Samples of these treated soils were taken every day for one week to check the presence of Gro-Safe at various depths. I assumed that if there was any migration of Gro-Safe into the soil, it would be observed through the glass tube. I also used two forcepts to remove soil from various depths below the treated surface for visual inspection. Any presence of black substance (activated carbon) would be easily detected.

The objective of the third experiment was to determine the amount of Gro-Safe required to protect grass seeds from three different rates of Treflan. In this experiment, 32 small plastic pots, each containing 1.5 kg of sandy loam, were prepared for a greenhouse study. There were two replications for each treatment. Rates of Treflan were based on the recommendation of incorporating Treflan into the top four inches of soil. From the general assumption that a six-inch layer of topsoil weighs two million pounds, the appropriate rates for treating a four-inch layer was derived for Gro-Safe and Treflan. The recommended rate of Gro-Safe for sandy loam soil was 224 kg/ha. Rates of Gro-Safe selected for this experiment were 0, 224, 448 and 896 kg/ha.

The minimum rate of Treflan for a sandy loam soil was 1.17 l/ha, and the rates selected for this experiment were 1.17, 1.75 and 2.33 l per hectare. The appropriate rate of Treflan was added to 11.3 kg of soil, which for the 1.17 l/ha was equivalent to .0085 ml achieved by serial dilution. To achieve adequate distribution of Treflan, it was diluted with water before mixing with the soil. Then each 11.3 kg of Treflan-treated soil was divided into three groups of 3.6 kg each. A slurry prepared from each of the three Gro-Safe rates (.55 g, 1.1 g, 2.2 g) was applied to each 3.6 kg of Treflan-treated soil and mixed thoroughly. Two replicates of 1.5 kg of Gro-Safe plus Treflan were taken from the 3.6 kg described above.

In the first stage of this greenhouse study, the 32 plastic pots containing the treatments were seeded with blue panicgrass They were hand watered the first day and in the subsequent days moisture was provided by an automatic overhead sprinkler. Every day for about ten days, the plastic pots were examined to determine whether emergence occurred.

The fourth experiment was conducted using the same procedures described in the third experiment. This time, three plant species (two grasses and one forb) and only three rates of Treflan (0, 1.1, 2.2 kg/ha) and three rates of Gro-Safe (0, 224 and 896 kg/ha) were used. The reason for using three plant species in this experiment was to determine if they would react the same as blue panicgrass to the treatments. The two grass species were Cochise lovegrass and Boer lovegrass. The forb was twinberry. A total of 54 plastic pots were prepared to give three replications per plant. In the same manner as the third experiment, all the plastic pots were observed every day for about ten days to detect any germination and emergence that would have taken place.

The fifth experiment was designed to determine the amount of Gro-Safe required to provide safety zones to the plant, to determine the effects of Treflan on the resistant species (twinberry and blue panicgrass) using limited moisture, and to determine the enhancement of germination by the activated carbon. In the previous greenhouse studies it appeared that ideal moisture conditions were masking some of the effects of Treflan. Therefore, procedures were changed to allow plants to undergo some moisture stress. They received water only on the day of seeding and then five days later. This moisture stress would hopefully accentuate the effects of Treflan on the more resistant species such as blue panicgrass and twinberry. Observations of germination were taken every day for two weeks.

Greenhouse and Field Experiments of 1981 Summer

Greenhouse and field experiments were conducted during the period of June 1 through August 27, 1981 at the Plant Materials Center. The main objective of the greenhouse study was to determine whether Surflan, a preemergent herbicide, has the same characteristics as Treflan, another preemergent herbicide. Moreover, I wanted to make sure that substituting Surflan for Treflan would not materially affect the outcomes of the experiment as predicted from the results of the 1980 summer greenhouse studies. Surflan was used instead of Treflan in the field experiment to overcome some of the practical problems associated with the application of Treflan to the soil. Treflan must be incorporated about two or more inches into the soil to prevent degradation by sunlight. In this particular study, if we incorporated Treflan two inches into the soil, then plant the four species and apply the charcoal we would be confronted with few problems. To provide a safety zone for the planted seeds, activated charcoal must be incorporated into the soil so that it could get in contact with the herbicide and deactivate it. Lack of the appropriate equipment makes it practically impossible to perform the incorporation of both charcoal and Treflan. Moreover, incorporation of charcoal would disturb the planted seeds. On the other hand, if Treflan is incorporated into the soil and the charcoal sprayed on the surface of the soil, a few inches of the soil underneath the charcoal layer would not be in contact with Gro-Safe. Consequently, when the radicle of the germinating seed extends downward and laterally, it would be exposed to a Treflan infected zone which is Gro-Safe free . This would result in plant injury.

Greenhouse Studies

In this study, activated carbon, Surflan and four plant species (twinberry, Cochise lovegrass, Boer lovegrass and blue panicgrass) were used. The two Gro-Safe rates used were 224 and 896 kg per ha. The two Surflan rates were 1.1 kg per ha and 2.2 kg per ha. A total of 56 plastic pots were prepared (14 pots per species) and installed in the greenhouse. All the treatments were watered with an automatic set overhead sprinkler. The plastic pots were examined for germination for a period of one week.

Field Experiment

The field experiment was conducted from June 16 to September 5, 1981 on sandy loam at the Tucson Plant Materials Center in Tucson, Arizona. In this study, the use of activated carbon to protect new plantings of Cochise lovegrass, blue panicgrass, Boer lovegrass and twinberry from Surflan was investigated. A split-split plot design with four replications (blocks), four species, four rates of activated carbon, and four rates of Surflan were used in the study. A "Planet Junior" seed planter was calibrated for each species to deliver 20 pure live seed per foot. A small tractor equipped with a spray tank was used to apply Surflan. The sprayer was calibrated to deliver ten gallons on a plot size of 22 by 9 m (72 by 30 feet). The field was divided into four blocks, 22 x 8 m (72 by 27 feet) with three 4.5 m (15 ft.) alleys between the replications. Species, rates of Surflan and rates of activated carbon were randomly distributed within replications. Each plant species was planted in two rows within each plot 22 by 0.5 m (72 by 1.5 feet). It was very difficult to mix the activated carbon (Gro-Safe) with water. To facilitate mixing, Gro-Safe was mixed with water in a small bucket and then transferred to the spray tank. Each rate was applied in ten gallons of water uniformly sprayed over the plot. Rates were 224, 448 and 896 kg per ha. To each mixture of Gro-Safe, 0.1% surfactant was added to get a more consistent mixture.

The area of $180m^2$ (1,944 $ft.^2$) represented four small sub-units 8 by 5 m (27 by 18 ft.) each $45m^2$ (486 $ft.^2$). Charcoal was sprayed directly over the seeded rows through drop nozzles at right angles. The nozzles were angled to obtain the proper band width. The carbon was kept suspended in the spray tank by a vigorous agitation with a long stick. Despite the removal of screens from the nozzles and the agitation, there was the problem of nozzles plugging. The band of Gro-Safe resulting from the spray was 8 m wide and 5 m long for each replication. Each carbon plot included 32 rows of plants planted 15 cm (six inches) apart.

The Surflan rates were as follows: 1.1, 1.6, 2.2 kg per ha. The area of $79m^2$ (864 $ft.^2$) represented eight subplots, each 22 m by 0.5 m. A three-gallon hand sprayer was used for the application of Surflan. Surflan was applied over and in the same direction as the seeded rows. Thus, the herbicides were superimposed on the carbon treatments to give a split-split plot design. After herbicide application, the whole field was irrigated for three hours to get the Surflan to infiltrate the soil. Subsequent sprinkler irrigation followed for about one month and then after the plants were established flood irrigation was used when necessary.

Data consisted of visual estimates of the height of crop stand in each plot two weeks after planting and applying all the treatments. Also, the number of plants in each subplot was determined by counting plants in a .8 by .3 m (2.5 by 1.0 ft.) quadrat. In each plot, three quadrats were taken and the mean number of plants per quadrat was used to describe the initial response from the various treatment.

CHAPTER 4

RESULTS AND DISCUSSION

The mobility of Gro-Safe into the soil was determined by visual observations in a laboratory study. The results of greenhouse experiments were also qualitative and provided direction and support for field studies. Data from the field experiments were quantitative and were subjected to two forms of statistical analyses (Appendix A). These analyses were designed to take care of the irregularities of the data. Missing data were possibly analyzed by the two analyses. These two analyses were threshold and rate analyses on which the general discussion of the results was based. Orthogonal polynomials and Student-Newman-Keul's tests (SNK) were used to determine the form of significance existing between the levels of various factors within each other (i.e., carbon within herbicide levels or species within herbicide levels) and to separate the means of these variables.

Migration of Gro-Safe Into the Soil

There was no visible evidence that activated carbon had any movement in either a sandy loam or a clay loam soil under the influence of water movement. This was true in plain water or with water treated with 0.1% of non-ionic wetting agent. These observations show partly that once activated carbon is applied over the rows of seeds, it is very resistant to movement by leaching. However, to avoid going beyond the scope of this study, it would not be accurate to state that Gro-Safe does not leach at all. The major uncertainty lies in the fact that it is not known how long Gro-Safe maintains its ability to neutralize Surflan because the adsorptive capacity would become saturated with a miriad of other organic compounds. There is a possibility that the mobility of activated carbon could be influenced by the irrigation system used during the experiments. While conducting my study, I noticed that if water was supplied to the soil by flood irrigation, some activated carbon would be washed away. Thus, to eliminate this problem, sprinkler irrigation would be the appropriate type of irrigation to use, at least during the first days of the experiments. Another advantage of the sprinkler irrigation would be uniform distribution of moisture over the whole field. Sprinkler irrigation does not affect the ability of carbon to inactivate herbicides. This was confirmed by Burr, Lee and Appleby (1972) who stated that when carbon rates are adequate, the amount of irrigation applied after treatment should not significantly affect protection and that irrigation can be applied on the basis of need for and availability of additional water.

Germination of Blue Panicgrass, Boer Lovegrass, Cochise Lovegrass and Twinberry as Affected by Activated Carbon and Surflan Treatments

Greenhouse Studies

Preliminary greenhouse studies indicated that blue panicgrass and twinberry were tolerant to Surflan whereas Cochise and Boer lovegrass were sensitive to it. The greenhouse studies also showed that the resistant species which germinated in pots treated with high rates of Surflan (2.2 kg/ha) and low rates of charcoal (224 kg per ha) had severely reduced root systems. However, under adequate moisture these roots appeared to be slightly functional and allowed some plant growth. The sensitive species did not develop any roots. The effects of Surflan were more severe on tolerant species when moisture was limited. Higher rates of Surflan are required to be detrimental to the tolerant species, thus less charcoal is needed to deactivate the herbicide and protect the plants.

Field Studies

As the rate of activated carbon increased to 896 kg per ha, more protection from the Surflan toxicity was expected to be provided to the various seedlings; consequently, the counts of plants per quadrat should have been higher. This was not the case with all the treatments as presented in Table 1. The irregularities of responses of some of the treatments made it necessary to use two forms of analyses (threshold and rate) to interpret the data.

The threshold analysis classified the response from the various treatments as 0 or one. According to this concept, seeds had to attain a certain state of readiness before they could germinate. That state of readiness could be influenced by soils or environmental factors and seed characteristics. The analysis of variance (Table 2) indicates a significant interaction between activated carbon and herbicide treatments within the threshold analysis. This interaction, illustrated in Table 3, indicates that Surflan was very effective when 0 kg per ha of

TABLE 1. Average number of emerged plants per quadrat as affected by the various treatments.

Treatments*	SPECIES Blue Panicgrass	Boer Lovegrass	Cochise** Lovegrass	Twinberry
A = C_1H_1	86	74	75	8
B = C_1H_2	31	0	0	12
C = C_1H_3	2	0	0	7
D = C_1H_4	0	0	0	1
E = C_2H_1	240	76	100	18
F = C_2H_2	207	80	65	18
G = C_2H_3	164	37	14	9
H = C_2H_4	188	67	20	8
I = C_3H_1	116	10	95	10
J = C_3H_2	152	18	56	2
K = C_3H_3	130	20	6	5
L = C_3H_4	120	23	12	1
M = C_4H_1	195	49	123	4
N = C_4H_2	190	16	107	14
O = C_4H_3	176	22	48	10
P = C_4H_4	181	29	30	4

*Treatments: Carbon at C_1, C_2, C_3 and C_4 equals 0, 224, 448 and 896 kg per ha, respectively. Surflan at H_1, H_2, H_3 and H_4 equals 0, 1.1, 1.6 and 2.2 kg per ha, respectively.

**Cochise lovegrass (E. lehmanniana X E. trichophora).

TABLE 2. Analysis of variance for the interaction between activated carbon and herbicide, and species and herbicide with threshold analysis.

Source of Variation	Sum of Squares	D.F.	M.S.	F Value
Within + Residual (Error)	.50533	27	.01872	
Herbicide	.40633	3	.13544	7.235**
Carbon by Herbicide	.66471	9	.07386	3.945*
Species by Herbicide	.38442	9	.04271	2.280

* = Significant relationship at .05 level.
** = Significant relationship at .01 level.

TABLE 3. Average number of emerged plants per quadrat as affected by carbon and herbicide treatments.

	Herbicide Rates (Kg per Ha)			
Carbon Rate (Kg per Ha)	0	1.1	1.6	2.2
0	243a*	43b	9bc	1c
224	433a	369a	224a	283a
448	230a	229a	160a	156a
896	370a	327a	257a	244a

*Numbers with same letter in a row have same mean at .05 level. Numbers with different letters in a row have different means at .05 level.

activated carbon was used. The number of seedlings decreased from 243 to 1 at 0 and 2.2 kg per ha of Surflan, respectively. However, when activated carbon was applied at 224 kg per ha, a large number of seeds had emerged.

Figure 1 shows that the average number of plants which emerged reached the peak at 224 kg per ha of Gro-Safe for all the four Surflan rates; the emerged plants then decreased in number at 448 kg per ha of Gro-Safe and increased at 896 kg per ha. No sound explanation can be given to the inhibitory effect of Gro-Safe at 448 kg per ha. This unexplained pattern of increase-decrease-increase characterizes the cubic relationship between carbon and Surflan in Figure 1. Also, orthogonal polynomials (Table 4) indicate a highly significant cubic relationship between activated carbon and Surflan rates.

Student Newman-Keul's tests on the data presented in Table 3 indicates that the means of the plant response at 0 kg per ha and the four rates of herbicides are different from each other. The same SNK test showed that at .05 level the means of the number of plants which emerged could not be separated at 224, 448 and 896 kg per ha of Gro-Safe and at all the four Surflan rates. This observation means that all the three rates of activated carbon had similar effects on all levels of Surflan. Thus, it can be partially concluded that only 224 kg of Gro-Safe might be sufficient to deactivate Surflan applied at 1.1, 1.6, 2.2 kg per ha. However, we have to keep in mind that this SNK test was done at the .05 level and that the actual number of plants which emerged differed from one treatment to another.

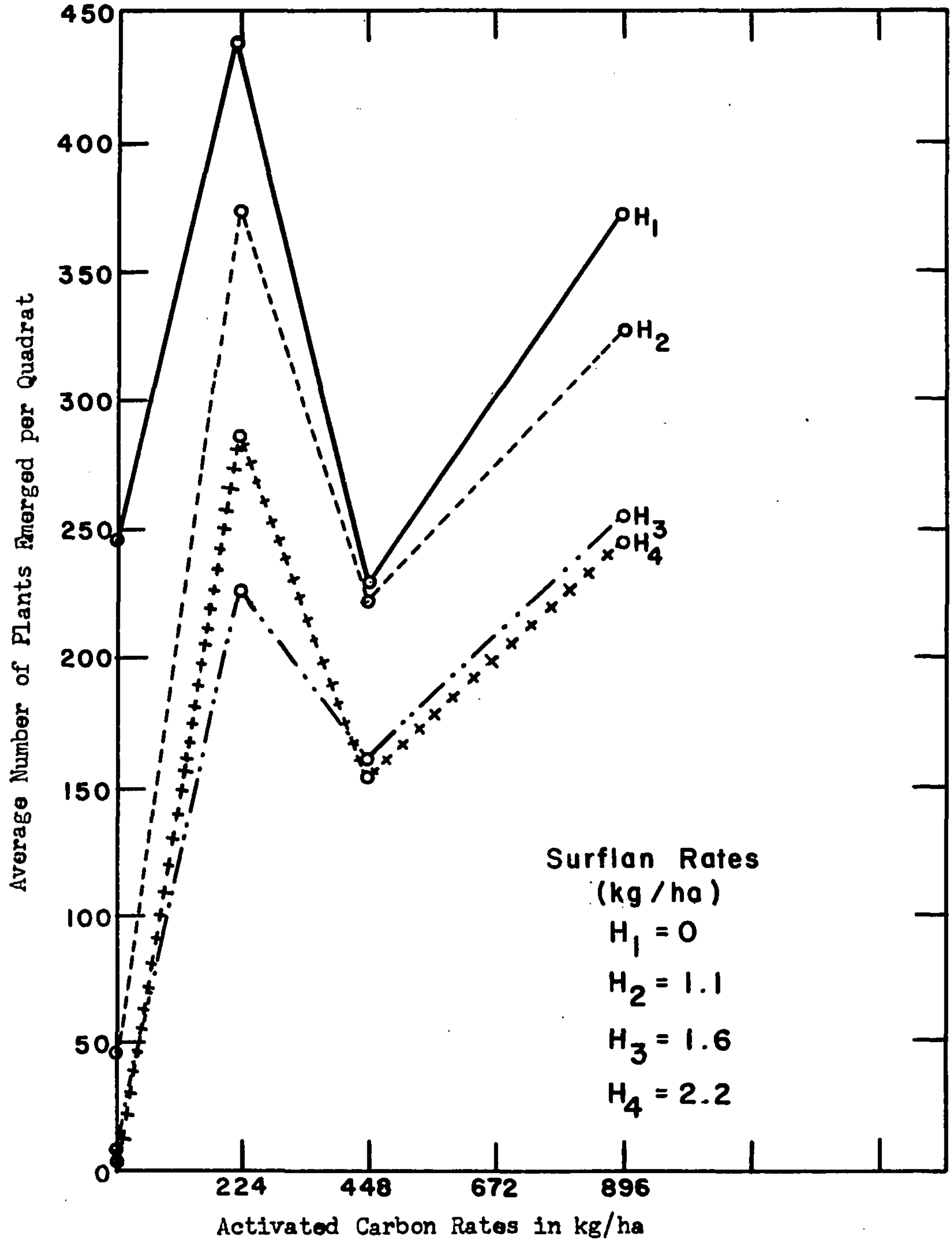

Figure 1. Response of Plants from the Different Activated Carbon Rates at Four Rates of Surflan

TABLE 4. Orthogonal polynomials determining the type of relationship between carbon and herbicide rates.

Source		D.F.	SS	MS	F
$*C/H_1$	linear	1	.00215		.11485
	quadratic	1	.00235		.12553
	cubic	1	.27336		14.60256**
C/H_2	linear	1	.02859		1.52724
	quadratic	1	.01095		.58493
	cubic	1	.31791		16.98237**
C/H_3	linear	1	.08562		4.5737*
	quadratic	1	.05154		2.7532
	cubic	1	.86803		46.36912**
C/H_4	linear	1	.66248		35.3888**
	quadratic	1	.08526		4.55448*
	cubic	1	.84551		45.16613**
Error		27	.50533	.01872	

*C = Average of carbon over all treatments and replications.

* = Significant relationship at .05 level.

** = Significant relationship at .01 level.

The rate analysis was the second form of analysis performed on the data. In the rate analysis it was assumed that the seeds had already reached the threshold level and emerged from the soil. The analysis of variance (Table 5) indicates a significant interaction between species and herbicide treatments at .01 level. As expected, the effects of Surflan vary from species to species. Table 6 presents the average number of blue panicgrass, Boer lovegrass, Cochise lovegrass and twinberry plants as affected by each of the four Surflan rates. As Surflan rates increased from 0 to 2.2 kg per ha, all four species were reduced in number, but a difference in sensitivity was noted. The reduction in seedling numbers of blue panicgrass and twinberry was 63% and 65%, whereas Boer lovegrass and Cochise lovegrass were reduced 91% and 84%, respectively. This follows the findings of the greenhouse studies which categorized blue panicgrass and twinberry as tolerant species and Boer lovegrass and Cochise lovegrass as sensitive plants.

Orthogonal polynomials (Table 7) showed that there is a significant linear relationship between the species and herbicide rates. The linear relationships among species and Surflan rates are illustrated in Figure 2.

Both of the threshold and rate analyses were used in evaluating the overall growth parameters of the four species as affected by the various treatments. Table 8 presents the results of the number of blue panicgrass seedlings as affected by activated carbon and herbicide treatments. Surflan at 1.1, 1.6 and 2.2 kg per ha reduced blue panicgrass seedling numbers by 48.6, 70.8 and 85.1 percent, respectively,

TABLE 5. Analysis of variance for the interaction between species and herbicide within the rate analysis.

Source of Variation	D.F.	SS	MS	F
Replications (R)	3	55.512	18.504	1.002
Carbon Levels (C)	3	122.616	40.872	2.220
RC (Error A)	9	166.080	18.453	
Species (S)	3	1587.608	529.203	35.137**
CS	9	242.640	26.960	1.790
RS + RCS (Error B)	20	301.227	15.061	
Herbicide Levels (H)	3	155.823	51.941	9.224**
CH	9	19.789	2.198	.390
SH	9	155.588	17.287	3.069**
CSH	20	28.561	1.428	.253
RH+RCH+RSH+RCSH (Error C)	65	366.040	5.631	

**Significant at .01 level.

TABLE 6. Average number per quadrat of emerged blue panicgrass, Boer lovegrass, Cochise lovegrass and twinberry plants as affected by Surflan.

	Herbicide Rates (Kg per Ha)			
Species	0	1.1	1.6	2.2
blue panicgrass	637	580	491	489
Boer lovegrass	208	114	79	119
Cochise lovegrass	393	227	68	62
twinberry	41	46	31	14

TABLE 7. Orthogonal polynomials determining the type of relationship between species and herbicide rates.

Source	D.F.	SS	MS	F
H/blue panicgrass (S_1)1/				
linear	1	59.96496		10.649000**
quadratic	1	.23893		.042430
cubic	1	7.08106		1.257500
H/Boer lovegrass (S_2)				
linear	1	39.62990		7.037808*
quadratic	1	20.34136		3.612388
cubic	1	.60505		.107449
H/Cochise lovegrass (S_3)				
linear	1	320.61530		56.937540**
quadratic	1	4.46483		0.792900
cubic	1	17.66014		3.136230
H/twinberry (S_4)				
linear	1	9.30100		1.657749
quadratic	1	6.78329		1.204633
cubic	1	.01211		.0021505
Error	65	366.04	5.631	

1/Average of herbicide over all treatments and replications.

* Significant relationship at .05 level.

** Significant relationship at .01 level.

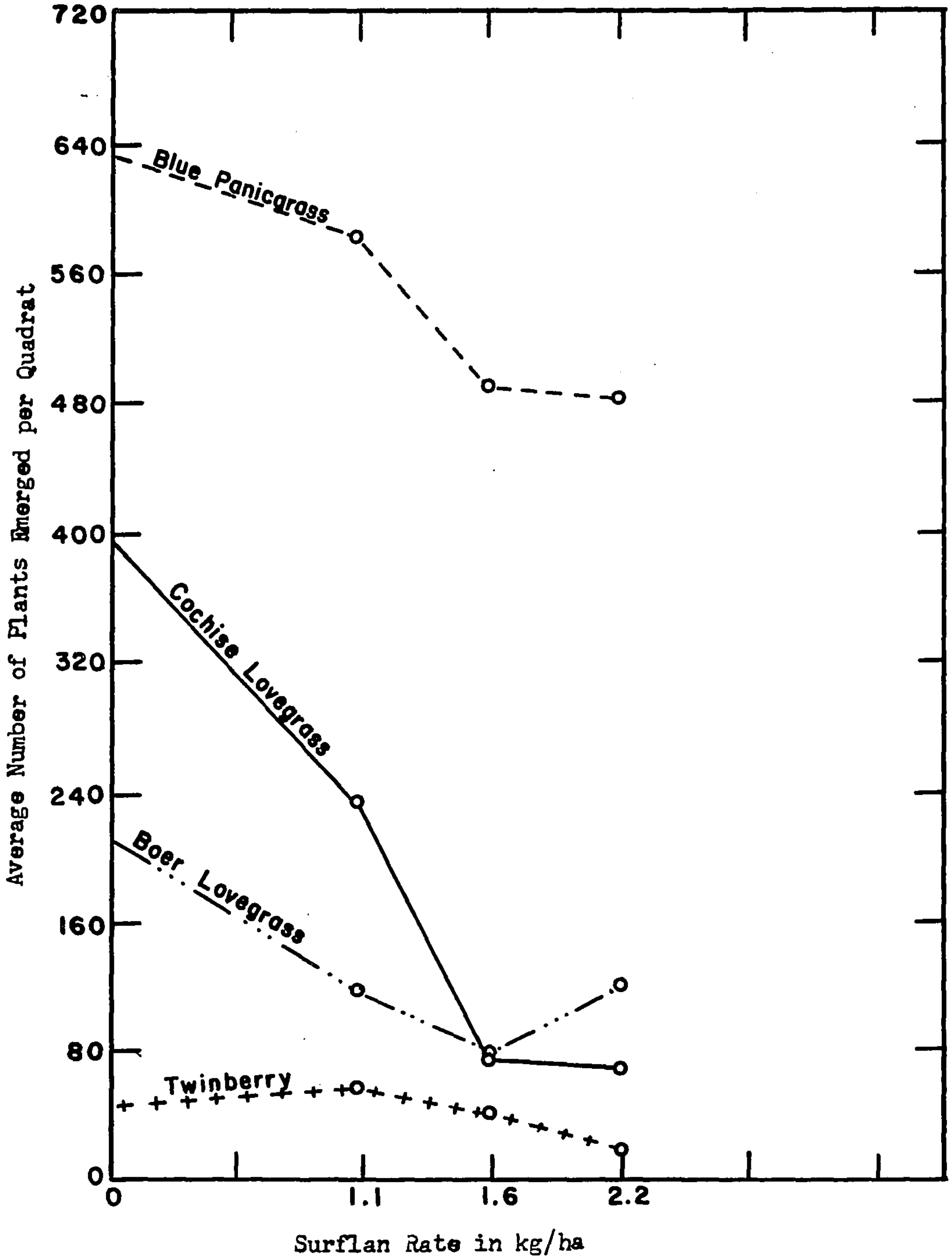

Figure 2. Response of Various Plant Species at Four Rates of Surflan

TABLE 8. Emergence per quadrat of blue panicgrass as affected by activated carbon and herbicide treatments.

Carbon Rate (Kg per Ha)	Herbicide Rates (Kg per Ha) 0	1.1	1.6	2.2
0	93	48	27	14
224	115	85	81	111
448	79	51	43	64
896	100	79	66	111

when activated carbon was not used. Field emergence seemed to be more seriously affected by Surflan treatments than was indicated in greenhouse studies. There is a possibility that under field conditions, environmental, soil factors and climatic factors (i.e., temperatures) contributed to the effectiveness of Surflan in affecting blue panicgrass. Even though the reduction in seedling numbers was considerable, Surflan at 2.2 kg per ha did not completely eliminate the stand. It should be pointed out that 2.2 kg per ha of Surflan is two times the rate recommended to completely control various grass seeds planted on sandy soils. Since blue panicgrass seedlings were not totally killed, it could be said that blue panicgrass seedlings showed some limited tolerance to high levels of Surflan.

Activated carbon at 224 kg per ha significantly reduced Surflan toxicity when compared with treatments receiving no carbon. Not only did carbon deactivate Surflan, but it also appeared to enhance germination of blue panicgrass. The number of seedlings increased from 93 to 115 with the application of 224 kg per ha of Gro-Safe without any herbicide treatment. An unusual situation appeared in the respect that seedling numbers decreased when Gro-Safe rate was increased from 224 kg per ha to 448 kg per ha; then there was an increase in seedling number when Gro-Safe rate went from 448 kg per ha to 896 kg per ha. These results do not agree with the findings of Kratky, Coffey, and Warren (1970) who stated that higher rates of activated carbon would be beneficial to the germination of seeds until a maximum level is attained. Figure 3 illustrates the cubic relationship between Surflan and activated carbon rates for blue panicgrass. The sharp decrease in seedling number at 448 kg per ha of Gro-Safe can be well depicted in that figure. As mentioned earlier, the reason for that decrease is unclear.

Surflan at 1.1, 1.6 and 2.2 kg per ha reduced Boer lovegrass seedling numbers by 51.2, 78.7 and 92.4%, respectively, where there was no charcoal treatment. Comparing the reduction percentages to those of blue panicgrass indicated that Surflan effect was more pronounced with Boer lovegrass seeds than with blue panicgrass seeds. This observation confirms the results of the greenhouse study which showed that Boer lovegrass was more sensitive to Surflan than blue panicgrass. Table 9 presents the results of Boer lovegrass seedling numbers as affected by activated carbon and Surflan treatments. Activated carbon at 224 kg per ha provided about the same protection to Boer lovegrass seedlings as to blue panicgrass. The response of

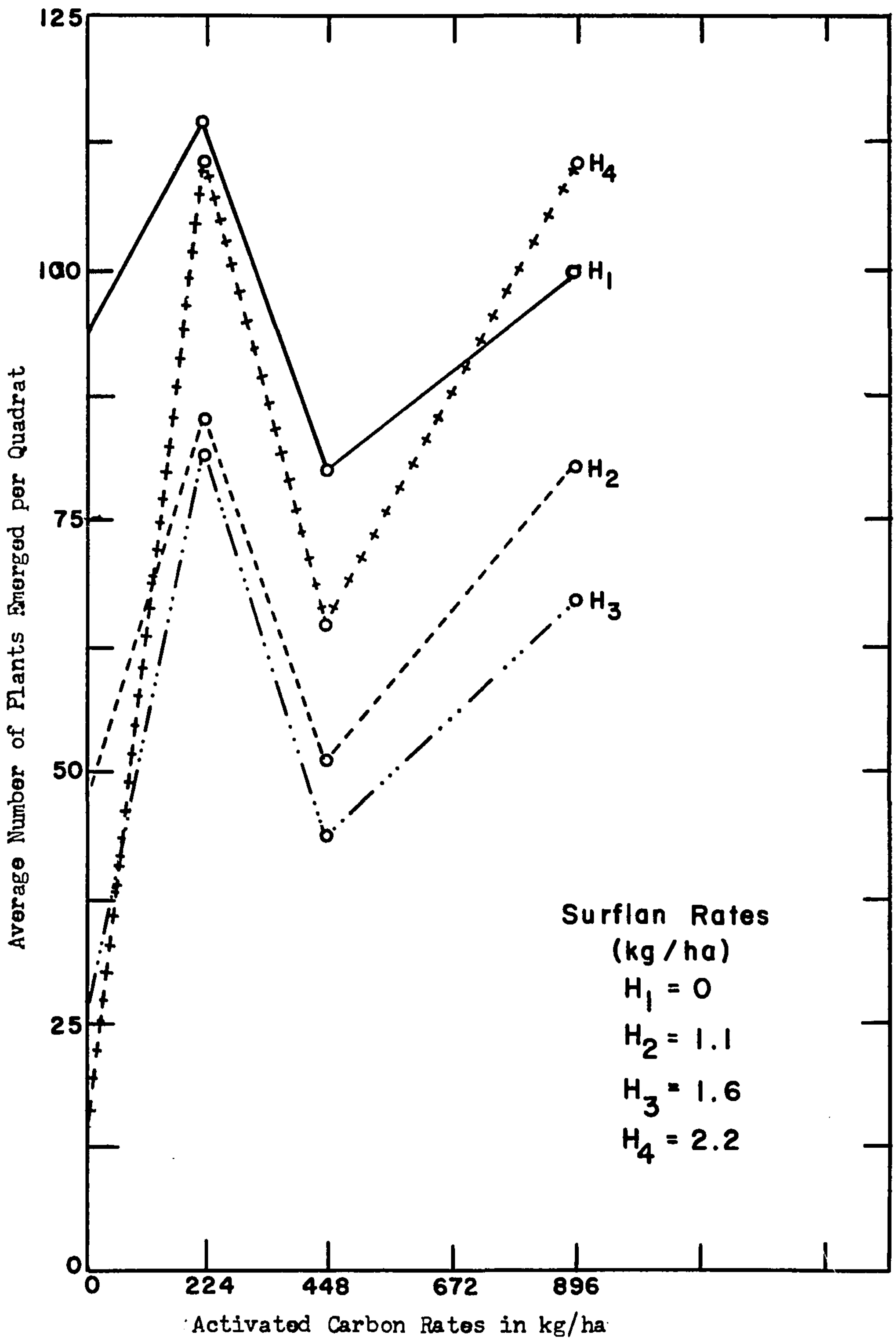

Figure 3. Emergence of Blue Panicgrass per Quadrat as Affected by Activated Carbon and Surflan Treatments

TABLE 9. Emergence per quadrat of Boer lovegrass as affected by activated carbon and herbicide treatments.

	Herbicide Rates (Kg per Ha)			
Carbon Rate (Kg per Ha)	0	1.1	1.6	2.2
0	48	23	10	4
224	59	41	30	29
448	41	25	16	17
896	51	39	25	29

Boer lovegrass was similar to that of blue panicgrass (Figure 4). However, the reduction in seedling number from the treatment of 224 kg per ha of activated carbon to 448 kg per ha was less pronounced and the average number of Boer lovegrass seedlings did not differ considerably across all the three activated carbon rates (224, 448, and 896 kg per ha).

Table 10 presents the results of Cochise lovegrass seedling emergence as affected by Gro-Safe and Surflan treatments. Surflan at 1.1, 1.6 and 2.2 kg per ha reduced Cochise lovegrass seedling numbers by 57.3, 90.7 and 97.2%, respectively, at 0 kg per ha of activated carbon. The reduction in Cochise lovegrass seedlings was more significant than in blue panicgrass and Boer lovegrass. Cochise is highly sensitive to Surflan. There was nearly a 100% reduction in seedling number at 2.2 kg per ha of Surflan. Activated carbon at 224 and 896 kg per ha provided some protection to the new seedlings as

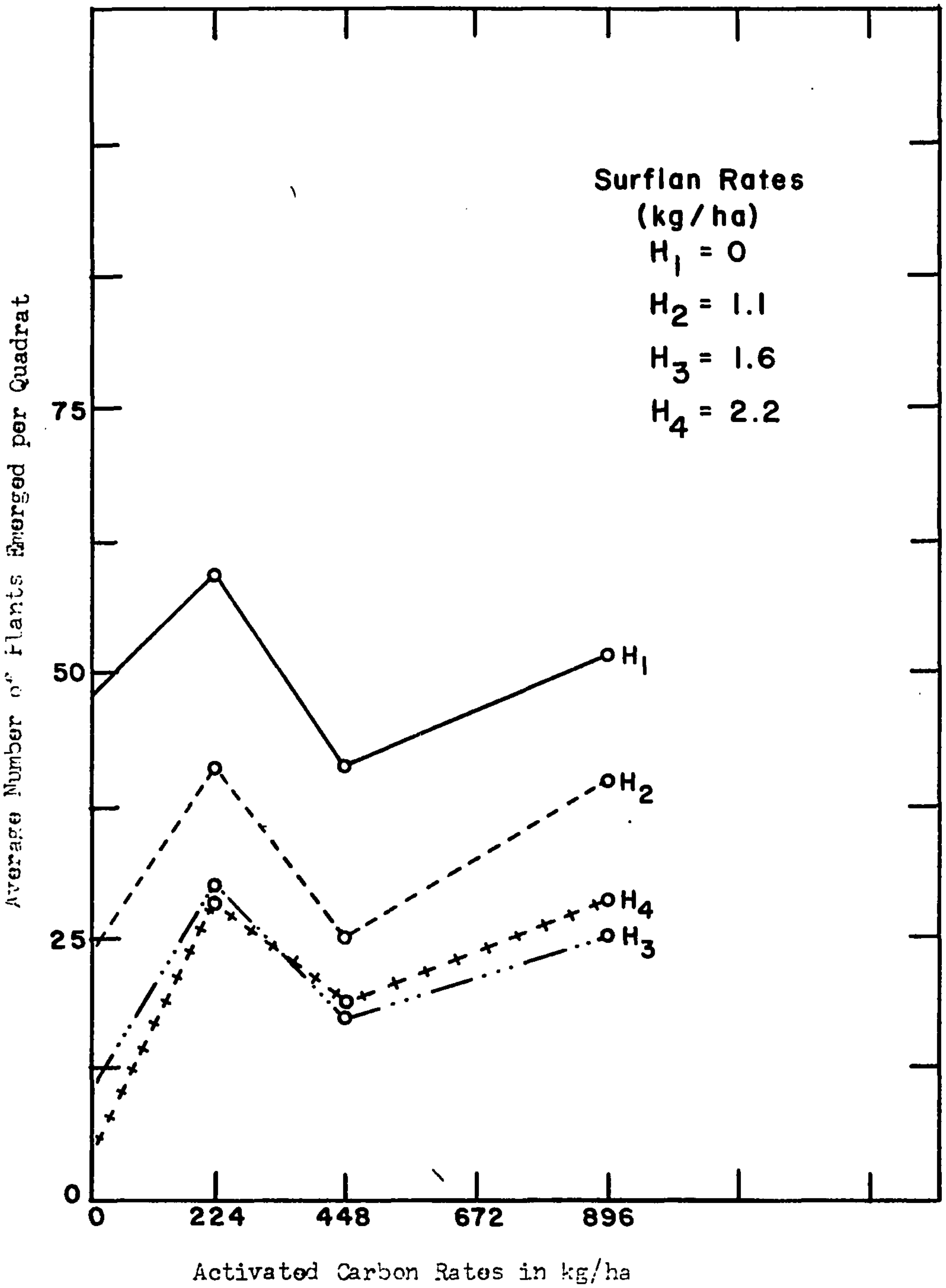

Figure 4. Emergence of Boer Lovegrass per Quadrat as Affected by Activated Carbon and Surflan Treatment

TABLE 10. Emergence per quadrat of Cochise lovegrass as affected by activated carbon and herbicide treatments.

Carbon Rate (Kg per ha)	Herbicide Rates (Kg per Ha)			
	0	1.1	1.6	2.2
0	72	31	7	2
224	89	54	20	16
448	61	33	10	9
896	77	51	16	16

illustrated by Figure 5. Low numbers of seedlings were obtained at 0 and 448 kg per ha of activated carbon. Here again there is no explanation for the inhibitory effect of Gro-Safe at 448 kg per ha.

Table 11 presents the results of twinberry seedling emergence as affected by activated carbon and Surflan treatments. Surflan at 1.1, 1.6 and 2.2 kg per ha reduced twinberry seedlings by 8.6, 57.8 and 91.02, respectively, at 0 kg per ha of activated carbon. In the preliminary greenhouse studies, twinberry was found to be tolerant to low rates of Surflan and Treflan. This is confirmed by the small reduction percentage (8.6%) in seedling number at 1.1 kg per ha of Surflan. Figure 6 shows the relationship between the herbicide and activated carbon treatments over the twinberry seedlings. Twinberry was extremely slow growing as the numbers of emerged seeds in Table 11 indicated. Consequently, the increase or decrease in seedling numbers is small across all the treatments.

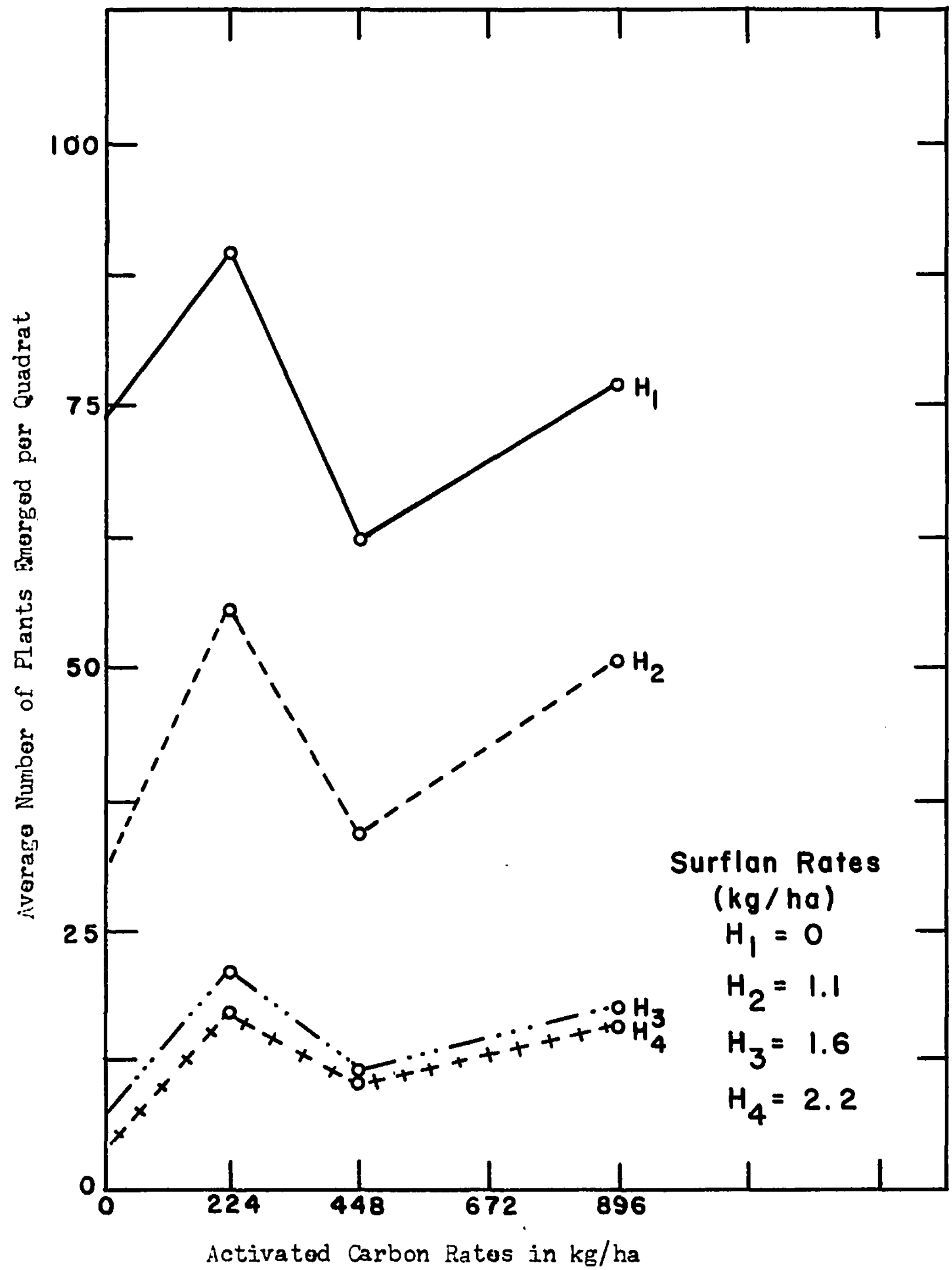

Figure 5. Emergence of Cochise Lovegrass per Quadrat as Affected by Activated Carbon and Surflan Treatments

TABLE 11. Emergence per quadrat of twinberry as affected by activated carbon and herbicide treatments.

Carbon Rates (Kg per Ha)	Herbicide Rates (Kg per Ha) 0	1.1	1.6	2.2
0	5	4	2	1
224	8	5	5	3
448	5	4	3	2
896	8	5	4	3

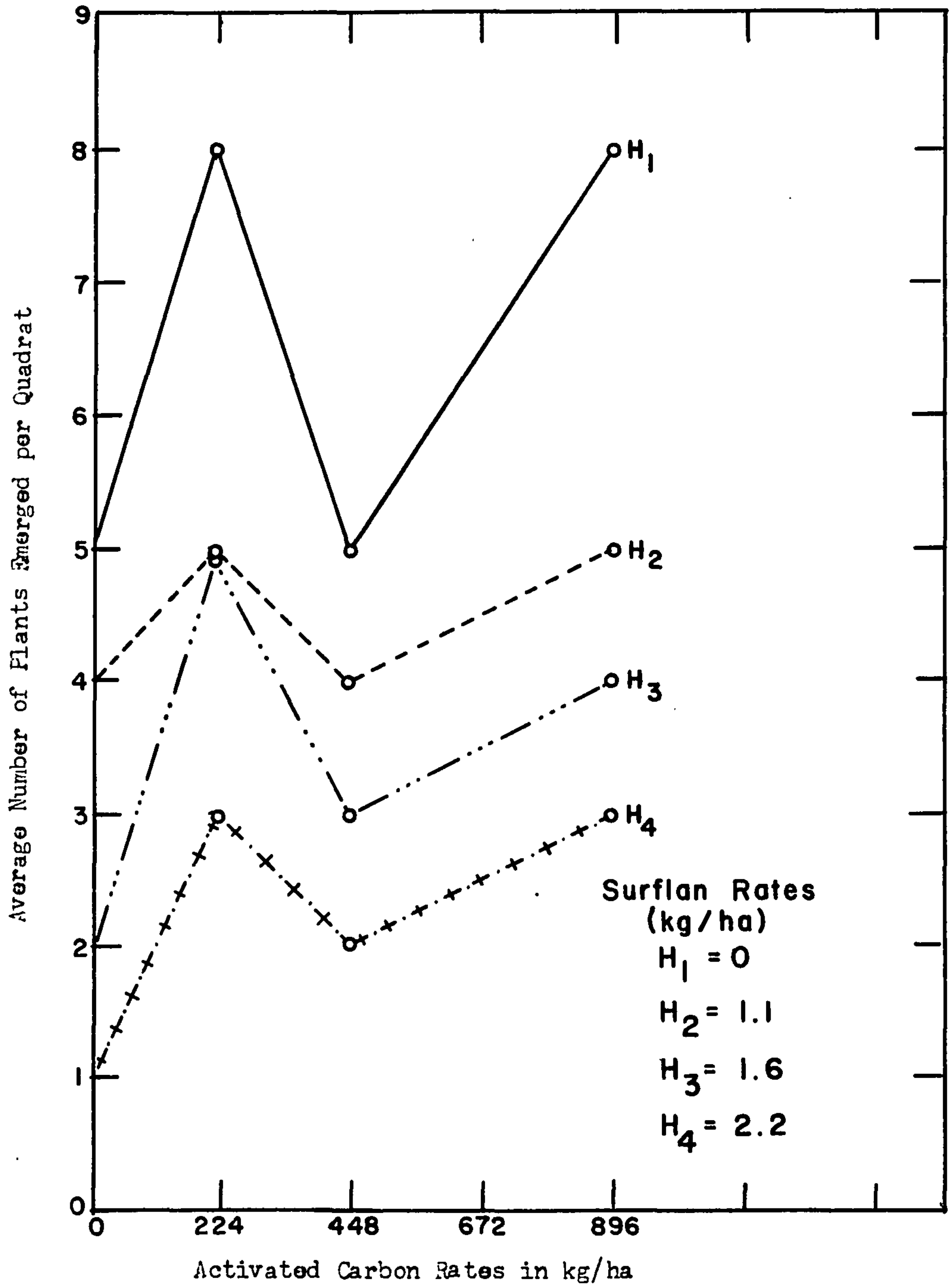

Figure 6. Emergence of Twinberry per Quadrat as Affected by Activated Carbon and Surflan Treatments

CHAPTER 5

SUMMARY AND CONCLUSIONS

This study showed that activated carbon could be used successfully in establishing various plant species. The laboratory results indicated that Gro-Safe applied in either sandy or clay loam does not leach into the soil. This non-leaching characteristic of Gro-Safe is a desired one since Gro-Safe could maintain its ability to deactivate herbicide for a long time. Nevertheless, Gro-Safe should be applied every time seeds are planted in preemergent herbicide treated soils to make sure that the previous application was not hindered by some unpredicted factors.

Even though the results of the field experiments differed from most of the findings of some researchers and the greenhouse studies, the general characteristics and properties of activated carbon were successfully investigated in this study.

Activated carbon at 224 kg per ha appeared to be effective in providing good protection to all the four species (Cochise lovegrass, Boer lovegrass, twinberry and blue panicgrass) from preemergent herbicide. In general, the degree of protection varied with the plant species, the herbicide rate and the rate of activated carbon.

The unexplained outcome of the experiment was the reduction in seedling numbers of all four species at 448 kg per ha of activated charcoal. The cubic relationship between activated carbon and herbicide (Table 4, Figure 1) illustrates the inhibitory effect of activated carbon applied at 448 kg per ha.

Blue panicgrass and twinberry, which were found to be quite tolerant to Treflan and Surflan in the greenhouse studies, were relatively less harmed by Surflan treatment than Boer lovegrass and Cochise lovegrass. Thus, less activated charcoal was required to provide adequate protection to the two tolerant species.

In general, blue panicgrass, Boer lovegrass, Cochise lovegrass and twinberry were successfully established by the use of activated carbon at 224, 448 and 896 kg per ha with Surflan at 1.1, 1.6 and 2.2 kg per ha. However, considering the economical side of the operation, it appeared that 224 kg per ha of activated charcoal would yield satisfactory results in establishing plants with use of preemergent herbicide.

For further investigation on the neutralizing effects of activated carbon on preemergent herbicides, different types of herbicides, different soil types and various techniques of application of Gro-Safe should be used in future studies.

Activated carbon holds a great promise in improving the selectivity of preemergent herbicides; however, the costs involved and the difficulties in its application make it inappropriate for use on very large scales nowadays. Simple techniques such as pelleting suggested by Kratky and Warren (1971) should be improved and used for seedling establishment in herbicide treated soils.

APPENDIX A

THRESHOLD ANALYSIS

$$Z_{ijk} = \tfrac{1}{2}\left(\arcsin\sqrt{\frac{X_{ijk}}{n+1}} + \arcsin\sqrt{\frac{X_{ijk}}{n+1}} + 1\right.$$

i = charcoal rate

j = species

k = herbicide rate

$$Z_{i\cdot k} = \tfrac{1}{4} \sum_{J=1}^{4} Z_{ijk}$$

$$P_{ik} = (\mathrm{Sin}\ \bar{Z}_{i\cdot k\cdot})^2$$

RATE ANALYSIS

$$Z_{ijkl} = \sqrt{X_{ijkl} + 3/8}$$

with i^{th} charcoal level k^{th} herbicide level

j^{th} species l^{th} replication

$$\bar{Z}_{\cdot jk\cdot} = \frac{1}{n_{jk}} \sum_{i=1}^{4} \sum_{l=1}^{4} Z_{ijkl}$$

where n_{jk} = nbre of non-missing plots added together

$$\lambda_{jk} = (Z_{\cdot jk\cdot})^2 - 3/8$$

OVERALL GROWTH PARAMETER

$$\theta_{ijk} = P_{ik}\ \lambda_{jk}$$

APPENDIX B

CHEMICAL NOMENCLATURE OF COMPOUNDS

(1) G.36393 = 2.isopropylamino-4-(3-methoxypropyl-amino) - 6 methylthio-s-thiazine.

(2) Pyrazon = 5-amino-4-chloro-2-phenyl-3(2H)-pyridazinone.

(3) Propachlor = 2 chloro-N-isopropylacetanilide.

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