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To the Graduate Council:

I am submitting herewith a thesis written by Larry B. Jones entitled "A Three-Year Study of the Persistence of 2,4-D, Diuron, Simazine, Atrazine, DNBP, DCPA, and Amiben in the Soil." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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A THREE-YEAR STUDY OF THE PERSISTENCE OF 2,4-D, DIURON, SIMAZINE, ATRAZINE, DNBP, DCPA, AND AMIBEN IN THE SOIL

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Larry B. Jones

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CHAPTER I

INTRODUCTION

To be satisfactory for use in crops a preemergence herbicide must remain active in the soil long enough to provide adequate weed control without persisting long enough to injure succeeding crops. The emphasis in development of herbicides following the advent of 2,4-dichlorophenoxyacetic acid (2,4-D) was to increase persistence to provide full-season weed control. From this effort have evolved chemicals capable of persisting beyond the growing season, possibly injuring succeeding crops.

Since several of the more persistent herbicides used at low rates for selective weed control may be used at high rates as soil sterilants, the persistence and possibility of accumulation of these chemicals in the soil need to be understood. Therefore, a study of the persistence of several preemergence herbicides in the soil was initiated at The University of Tennessee in 1961.

CHAPTER II

REVIEW OF LITERATURE

I. FACTORS AFFECTING PERSISTENCE OF HERBICIDES

Some herbicides such as 2,4-D and 3-amino-2,5-dichlorobenzoic acid (amiben) disappear from the soil surface in a few weeks while others like 2-chloro-4,6-bis(ethylamino)-s-triazine (simazine) and 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine) sometime persist until the next season (4).[1] Residual herbicidal toxicity depends upon the nature of the herbicide and the environment to which it is subjected (8, 45). Important environmental influences include the soil, microorganisms, rainfall, temperature, light, and the crop. The primary factors affecting the persistence of a herbicide are microbiological decomposition, leaching, adsorption, chemical decomposition, vaporization, and plant uptake (4, 6, 39, 40, 62). The relative importance of these factors is difficult to determine because of their interaction. With some materials an individual factor such as microorganisms or leaching is most important while with others a combination of factors is most important (39). Many research workers have indicated that microbiological decomposition, leaching, adsorption, and vaporization are the most important factors of herbicide inactivation.

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[1]Numbers in parentheses refer to literature cited.

Microbiological Decomposition

When considering the extent and range of effects, microorganisms probably play the leading role in herbicide inactivation (4, 8). Early soil microbiology studies determined that practically any organic compound, including highly resistant and toxic materials, could be decomposed, at least partially, by one or more soil microbes (37). Although short-chained organic compounds are more resistant to microbial decomposition than long-chained ones and cyclic compounds are the most resistant, organisms which utilize all three types have been isolated (37). Microorganisms have been reported to be the most important factor in detoxification of 2,4-D (3, 4, 39, 45), 2-chloro-N,N-diallylacetamide (CDAA), 2-chloroallyl diethyldithiocarbamate (CDEC) (16), 3-(p-chlorophenyl)-1, 1-dimethylurea (monuron) (36, 45, 54), 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron) (45, 54), amiben (43), isopropyl N-phenylcarbamate (IPC) (38), isopropyl N-(3-chlorophenyl) carbamate (CIPC), and 2,2-dichloropropionic acid (dalapon) (45). Behrens (4) proposed that the slow rate of microbial decomposition of such materials as simazine and atrazine partially explained why residual problems have been experienced with them.

DeRose and Newman (10) discovered no loss of activity of 2,4-D, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2-methyl-4-chlorophenoxyacetic acid (MCPA) during 6 weeks in sterilized soil while all three disappeared within 3 to 6 weeks in non-sterilized soil. Newman et al. (38) found IPC to persist more than 9 weeks in autoclaved soil while disappearing during 2 weeks in non-autoclaved soil. Bioassays

of oats (Avena sativa L.) were used in both experiments to detect chemical activity. Sheets and Crafts (54) mixed diuron, monuron, 3-phenyl-1,1-dimethylurea (fenuron), and 3-(3,4-dichlorophenyl)-1-methylurea (DMU) with autoclaved and non-autoclaved soil and repeatedly cropped the soils with oats to determine persistence. The toxicity of all four was lost more rapidly from the non-autoclaved soil.

Most herbicides have been inactivated more rapidly under environmental conditions favorable for microbiological activity (50, 52). Warmth and moisture are essential for microbial activity. Most soil microbes are dormant below 4°C (33) with greatest activity occurring at temperatures of 20 to 32°C (33, 44). Disappearance of 2,4-D, 2,4,5-T, and MCPA was determined by DeRose and Newman (10) to double as temperature was increased from 10 to 30°C and to increase as soil moisture was increased from 20 to 100% of the water-holding capacity. Newman et al. (38), studying IPC at temperatures of 10, 15, 20, 25, and 30°C, found oat emergence 8 days after treatment to be 0, 40, 50, 80, and 100% respectively of the control. Disappearance was equal from 20 to 80% of the water-holding capacity but was reduced at 100% and in flooded soil. Sheets and Crafts (54) found diuron, monuron, fenuron, and DMU activity to disappear more rapidly from soil continuously moist enough for oat growth than from soil alternately moist 1 month and dry the next. Food and oxygen are also necessary for soil microorganisms to be active. Additions of manure (41) and leaf mold (34) have reduced the persistence of certain herbicides, but large additions of manure or peat have temporarily inhibited the decomposition of

dalapon (29). Reid (44) increased the rate of inactivation of several herbicides, including 2,4-D, diuron, atrazine, and amiben, by increasing aeration.

Holstun (29), working with dalapon, and Reid (44), working with several herbicides, discovered that a soil reaction near neutral accelerated inactivation over that of soils below a pH of 6.5. In general, bacteria are favored by medium to high pH conditions while fungi predominate at pH values below 5.5 (33). Both groups are reported to participate in herbicide decomposition (20, 62).

The position of halogens on the benzene ring has been found to govern microbial degradation of certain phenoxy herbicides more than the number of halogens. Whiteside and Alexander (70), using absorption of ultraviolet light by the compounds to indicate decomposition, found 2,4-D to be readily decomposed when incubated in soil suspension while 2,4,5-T persisted. Further studies by Alexander and Aleem (1), using the same technique, determined that a chlorine in the meta position of the benzene ring, as in 2,4,5-T, retarded microbial decomposition.

Leaching

Leaching is considered along with microbial action as a major factor of herbicide inactivation (3). Movement of a herbicide through the soil reduces its concentration by dilution and increased adsorption onto soil particles (52). Hanks (22) reported greater dissipation of 2,4-D with the application of 16 inches of water during 6 weeks than with 10 inches. Weldon and Timmons (68) disclosed that diuron persisted

for two seasons in Wyoming under infrequent irrigation while it disappeared in one season under semi-flood irrigation. Field results of Burnside et al. (6) on loam and silty clay loam soils in Nebraska indicated that simazine and atrazine, although resistant to leaching, could be moved through a 24-inch soil profile.

Leaching is greatest in sandy soils because of greater percolation and less adsorption (4). Rauser and Switzer (42) found that 5 inches of applied water completely leached amiben from surface sand while only a portion was removed from muck. Rodgers (48) studied leaching of four triazines, including simazine and atrazine, in two sands at 2 and 4 pounds per acre and in a muck at 4 and 8 pounds per acre. Simulated rainfall was applied in 1 or 2-inch increments to totals of 1 to 16 inches over a period of 1 to 4 weeks. Leaching in the two sands followed the same pattern with atrazine being leached most as it moved through the 6-inch column, but little or no movement of any of the herbicides below 1 inch occurred in the muck. A given amount of water applied over a short period was more effective in moving the herbicides than if applied over a long period. The greater total amounts of water generally resulted in greatest leaching.

Adsorption

Adsorption acts against the force of leaching and generally influences persistence by decreasing herbicide availability in the soil solution. However, Behrens (4) cautioned that adsorption should not be considered as an important factor in reducing residues.

Organic matter appears to be the most important single factor influencing adsorption of herbicides (4, 5, 6, 11, 27, 55, 61, 64). Rates of most preemergence herbicides must be increased for use in muck; however, amiben was reported by Warren (65) to be an exception. Burnside and Behrens (5), using corn (Zea mays L.) bioassays to determine phytotoxicity of simazine in sand, silt loam, clay, and muck soils, concluded that toxicity decreased as organic matter and/or clay content increased. Burnside et al. (6) found residual toxicity of atrazine to be least in soil that was highest in organic matter. Upchurch and Pierce (64) varied soil organic matter by interchanging layers of soils and found retention of monuron in soil leached by simulated rainfall to increase from 12 to 40% as organic matter was increased from 0.87 to 1.44%.

Frissel and Bolt (15) discovered that an increase in pH decreased adsorption of herbicides, including 2,4-D, simazine, and 4,6-dinitro-o-sec-butylphenol (DNBP), on clay in aqueous solutions. They used ultraviolet spectrophotometry to determine the presence or absence of the organic herbicides. Talbert and Fletchall (61) in a similar experiment with C^{14}-labeled simazine and atrazine found increased pH and temperature to decrease adsorption. Leopold et al. (35) studied adsorption of several herbicides, including 2,4-D, 2,4,5-T, monuron, CIPC, and IPC, on activated charcoal by maintaining a carbon-water-herbicide slurry at 25°C. The mixture was filtered and the filtrate tested spectrophotometrically to detect adsorption of the herbicide on the carbon. They found uniform adsorption at pH values from 2.2

to 8.0. By increasing temperature to 95°C release of 2,4-D reached 50% in 2 minutes and was virtually complete in 60 minutes.

Chemical Decomposition

The difficulty of isolating specific chemical reactions in soils makes the evaluation of chemical decomposition difficult. The most discussed example of chemical decomposition is photodecomposition. Considerable interest in this process has evolved since Hill et al. (26) reported an 83% loss of monuron from an 88.3 ppm aqueous solution upon exposure to sunlight for 48 days in sealed quartz tubes. Weldon and Timmons (69) dissolved 10 ppm of monuron and diuron in 95% ethyl alcohol and exposed them to an 85 watt mercury lamp for periods of 0, 2, 8, and 28 hours. Oat bioassays indicated that photochemical degradation of both materials occurred with 28 hours of light, resulting in a 75% decrease in biological activity. Sheets (50) found a 50% loss of amiben to occur from an aqueous solution exposed to sunlight for 6 hours. Preliminary tests indicated a corresponding 50% reduction in herbicidal activity. It has been reported (4, 69) that 2,4-D is also subject to photodecomposition. Since direct effects of light have been determined only in the laboratory, it is difficult to accurately estimate this effect in the field. Behrens (4) considers the process insignificant with most herbicides in the field. Greatest losses in this manner are expected in the arid West where herbicides may remain on the soil surface for long periods (50).

Sheets (50) related results of work by Ercegovich which showed disappearance of 3-amino-1,2,4-triazole (amitrole) from a silt loam

soil to increase as temperature was increased to 100°C. Sheets considered the major degrading process to be something other than microbial. Burnside et al. (7) found the biological activity of simazine in aqueous solution to be decreased 25 to 75% when exposed to temperatures of 100°C and higher for 24 hours. However, they considered the process insignificant in the field because of the high temperatures required.

Vaporization

Disappearance by vaporization can be important with herbicides having high vapor pressures. The type of formulation affects volatilization. For example, short-chained esters of 2,4-D are more volatile than the long-chained esters (55). Ashton and Sheets (2) discovered ethyl N,N-di-n-propylthiolcarbamate (EPTC) to be highly volatile. Davis (9) found slight vapor injury of cotton by DNBP at 29°C to be rapidly increased to almost 70% kill at 36°C. Vaporization of EPTC and DNBP has been determined to increase with soil moisture content (2, 55).

Plant Uptake

Absorption and metabolism of herbicides by higher plants are considered directly involved in the inactivation of herbicides (4, 50). Results of several experiments reported by Gysin (20) indicated that considerable amounts of triazines could be removed in this fashion.

Rate of Application

Burschel and Freed (8) pointed out that most microbiological processes occur as first-order reactions. The rate of a first-order reaction is directly proportional to the concentration of the reacting

substance (18). Burschel and Freed proposed that since microorganisms are a major factor in the decomposition of herbicides, their disappearance from the soil would also follow first-order kinetics. They found IPC and amitrole to follow this pattern of disappearance with the rate of application having little influence on their half-lives. Newman et al. (38) also judged rate of application to have little influence on IPC persistence as 50 pounds per acre persisted only slightly longer than 10 pounds per acre. Audus (3), perfusing soil with 2,4-D solution, found its disappearance to also follow first-order kinetics.

Persistence of diuron, simazine, and atrazine has been increased by increased application rates, but not in proportion to the increased rates (28, 49, 59). Bioassays by Hollingsworth (28) five and one-half months after application disclosed that 2 to 4 pounds of diuron and monuron broadcast per acre would endanger fall-seeded oats while 1 pound per acre was safe if the soil was mixed. Hill et al. (25), using chemical and bioassay determinations, concluded that the majority of diuron and monuron at 1 and 2 pounds per acre applied 2 consecutive years disappeared each year in the Southeast. Lillie and Aldrich (36) applied monuron in New Jersey at the rate of 10 pounds per acre to the same plots in 1951 and 1952. They found greater residue in 1954 from this treatment than from a 50-pound application in 1951. This indicated that the climatic differences between years had more influence on persistence than the rate of application. Scudder (49), using simazine up to 16 and 32 pounds per acre on sand and peat respectively in Florida,

reported injury from residues of the high rates after 12 months, but found no injury after 18 months. Sheets (50) determined the percentages of simazine in soil after 13 months to be almost the same from applications of 5, 10, and 20 ppm. He proposed that the inactivation rate of simazine was related to the initial concentration and followed first-order kinetics. This is supported by results of Sigler (56) who found simazine at 40 pounds per acre to be effective as a soil sterilant for less than 1 year in Tennessee.

II. PERSISTENCE OF SPECIFIC HERBICIDES

2,4-D

Behrens (4) reported 2,4-D to persist 4 to 6 weeks. Primary factors effective in dissipating it include microbial utilization, leaching, adsorption and vaporization. It has been shown repeatedly that microorganisms are active in the decomposition of 2,4-D (3, 44, 62, 70). Several organisms capable of utilizing it have been isolated (3, 62). Audus (3) studying kinetics of 2,4-D disappearance found an initial rapid adsorption, a lag phase, and then rapid disappearance continuing indefinitely with additional treatments. He proposed that the few organisms capable of utilizing 2,4-D multiplied exponentially during the lag phase and then rapidly used the material present. The organisms evidently remain in the soil for some time afterwards, for delayed applications disappeared at the same rapid rate. Leaching is also important in the inactivation of 2,4-D (3). Warren (66) used bioassays to determine that the amine formulation of 2,4-D was leached

more readily in mineral soils than the propylene glycol butyl ether ester formulation. However, the activity of both disappeared in 2 weeks. Leopold et al. (35) determined spectrophometrically that 2,4-D was adsorbed on activated carbon more than materials which were more soluble and less than materials which were less soluble. They found uniform adsorption from pH 2.2 to 8.0 while Frissel and Bolt (15) discovered 2,4-D adsorption onto soil colloids in an aqueous environment to decrease as pH increased. Photochemical degradation and vaporization of 2,4-D are indicated by Behrens (4) as possible avenues of disappearance.

Diuron

Bioassays by Hollingsworth (28) indicated that residues from broadcast applications of 2 to 4 pounds per acre of diuron were toxic to oats after five and one-half months in Mississippi. Hill et al. (26) found 1 to 2 pounds of diuron and monuron broadcast per acre to lose their toxicity to oats in 4 to 8 months in the Southeast. They concluded that diuron and monuron disappeared at approximately the same rate. Lillie and Aldrich (36) stated that monuron used at rates of 1.6 to 2.4 pounds per acre in asparagus sometimes persisted into the next season in the Northeast. Weldon and Timmons (68) reported that diuron persisted 2 seasons when applied to established alfalfa (Medicago sativa L.) at 2 pounds per acre under infrequent irrigation while disappearing in 1 season under semi-flood irrigation. Switzer and Rauser (59) found diuron toxicity to disappear somewhat more quickly than simazine.

Several authors considered microorganisms of major importance in the disappearance of urea herbicides such as diuron (25, 39, 44, 45, 52). Hill et al. (26) found inactivation of diuron and monuron to be greater in non-sterilized soil than in sterilized soil. They applied 1 ppm to soil incubated at 27°C and 60% relative humidity. The rate of inactivation checked 2, 4, and 6 weeks after application was essentially constant. After 6 weeks in sterilized soil 0.80 and 0.88 ppm and in non-sterilized soil 0.55 and 0.73 ppm of diuron and monuron respectively remained. A bacterium was isolated from a yeast-monuron-agar culture.

The phytotoxicity of urea herbicides is reported by Sheets (52) to be reduced by adsorption on soil colloids. Sheets (53) used 17 soils and repeated croppings to determine the effect of soil type on diuron toxicity. He correlated toxicity to organic matter content, cation exchange capacity, and clay content of soil with toxicity decreasing as these values increased. His results indicated greater adsorption and slower inactivation of diuron than monuron, fenuron, and DMU. Hilton and Yuen (27) determined chemically that diuron adsorption was slightly more than simazine and was a function of easily oxidizable organic matter of the soil. Applications of 2 to 20 inches of water by Sheets (53) moved diuron less in a clay than in a sandy loam soil. Hill and McGahen (25) tested diuron broadcast at 1 and 2 pounds per acre for 2 years in the Southeast and found after 28 months that only negligible amounts had leached below 4 inches in sand, loamy sand, and silt loam soils.

Chemical reactions and vaporization can also affect the

persistence of diuron (52). Preliminary studies by Hill et al. (26) indicated that diuron was stable in aqueous solution and that disappearance from soil by chemical decomposition would be insignificant. However, they showed an 83% loss of diuron from an aqueous solution exposed to sunlight for 48 hours. Weldon and Timmons (69) disclosed a 75% reduction in biological activity of diuron in ethyl alcohol after exposure to a mercury vapor lamp for 28 hours. Sheets (50) found the activity of diuron to disappear more rapidly from sterilized soil exposed to sunlight than from the same soil in shade, but temperatures also varied during the experiment. If exposed on a hot, dry soil surface for several days, volatilization of diuron could be an important mode of disappearance (52). Removal of diuron from the soil by plants is still unevaluated (52).

Simazine and Atrazine

Little is known of what becomes of simazine and atrazine in the soil (60). Feight and Slife (12) revealed that rates of atrazine required on heavy soils of northern Illinois and Iowa have sometimes persisted to injure oats and soybeans 1 year later. Sweet et al. (58) reported that 5 to 10 pounds of simazine per acre persisted at toxic levels for 2 growing seasons in New York. Splittsoesser and Derscheid (57) observed severe injury to small grains 1 year after application of atrazine at 2 pounds per acre in South Dakota. Fink and Fletchall (13) found residues of simazine and atrazine from applications of 1, 2, and 4 pounds per acre in an unusually dry year in

Missouri to severely reduce stands of several forages the following year. Injury from simazine was more severe than from atrazine. Studies by Burnside et al. (6) of simazine and atrazine persistence on a silty clay loam and two loam soils in Nebraska, disclosed residual toxicity to oats in the field from 2.5, 5, and 10 pounds per acre 12 months after application except for atrazine on the silty clay loam. After 16 months, injury occurred only on the loams where 10 pounds per acre were applied. Scudder (49) reported normal growth of oats and several vegetable crops 1 year after incorporation of 8 pounds per acre of simazine in Florida sand. Talbert and Fletchall (60) found the initial toxicity of atrazine greater than simazine in Missouri but the persistence of atrazine to be less.

Burnside et al. (7) isolated cultures of microorganisms from mediums in which simazine was the only source of nitrogen and almost the sole souce of carbon. Five microorganisms tested by Gramlich et al. (19) survived on atrazine mediums. Gysin (20) reported that fungi present in soil with organic matter are able to decompose the chlorotriazines. Although microorganisms have been found to utilize the triazines, Sheets (50) stated that proliferation of the organisms apparently does not occur, thus indicating the possibility of either non-preferential utilization by microorganisms or adsorption to a degree which allows only a small portion to be available at any one time.

Leaching of simazine and atrazine is indicative of their solubility and adsorptive characteristics. Burnside et al. (6) found simazine exposed to 17.2 inches of rainfall in 4 months to move 3 to

6 inches into a silty clay loam soil while atrazine moved 12 to 18 inches. Burnside et al. (7) applied 2 inches of water to simazine applied at the rate of 2 pounds per acre on a silt loam soil. A significantly greater amount remained in the upper 1 inch, but a small amount moved into the 3 to 6-inch zone. Splittstoesser and Derscheid (57) found oats in the 2 to 4-inch layer of a silt loam soil uninjured after 5 inches of rainfall fell within 2 months following a band application of 4 pounds per acre of simazine. Several authors have noted that leaching of simazine is slow; however, results of Burnside et al. (6) indicated that simazine and atrazine would move through a 24-inch soil profile of loam and silty clay loam soils. Rodgers (47) found atrazine to leach through a 23-inch sand profile while simazine moved only to the 12-inch level.

That more material is required for the same results as soil organic matter and/or clay content increase, is indication that adsorption of simazine and atrazine occurs (12, 63). Gast (17), by growing sensitive crops in a soil-simazine-activated charcoal mixture without injury, showed that adsorption reduced the toxicity of simazine. Burnside et al. (6) reported that adsorption accounted for significant loss of toxicity from simazine and atrazine in soils. They considered organic matter to be the most important factor of adsorption. Hilton and Yuen (27) found adsorption to be a function of the easily oxidizable organic matter in Hawaiian sugar cane soils. Their results showed simazine to be adsorbed more than atrazine but less than diuron. Talbert and Fletchall (61) also found simazine to be adsorbed more than

atrazine with increased organic matter and/or clay generally leading to greater adsorption in soil. They discovered that adsorption decreased from organic matter to montmorillonite to illite with no detectable adsorption on kaolinite. Adsorption also decreased as temperature and pH were increased. Harris and Warren (23) found adsorption of atrazine in the laboratory to be strongly influenced by pH with adsorption decreasing as pH increased. Gast (17) reported that simazine adsorbed on activated charcoal was evidently protected from degrading influences for it could still be recovered after long periods. Behrens (4) also cautioned that adsorption should not be considered important in reducing soil residues.

Behrens (4) reported that triazines could be chemically decomposed, but that the importance of this process was unknown. Burnside et al. (7) considered temperatures required to be too high for significant alteration to occur in the field. Jordan et al. (31) found simazine and atrazine dried on filter paper to be decomposed by ultraviolet light and sunlight. Gast (17) reported reduced herbicidal activity on oats after exposure of treated soil to ultraviolet and infrared light together for 14 days. Losses were especially high on dry surfaces. Foy (14) observed little disappearance of C^{14}-labeled simazine and atrazine at 25°C; but upon exposure to an infrared heat lamp which raised the temperature to 60°C, atrazine disappearance reached 95% in 15 hours and 35% of the simazine disappeared in 24 hours.

Kearney et al. (32), using infrared heat lamps to control temperature, found volatility of atrazine much greater than simazine.

Atrazine volatilized more from moist soil than from dry soil while the reverse occurred with simazine. Increased temperature from 25 to 35°C essentially doubled the loss of atrazine from planchets. Exposure of atrazine for 72 hours at 45°C on loam, sandy loam, and loamy sand caused a loss of more than one-half of the C^{14}-labeled material.

Inactivation of simazine and atrazine appears to be affected by tillage and plant utilization. Richards (46) reported there was evidence that thorough seedbed preparation eliminated residual toxicity of simazine to fall-seeded oats. Gysin (20) stated that considerable amounts of simazine and atrazine were absorbed and metabolized by plants. Hamilton and Moreland (21) presented evidence of simazine conversion in corn to non-toxic hydroxysimazine.

DNBP

Newman and Downing (39) reported DNBP to be moderately to highly persistent. They indicated there was no direct information on the role of microorganisms in its decomposition. Dowler *et al.* (11) found movement of DNBP in soil to be a function of soil type and pH as much as amount of rainfall applied. When simulated rainfall was applied, they obtained significant movement to lower soil levels with activity occurring to greater depths in lighter soils. Newman and Downing (39) reported that DNBP was strongly adsorbed by soil. Warren (66) considered strong adsorption as the reason for the requirement of several times as much material to produce 90% inhibition of crabgrass (*Digitaria sp.*) growth in muck as in sand. Upchurch and Mason (63) revealed

a requirement of five times as much DNBP to reduce dry weight of cotton (Gossypium hirsutum L.) 50% in soil with 20% organic matter as in soil with 5% organic matter. Frissel and Bolt (15) found adsorption of DNBP on clay in an aqueous environment to decrease as pH increased. Results of Harris and Warren (23) expressed this same relationship as bentonite almost completely adsorbed DNBP at pH 2.3 but adsorbed none at pH 8.4. Complete adsorption occurred on an anion exchanger at pH 5.6 while none occurred on a cation exchanger at pH 4.1.

Newman and Downing (39) reported volatilization of DNBP from moist soils through water vapor. They said liming reduced vapor loss by evidently shifting the state to the calcium salt. Sheets and Danielson (55) associated extensive DNBP vapor injury to cotton in 1952 with high temperatures. Davis (9) found slight vapor injury to cotton at 29°C to be increased to almost complete kill at 36°C. Slaked lime applied from immediately before until 3 days after DNBP reduced the vapor injury.

DCPA

No literature concerning the persistence or inactivation of 2,3,5,6-tetrachloroterephthalic acid (DCPA) was found.

Amiben

Rauser and Switzer (43), attempting to measure microbial activity, determined the loss of herbicidal activity of amiben to be more rapid in muck than in clay soil. During the 10-week test period there was no detoxification of amiben in sandy soil. By leaching soil

columns they determined that amiben was removed most rapidly from sand, next from clay, and least from muck. The amount of water applied had little influence on the depth of leaching in muck while 2 inches of water evidently moved amiben entirely through 6 inches of sand. They proposed that amiben inactivation was primarily due to microbial decomposition in muck, leaching in sand, and the combination in clay soils.

Warren (65) found little difference among rates of amiben required for a 90% growth reduction of crabgrass in fine sand, silt loam and muck. He confirmed these results in the field. In Indiana 5.89 inches of rainfall in the 3 weeks following application greatly reduced the effectiveness of amiben on fine sand as compared to 0.88 inches of rainfall. In another field test which received 6 inches of rainfall in the 4 weeks following application, effectiveness was greatly reduced on fine sand while it remained high on silt loam.

Sheets (51) discovered a 50% decomposition of amiben in aqueous solution when exposed to sunlight for 6 hours at 45°C. Toxicity to oats was also reduced approximately 50%. Phytotoxicity of a corresponding solution maintained at 49°C in the dark was not altered. Slow but definite decomposition of dry amiben on filter paper also occurred.

III. POSSIBLE ACCUMULATION OF HERBICIDES IN THE SOIL

Reports by Hill et al. (26), studying monuron and diuron at 1 and 2 pounds per acre for 2 years in the Southeast; Sheets and Danielson (55), of monuron and diuron for weed control in cotton for 7 years in

the Southwest; and Harris (24), using diuron at 1 pound per acre pre and postemergence for 10 years to control weeds in cotton in Mississippi, indicated no significant accumulation of herbicides. Rahn and Baynard (41) reported that monuron at 1.6 pounds per acre applied twice a year for three years in Delaware did not persist into the next season. At 3.2 pounds applied twice a year it did persist into the next year but no accumulation occurred. Gysin (20) reported that soils treated for 6 years with simazine at 10 pounds per acre had shown no accumulation. He did not identify the soils or conditions. Burnside et al. (6) proposed that if herbicides which decompose slowly were leached to soil depths where microbial activity is greatly reduced, they could accumulate there.

CHAPTER III

MATERIALS AND PROCEDURES

A persistence study involving several preemergence herbicides was initiated at Knoxville and Jackson in 1961. Herbicides chosen included those in common use at that time and others of which future use was anticipated. Rates of application included multiples of 1, 2.5, and 5 times the recommended rates of application (Table I). Each treatment was applied for 3 successive years to the same plot in a randomized block design. The treatments were replicated three times on Cumberland loam at Knoxville and on Collins silt loam at Jackson.

At Knoxville a tractor-mounted sprayer applying approximately 28 gallons of water per acre from an 80-inch boom was used to spray all materials across plots 10 feet by 10 feet. Plots 10 feet by 12 feet were treated by hand at Jackson. There, DNBP, DCPA, and amiben were applied as granules mixed with sand while all other materials were applied by sprinkler can in water at the rate of 500 gallons per acre. The wettable powder of DCPA was used in 1963 because granules were not available. Unfortunately the recalculation of material needed was overlooked and several times as much material as that desired was applied the third year.

Soil samples were taken from the plots periodically for bioassay determinations in the greenhouse. A bulb planter was used to obtain a soil core approximately 2 inches in diameter and 4 to 5 inches in depth.

TABLE I

HERBICIDES AND RATES OF APPLICATION USED FOR THREE YEARS IN PERSISTENCE STUDIES AT KNOXVILLE AND JACKSON

	Rates in pounds of active ingredient or acid equivalent per acre		
Herbicide	1X[a]	2.5X	5X
Check	---	---	---
2,4-D, PGBE esters	1.5	3.75	7.5
2,4-D, Alkanolamine salts	1.5	3.75	7.5
Diuron	1.0	2.5	5.0
Simazine	2.0	5.0	10.0
Atrazine	2.0	5.0	10.0
DNBP	6.0	15.0	30.0
DCPA	4.0	10.0	20.0
Amiben	2.0	5.0	10.0

[a]X = recommended rate of application.

The soil samples were placed in 16-ounce, squat, paper cups; mixed to simulate tillage; and planted to four seeds each of Forkedeer oats and cucumbers (Cucumis sativus L. variety A and C). Germination, living plants, and fresh weights of living plants were recorded after 4 weeks. The average weights of three replicates are reported.

Dixie 29 corn was used each year as a summer crop on the field plots with oats being seeded in the fall and spring whenever possible. Crimson clover (Trifolium incarnatum L.) seeded in the fall was also tried, but results were essentially identical to those of oats and since a good stand was difficult to obtain, it was discontinued.

Ratings of weed control and crop injury were made each year. A scale of 0 to 10 was used with 0 indicating no control or injury and 10 indicating complete control or kill. A weed-control rating of 7 or more was considered as satisfactory control while an injury rating of 3 or more was considered as significant crop injury. All ratings were in comparison to an ideal rather than an untreated check.

Bioassays were used as the primary tool to measure residual herbicidal toxicity with field ratings of weed control and crop injury used to supplement information derived from the bioassays. Corn injury ratings were compared in an attempt to measure any accumulation of herbicides.

Rainfall data were obtained from the climatalogical stations located on the experiment stations at Knoxville and Jackson.

CHAPTER IV

RESULTS AND DISCUSSION

I. GENERAL OBSERVATIONS

Results with oats and cucumbers as indicator crops were similar except in the case of DCPA which showed little toxicity to cucumbers. Oats were the easiest and most consistent crop with which to work. Variations in temperature and/or moisture had a much greater effect upon cucumbers than oats. Average fresh weights of both crops are reported, but only the weights of oats are graphed. Germination data indicated that none of the herbicides influenced the germination of either crop.

Weed control ratings in 1961 appeared good for both locations, but there was only a small weed population that season, as indicated by the ratings of the check plots. The grass population was high at both locations in 1962 and 1963, but broadleaf species were irregular at Knoxville and limited at Jackson. The primary weed species at Knoxville were crabgrass (Digitaria sanguinalis (L.) Scop.), common morningglory (Ipomoea purpurea (L.) Roth.), and jimsonweed (Datura stramonium L.). Crabgrass was the primary weed at Jackson.

II. HERBICIDES

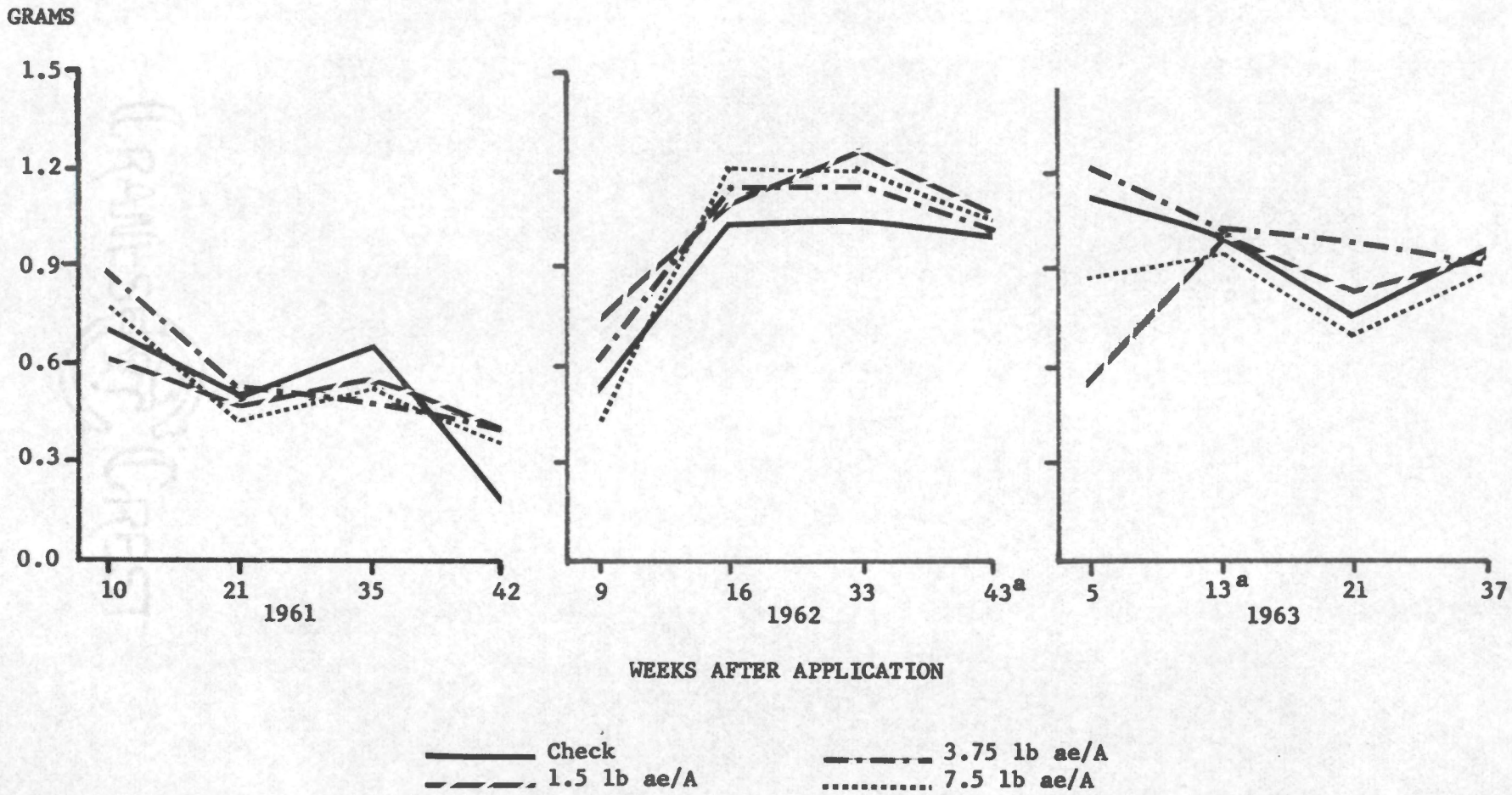
2,4-D

Neither formulation of 2,4-D showed appreciable persistence

at either location (Figures 1, 2, 3 and 4). Even at the 5X rate of application, bioassays 5 weeks after application in 1963 did not indicate any growth reduction. Weed control ratings at Knoxville in 1963 showed an almost complete loss of effectiveness between 5 and 12 weeks after application (Tables II and III, Appendix A). At Jackson there was essentially no control even at 5 weeks. Fall and spring-seeded oats showed no effects of previous applications at either location (Table IV, Appendix A). Corn sometimes showed stunting due to poor weed control with only small differences occurring among rates of application (Tables V and VI, Appendix A). Since there was no significant persistence, no accumulation could have occurred. The rapid disappearance of 2,4-D is in accord with results of others (3, 4, 66).

Diuron

Bioassays showed diuron to be persistent at high rates of application (Figures 5 and 6). At the 1X rate little or no residual toxicity was detected. However, it is possible that bioassays indicated toxicity 15 and 22 weeks after application at Jackson in 1962 and 5 weeks after application at Knoxville in 1963. The 2.5X rate showed varying degrees of persistence. Its effect was slight in 1961, but was greatly increased at Jackson in 1962 and at both locations in 1963. The increase does not necessarily mean accumulation, however, for disappearance in 1963 appeared to be more rapid than in 1962. This indicated that climatic differences among years probably exerted major influences upon persistence. The 5X rate of application was generally quite toxic and



[a]Data for this date are based upon observations rather than actual weights.

Figure 1. Fresh weights of oat seedlings from bioassays following three annual applications of low volatile PGBE esters of 2,4-D at three rates on Cumberland loam at Knoxville.

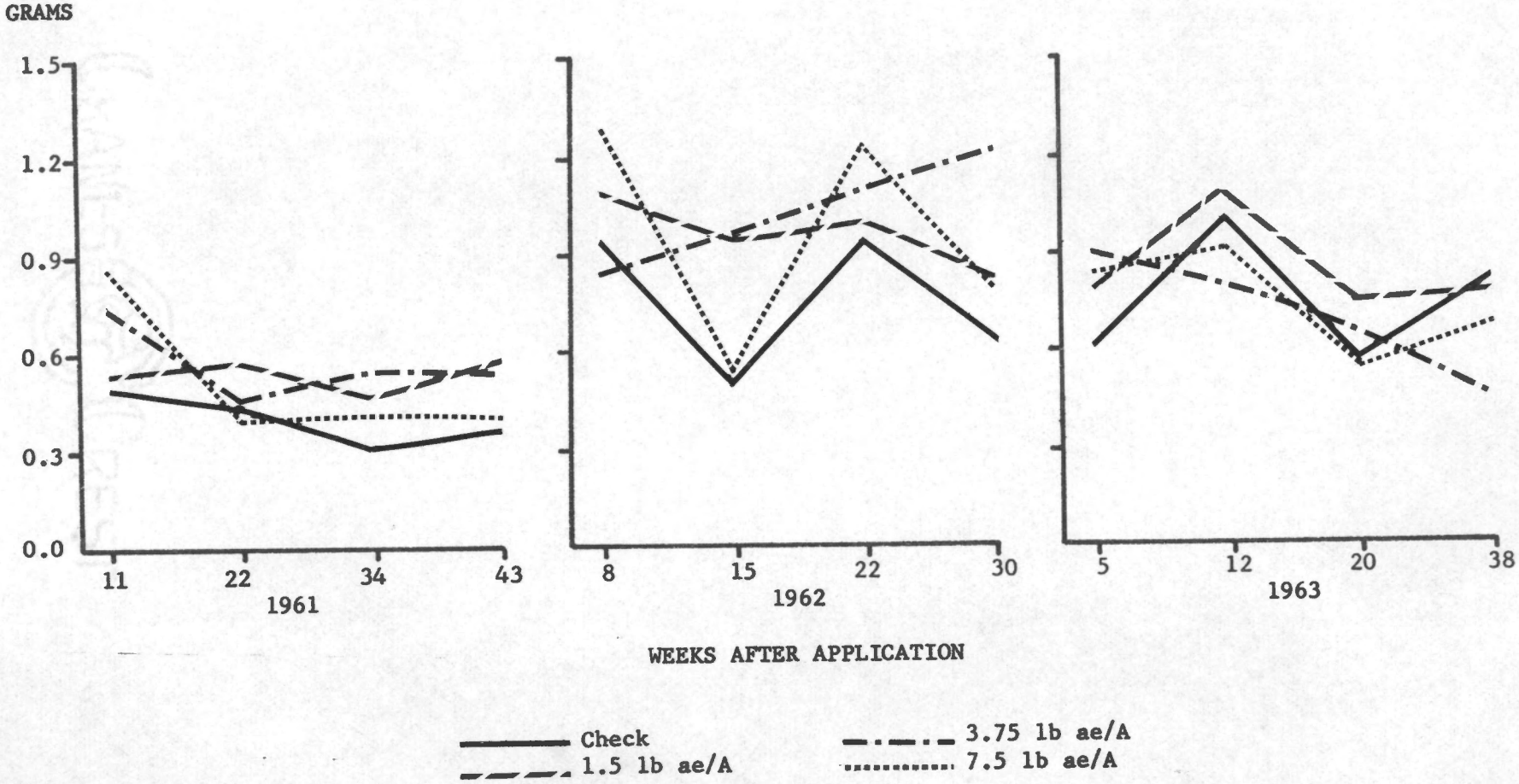
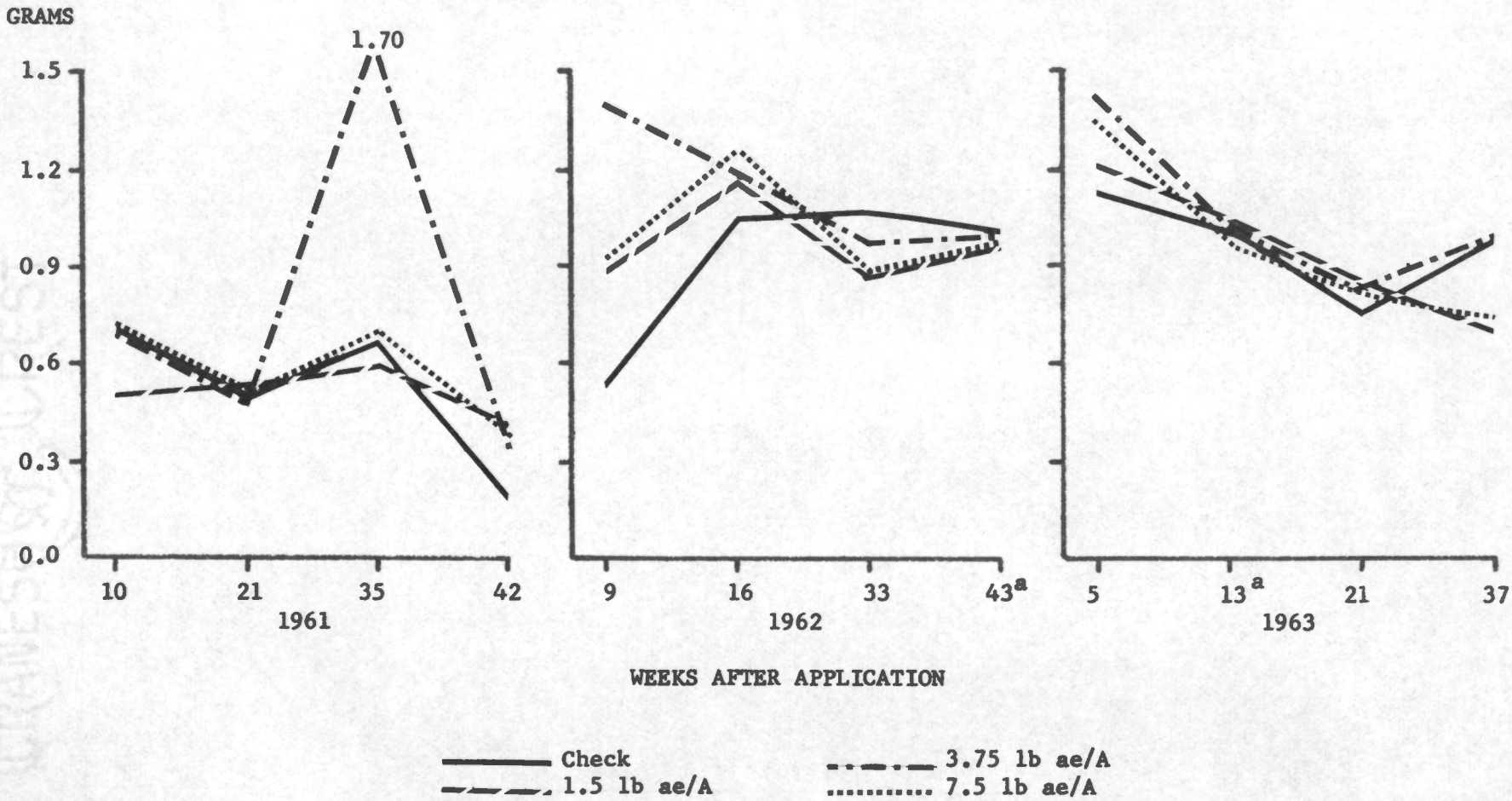


Figure 2. Fresh weights of oat seedlings from bioassays following three annual applications of low volatile PGBE esters of 2,4-D at three rates on Collins silt loam at Jackson.



[a]Data for this date are based upon observations rather than actual weights.

Figure 3. Fresh weights of oat seedlings from bioassays following three annual applications of alkanolamine salts of 2,4-D at three rates on Cumberland loam at Knoxville.

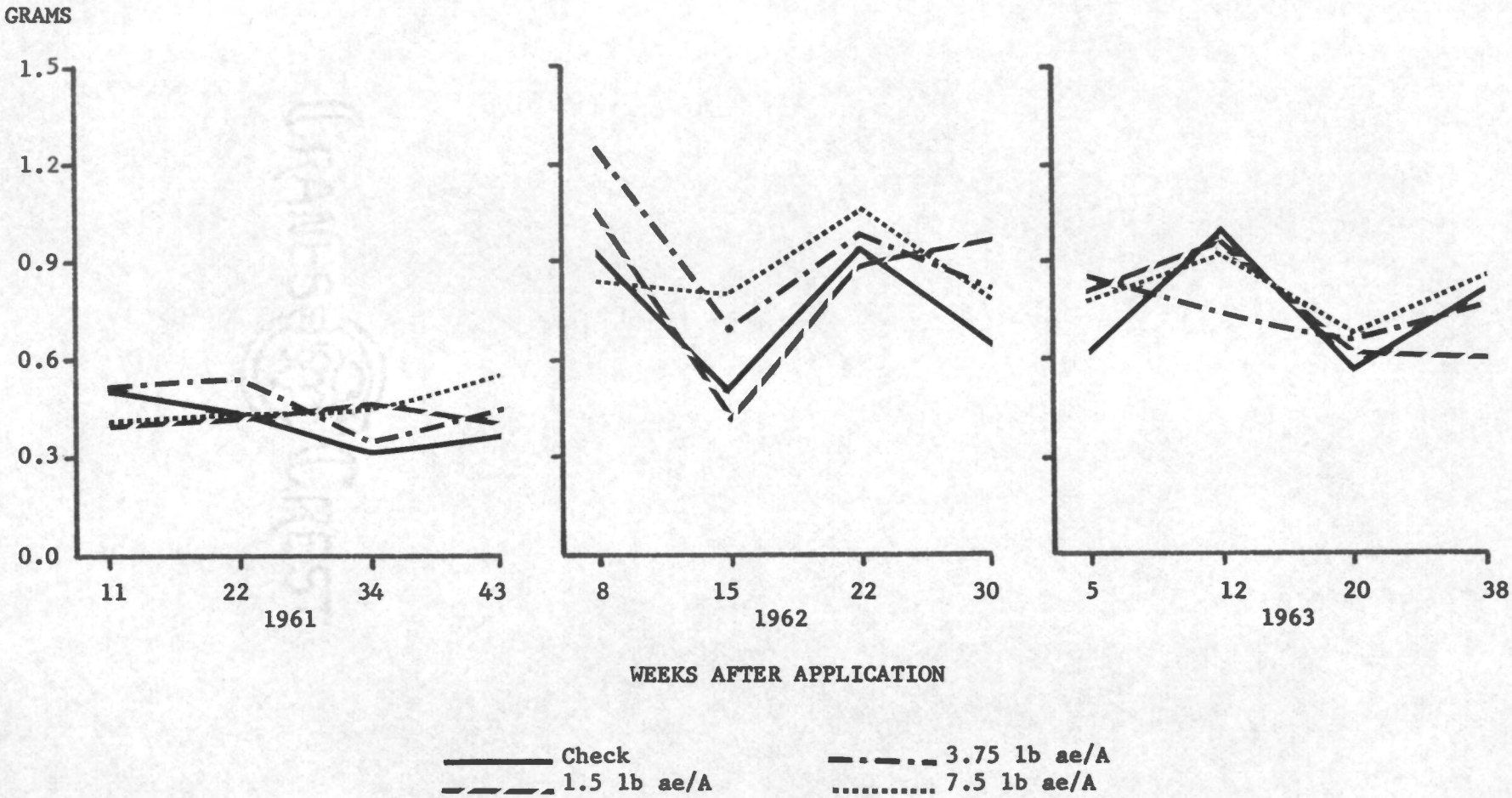
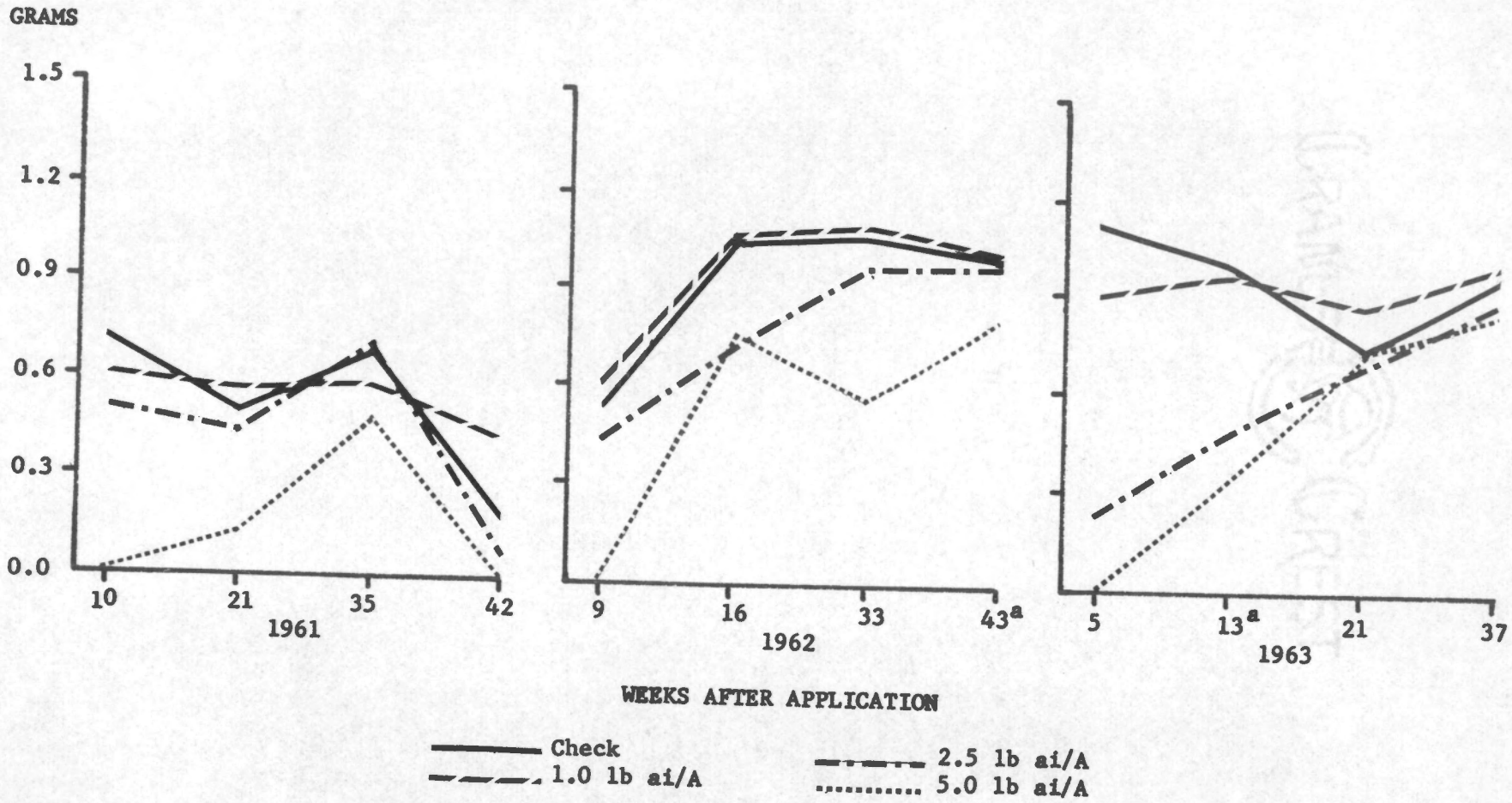


Figure 4. Fresh weights of oat seedlings from bioassays following three annual applications of alkanolamine salts of 2,4-D at three rates on Collins silt loam at Jackson.



[a]Data for this date are based upon observations rather than actual weights.

Figure 5. Fresh weights of oat seedlings from bioassays following three annual applications of diuron at three rates on Cumberland loam at Knoxville.

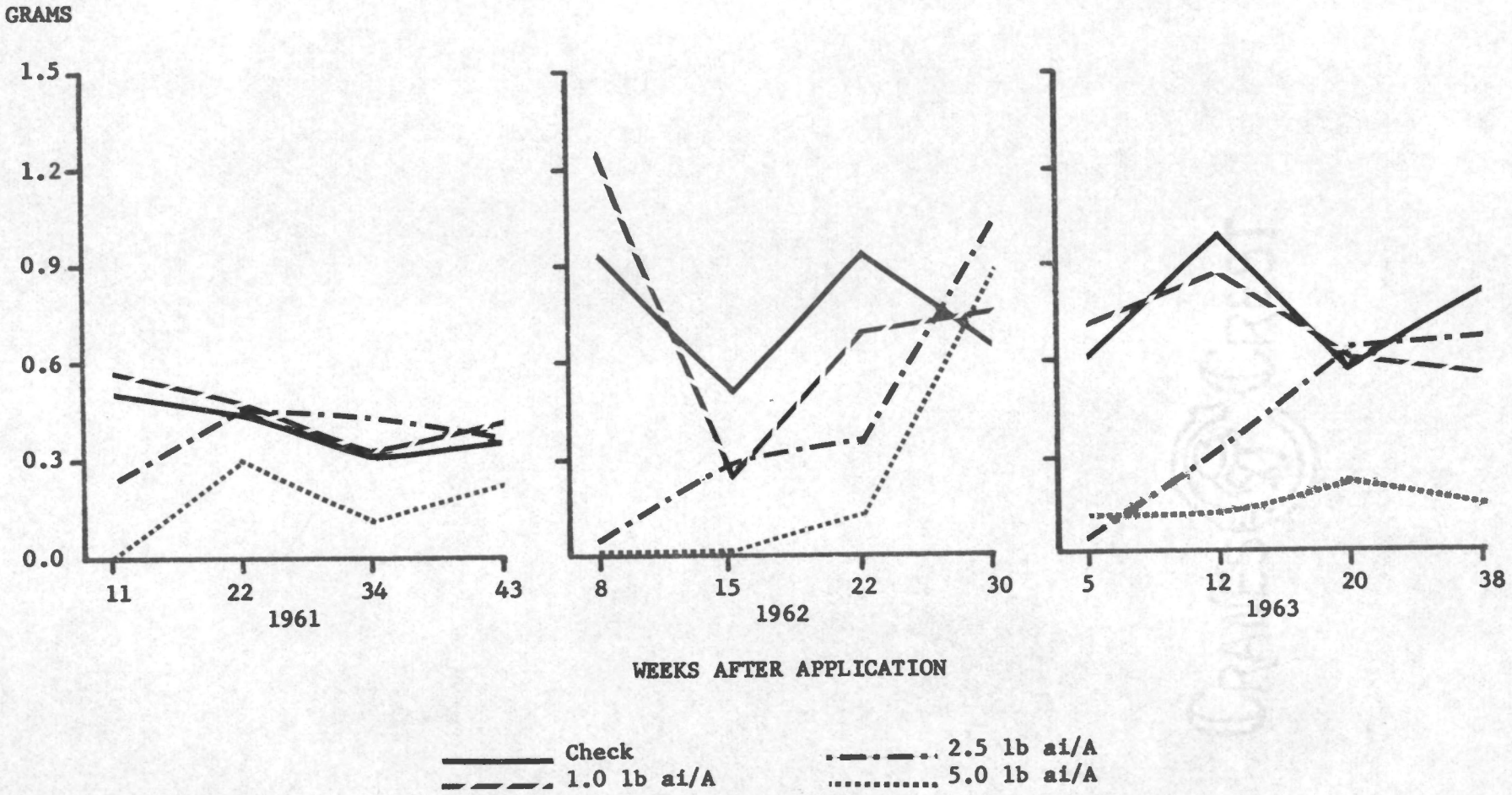


Figure 6. Fresh weights of oat seedlings from bioassays following three annual applications of diuron at three rates on Collins silt loam at Jackson.

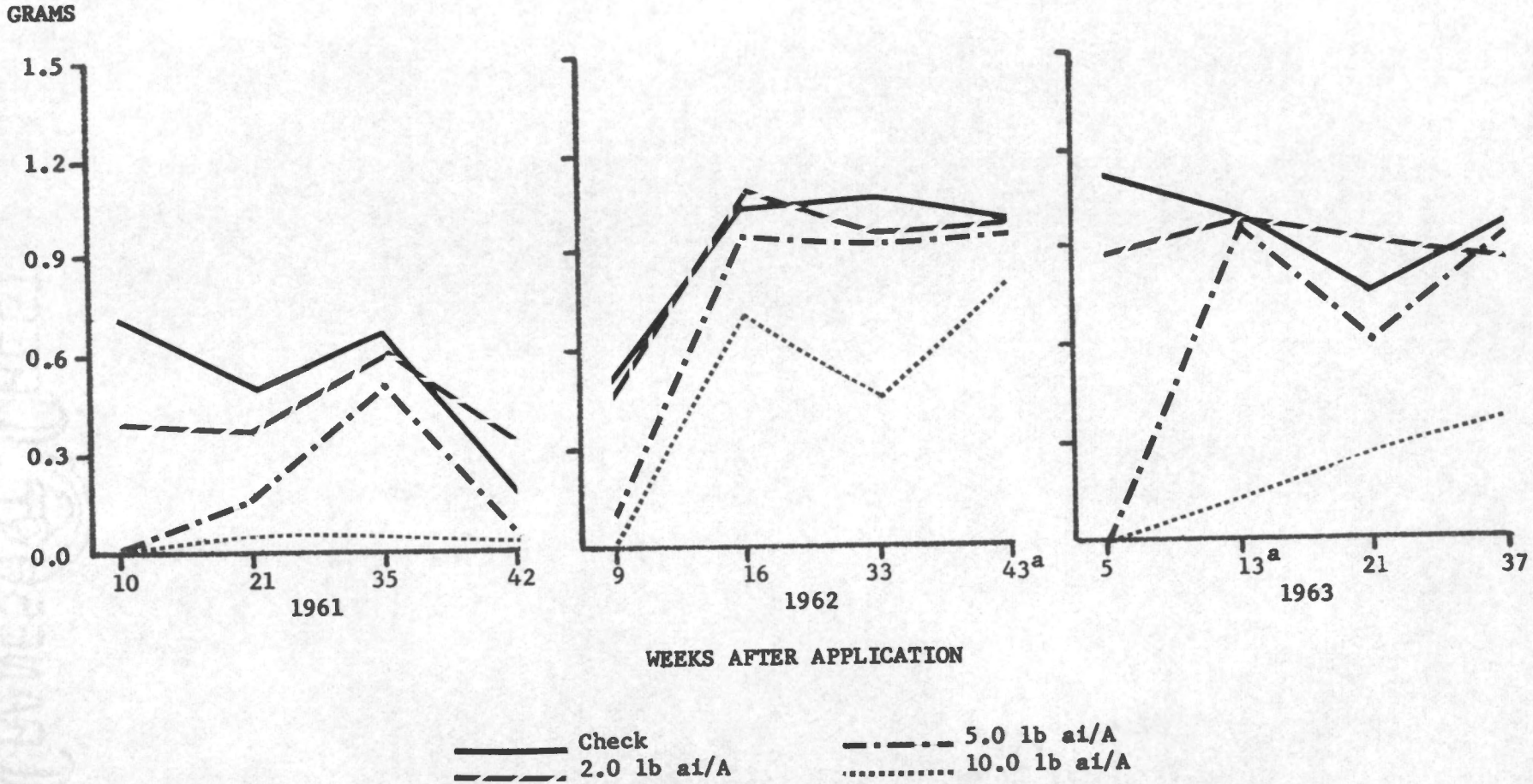
persistent, killing the oats in early bioassays and often reducing growth throughout the sampling periods.

Field ratings (Tables II through VI, Appendix A) showed weed control, with one exception, to remain good at both locations throughout the 1961 and 1962 seasons. Control broke down at the 1X rate between 5 and 12 weeks after application at Jackson in 1963. Injury to fall and spring-seeded oats at Knoxville was detected at the 5X rate only. At Jackson no injury occurred following any rate of application. This could be due to the lighter textured soil there which allowed more material to be removed by leaching. Results with diuron were similar to those of Hill et al. (26) who found toxicity from 1 and 2 pounds broadcast per acre to disappear in 4 to 8 months in the Southeast.

Diuron, especially at the higher rates, consistently reduced the stand of corn. Results were slightly more severe in 1963 than in 1962. This was most obvious with the 2.5X rate at Jackson. It is possible that some carryover from 1962 to 1963 occurred, although bioassays indicated that all toxicity disappeared from the 1962 application.

Simazine and Atrazine

Results with simazine and atrazine were similar, showing considerable persistence at both locations. Bioassays indicated that toxicity from the 1X rate of application generally disappeared within 20 weeks (Figures 7, 8, 9, and 10). Residual toxicity of the 1X rate of simazine appeared to be greater at Jackson than at Knoxville in 1962 and 1963.



[a]Data for this date are based upon observations rather than actual weights.

Figure 7. Fresh weights of oat seedlings from bioassays following three annual applications of simazine at three rates on Cumberland loam at Knoxville.

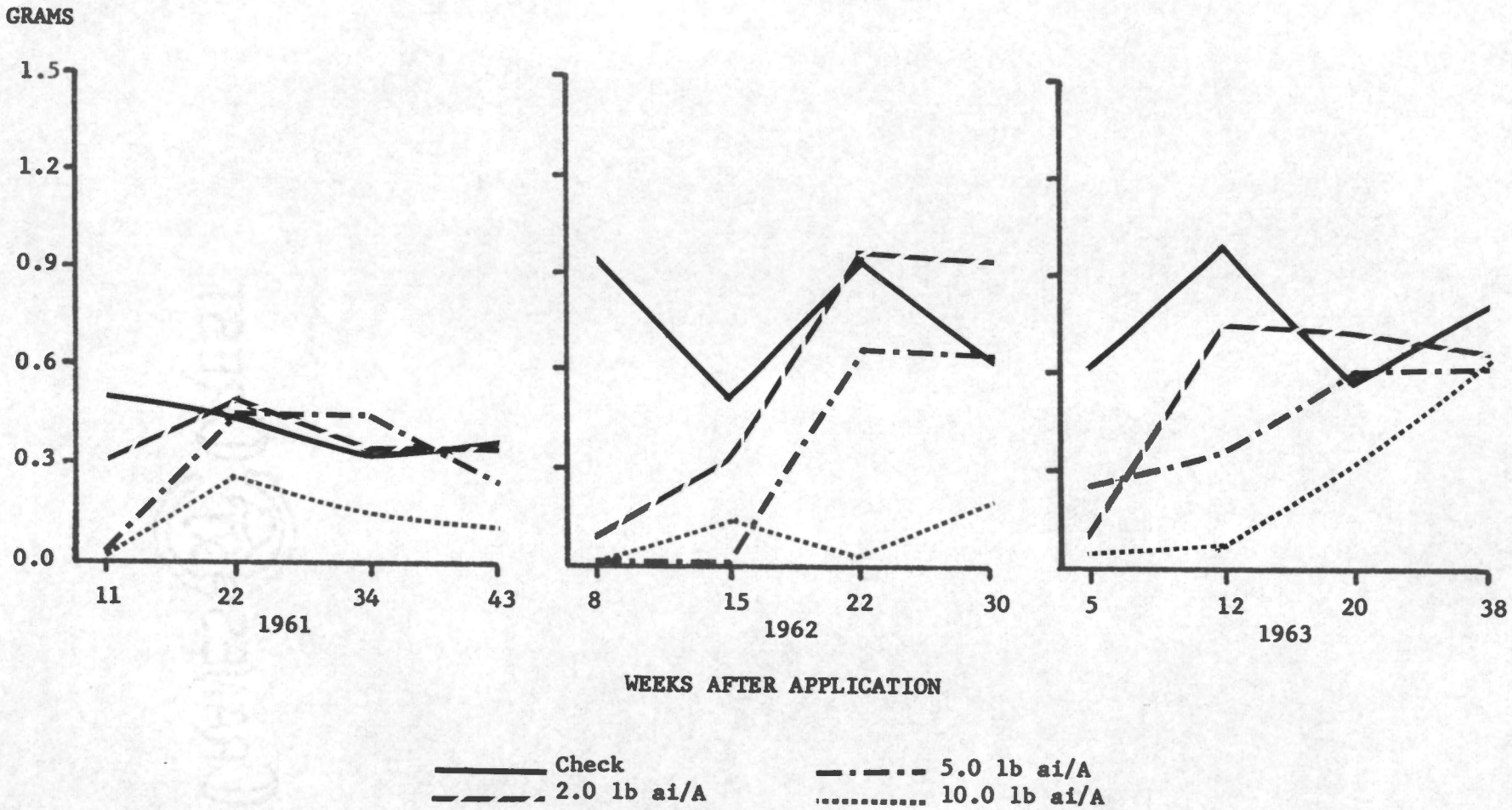
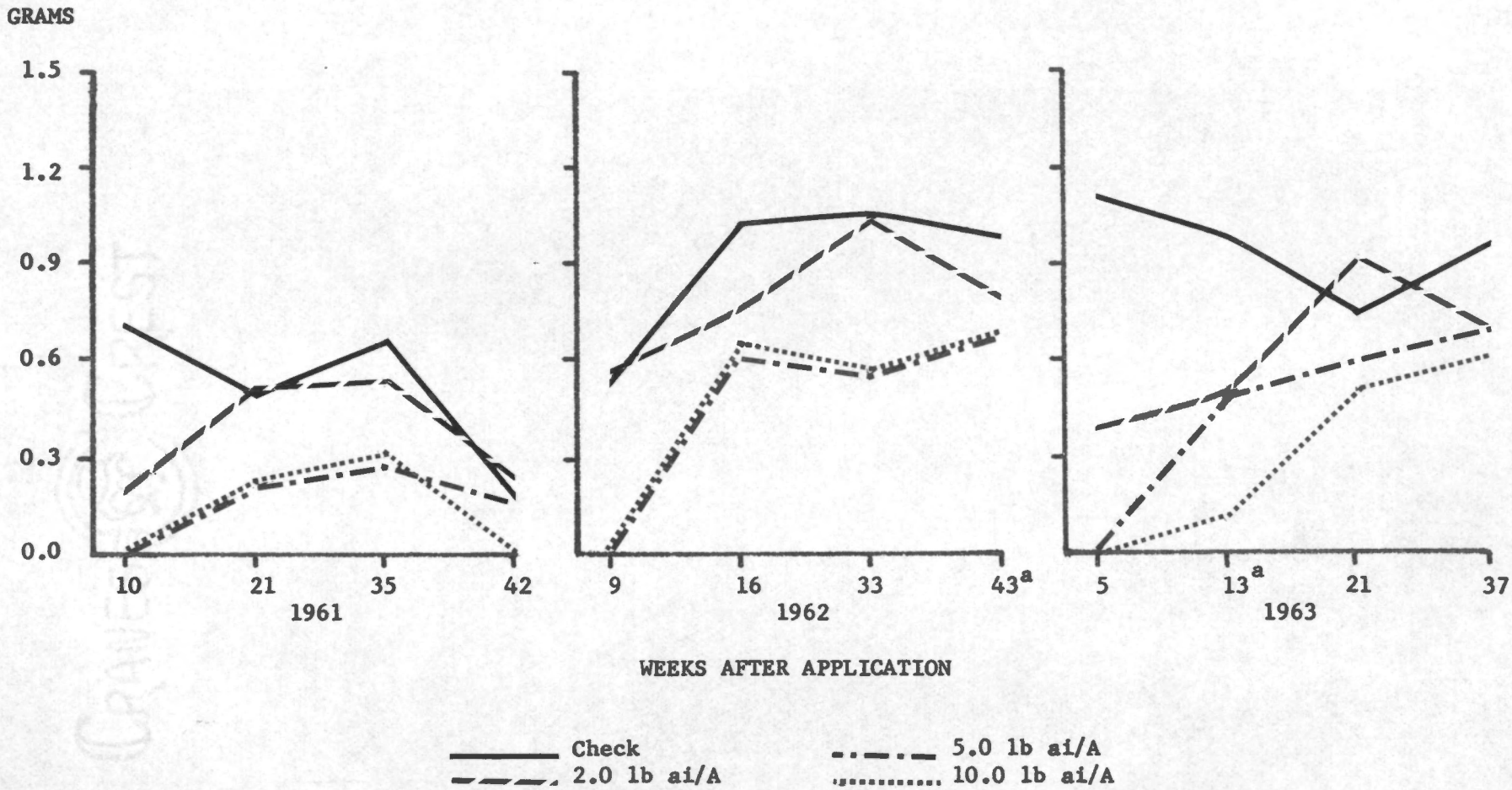


Figure 8. Fresh weights of oat seedlings from bioassays following three annual applications of simazine at three rates on Collins silt loam at Jackson.



[a]Data for this date are based upon observations rather than actual weights.

Figure 9. Fresh weights of oat seedlings from bioassays following three annual applications of atrazine at three rates on Cumberland loam at Knoxville.

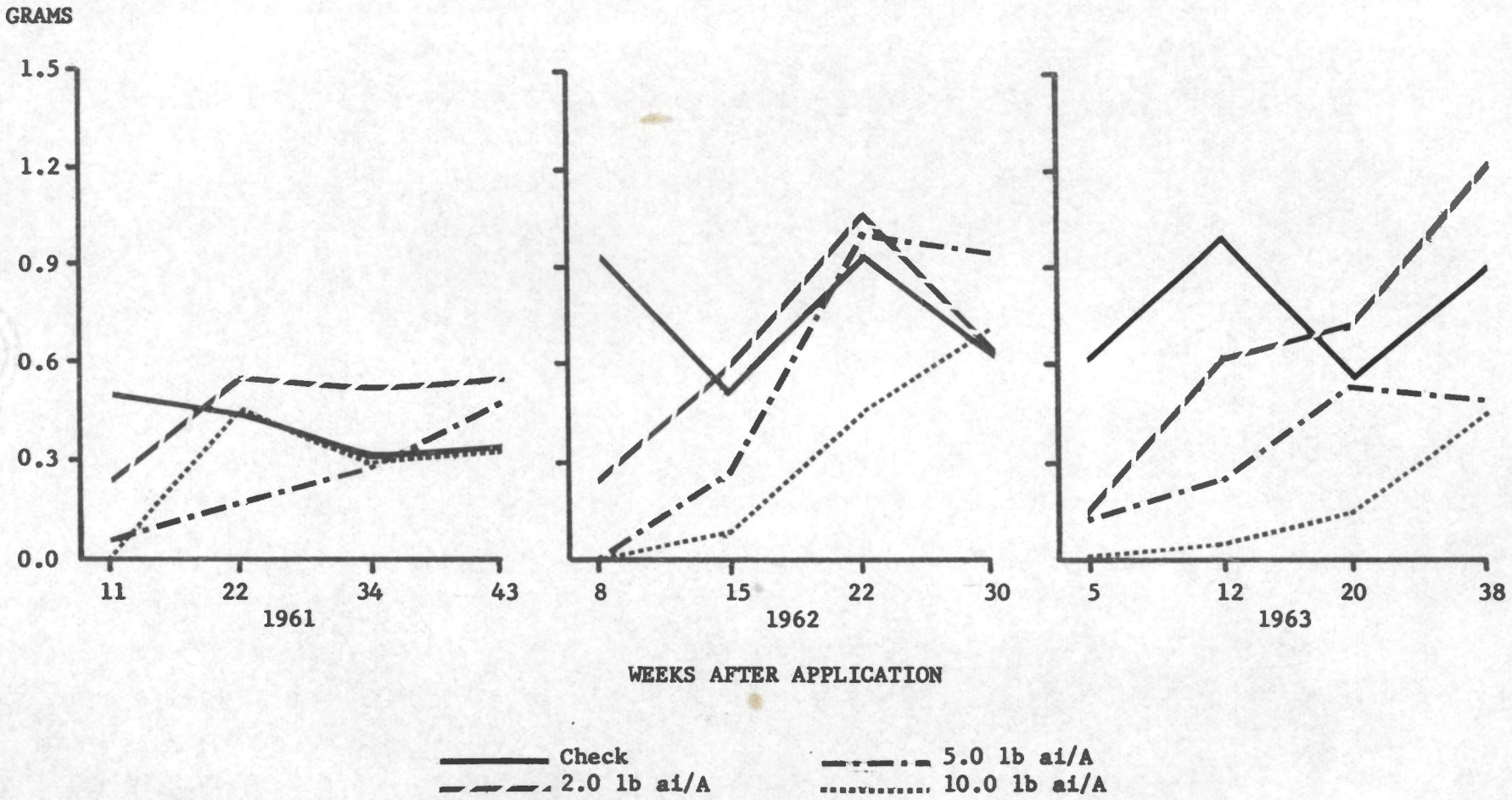


Figure 10. Fresh weights of oat seedlings from bioassays following three annual applications of atrazine at three rates on Collins silt loam at Jackson.

This also seemed to be true of atrazine in 1962. The low rainfall at Jackson during 1962 and 1963 is the probable reason (Tables XIV and XVI, Appendix B). Toxicity of the 2.5X rate was longer lived than the 1X rate, but in most cases it disappeared during the sampling periods. At the 5X rate of application persistence often continued throughout the sampling periods. At Knoxville there appeared to be little difference between the persistence of the 2.5X and the 5X rates of atrazine. Bioassays indicated that carryover from the 5X rate of application could possibly occur.

Weed control ratings in 1963 showed a slight decline in effectiveness of the 1X rate between 5 and 12 weeks after application (Tables II and III, Appendix A). In 1962 control was unsatisfactory at Knoxville after 15 weeks, but remained good after 22 weeks at Jackson. The slightly better control at Jackson could have been due to less rainfall to remove the herbicides from the surface soil (Appendix B).

Oats seeded in the field showed no significant residual injury at either location from either material at the 1X rate (Table IV, Appendix A). Simazine at the 2.5X rate showed significant injury only once. It occurred to fall-seeded oats at Jackson in 1961. Atrazine at the 2.5X rate was injurious to both fall and spring-seeded oats at Knoxville while it caused little injury at Jackson. Injury was severe at the 5X rate of application with simazine causing more severe injury than atrazine, especially at Jackson, except for 1963. Figure 11 shows the residual effects of three rates of simazine to oats seeded at Knoxville in the spring of 1963. The area had been treated 2 years receiving



Figure 11. Spring-seeded oats at Knoxville in 1963 following applications of simazine in 1961 and 1962: background--2 lb/A; center--5 lb/A; foreground--10 lb/A.

the 1X rate in the background, the 2.5X rate in the center, and the 5X rate in the foreground.

Injury ratings for 1962 at Knoxville indicated more severe injury to spring-seeded oats than those seeded in the fall. This is considered due to progressive injury occurring slowly because of the slow growth of fall-seeded oats. It was difficult to show this with a later rating because of the severe winter injury which occurred in 1962, but was observed in 1963.

Ratings of corn injury at Jackson showed a possible accumulation or carryover of simazine at the 5X rate (Tables V and VI, Appendix A). Early in the season corn was severely stunted, but continued throughout the season to outgrow the effect (Figure 12). Slight stunting was observed at the 2.5X rate of simazine and the 5X rate of atrazine, but was quickly outgrown. No stunting occurred at Knoxville.

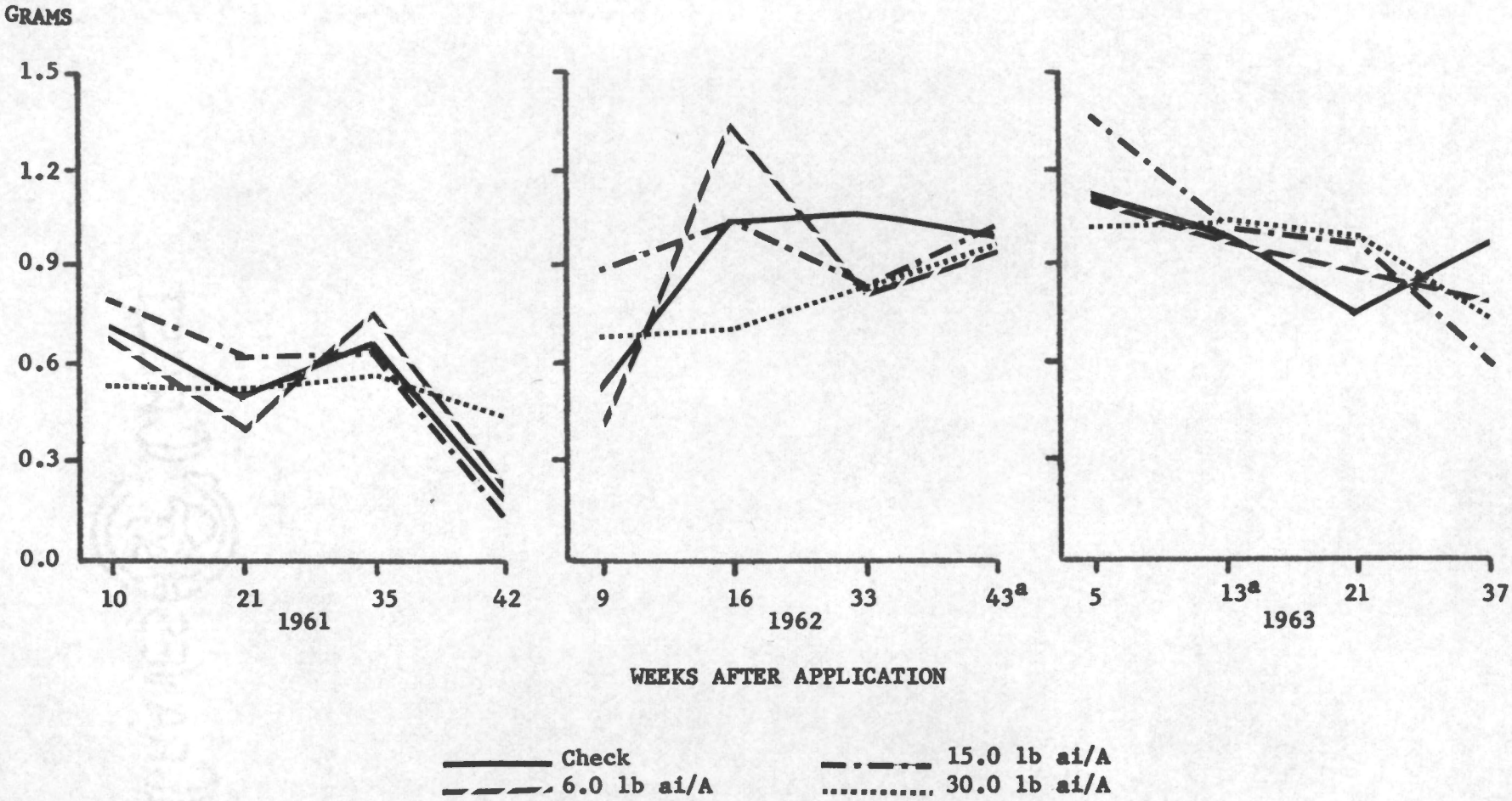
Several other investigators have also found simazine and atrazine to be persistent (6, 12, 13, 58, 59).

DNBP

No appreciable toxicity of DNBP at either rate of application or location was detected with bioassays (Figures 13 and 14). Weed control ratings for 1963 indicated a decline in activity between 5 and 12 weeks after application at Knoxville (Tables II and III, Appendix A). Only slight control was exhibited at Jackson after 5 weeks. High temperatures at Jackson may have caused greater volatilization of DNBP. In 1962 poor grass control by the lower rates was recorded after 15 and 22 weeks at



Figure 12. Stunted corn at Jackson in 1963 following the third successive annual application of simazine at the rate of 10 pounds per acre.



[a]Data for this date are based upon observations rather than actual weights.

Figure 13. Fresh weights of oat seedlings from bioassays following three annual applications of DNBP at three rates on Cumberland loam at Knoxville.

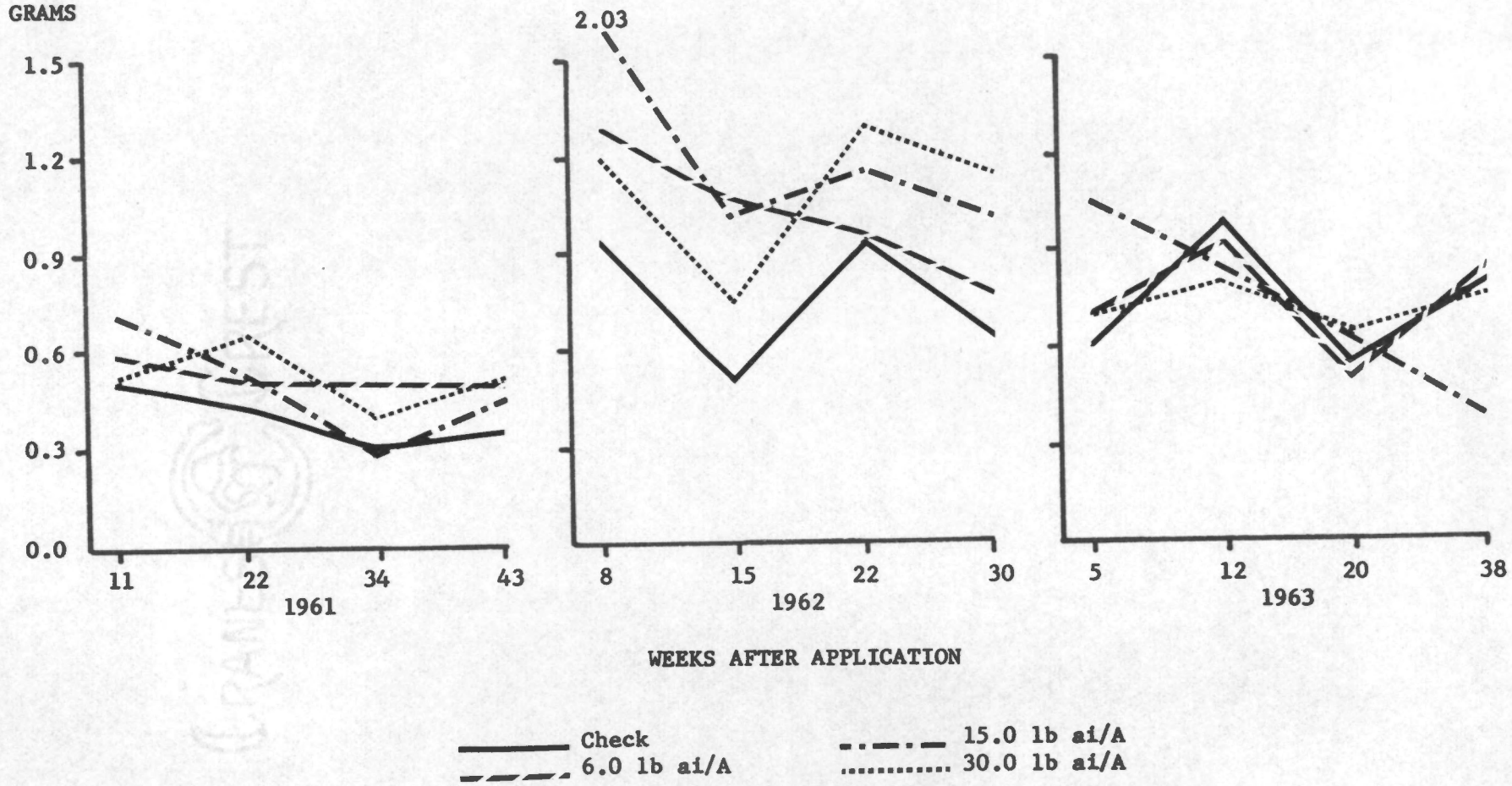
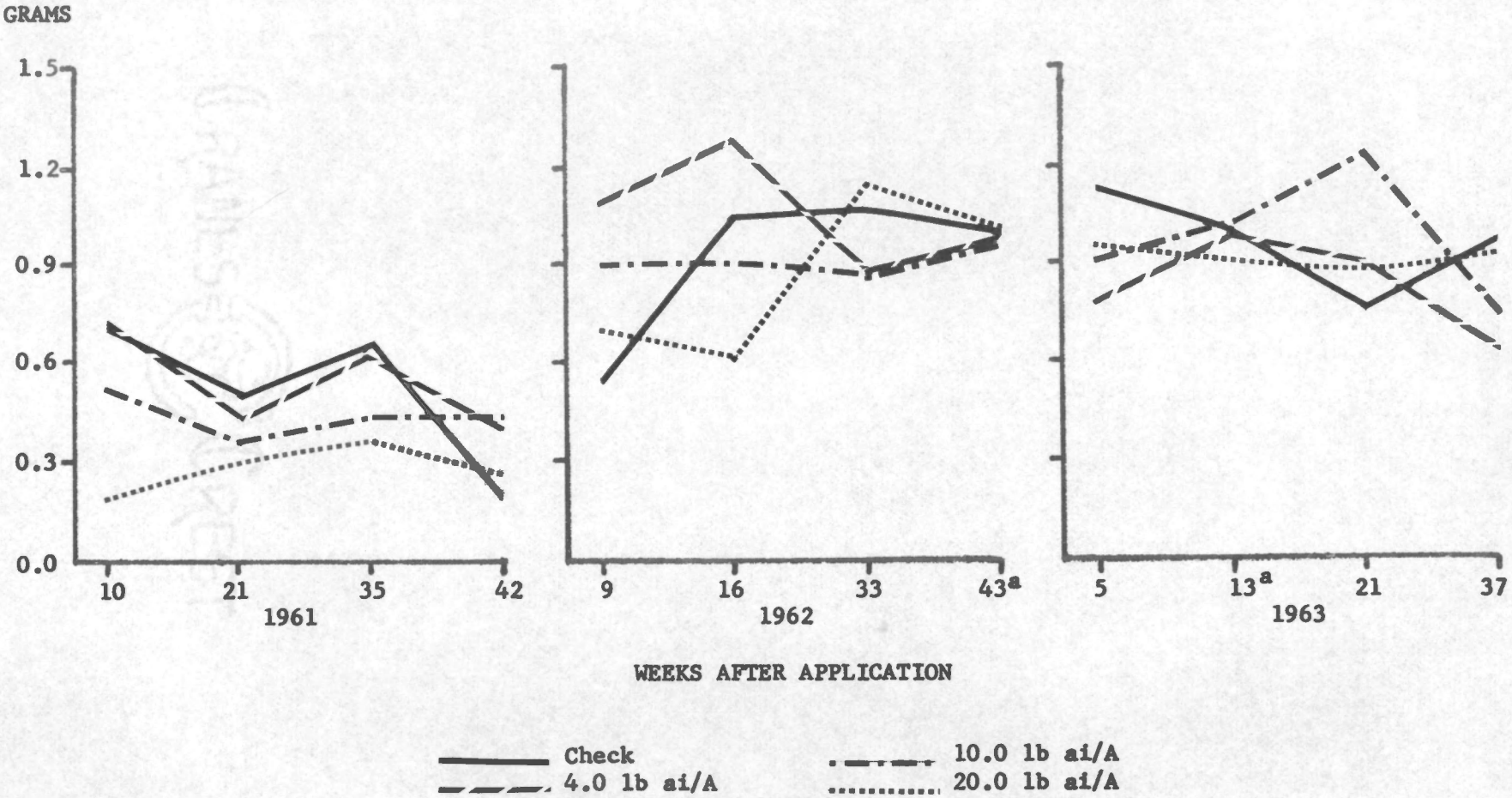


Figure 14. Fresh weights of oat seedlings from bioassays following three annual applications of DNBP at three rates on Collins silt loam at Jackson.

Knoxville and Jackson respectively. The only case of significant injury to oats in the field occurred with spring-seeded oats following the 5X rate of application at Knoxville in 1962 (Table IV, Appendix A). DNBP consistently injured corn with slight increases in severity being recorded in ratings (Tables V and VI, Appendix A). However, the increases were probably due to poor control of the increased weed population.

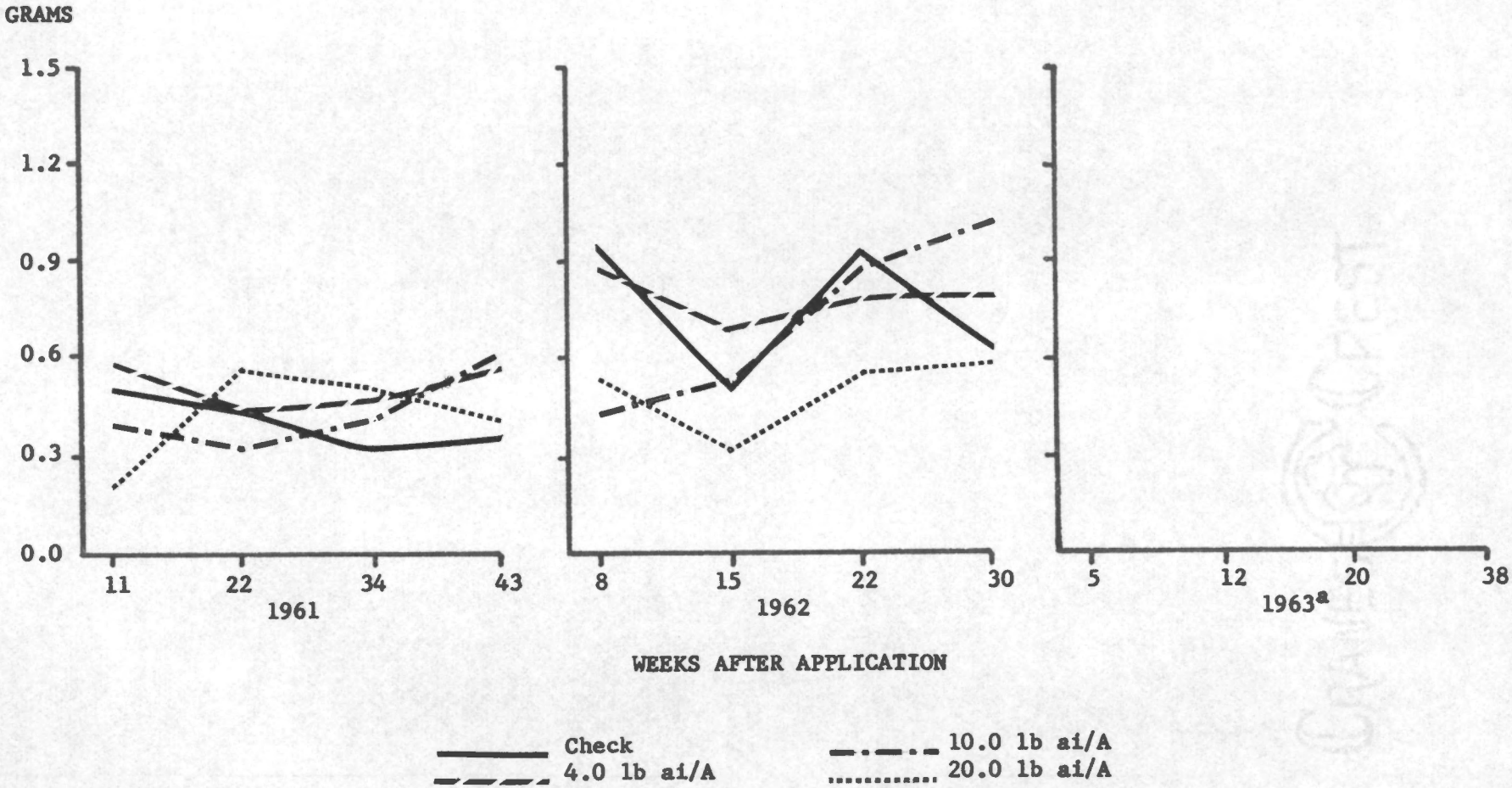
DCPA

Bioassays at Knoxville indicated persistence of DCPA to be greatest in 1961 (Figures 15 and 16). At Jackson where only 2 years of data are shown, persistence appeared slightly greater in 1962. This was probably due to less rainfall during the 1962 growing season at Jackson (Table XIV, Appendix B). No appreciable persistence of the 1X rate of application was detected. Weed control ratings at Knoxville in 1963 indicated a decline in effectiveness between 5 and 12 weeks after application. Poor control by the 1X rate was shown in 1962 after 15 and 22 weeks at Knoxville and Jackson respectively (Tables II and III, Appendix A). Ratings of injury to oats in the field showed injury at Knoxville only once (Table IV, Appendix A). This was at the 5X rate in 1963. At Jackson significant injury occurred after the 1961 application of the 5X rate. Injury in 1963 followed an accidental application of fifteen times the desired rates. This mistake had not been detected when an abstract of the results was published in January, 1964 (30). No injury to corn was attributed to DCPA (Tables V and VI, Appendix A). Evidently, no accumulation occurred.



[a]Data for this date are based upon observations rather than actual weights.

Figure 15. Fresh weights of oat seedlings from bioassays following three annual applications of DCPA at three rates on Cumberland loam at Knoxville.



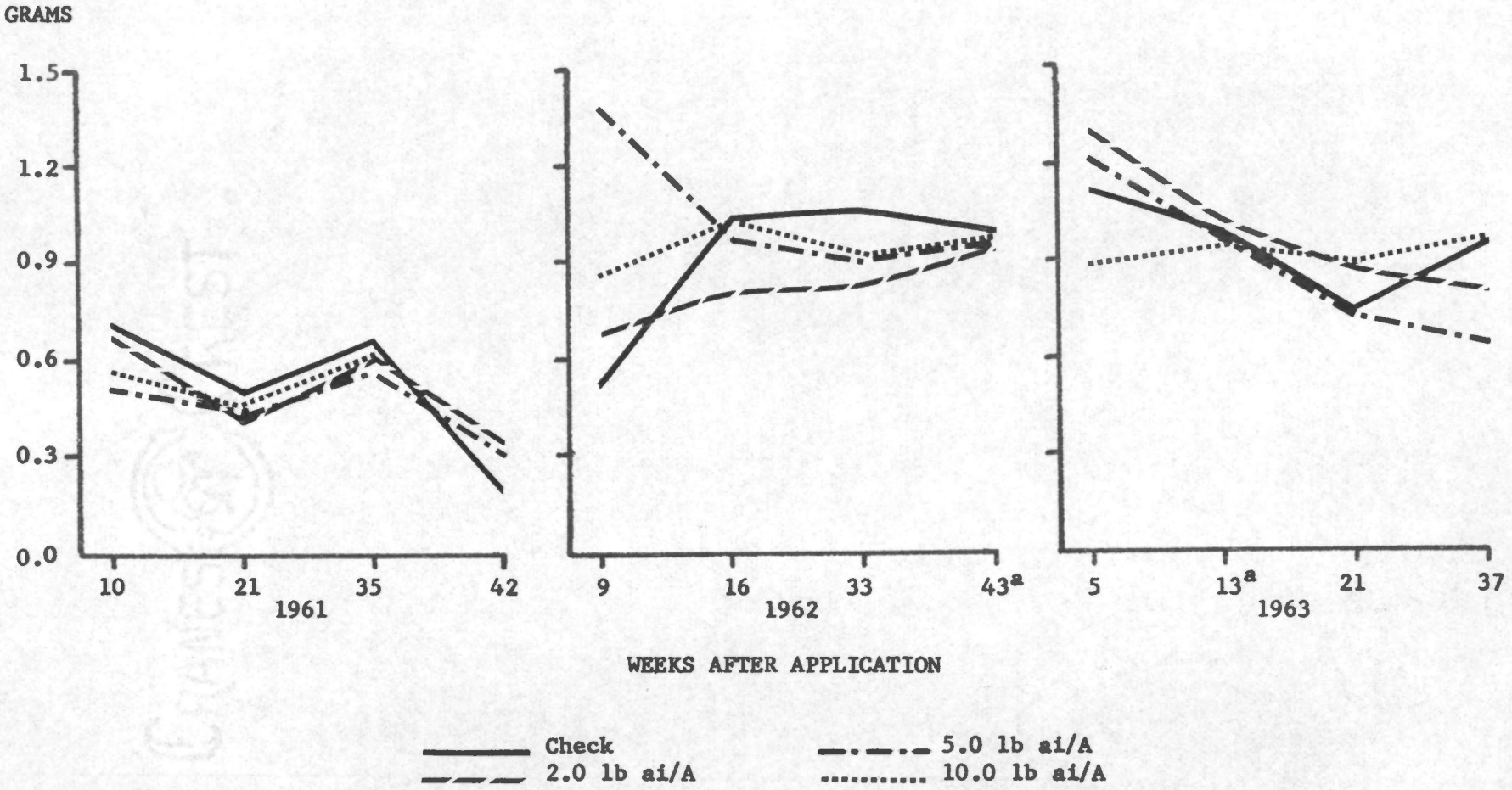
[a]Data for 1963 are not shown because of an incorrect rate of application.

Figure 16. Fresh weights of oat seedlings from bioassays following three annual applications of DCPA at three rates on Collins silt loam at Jackson.

Amiben

Little or no persistence of amiben was detected with bioassays (Figures 17 and 18). Only at 5 weeks after application of the 5X rate at Knoxville in 1963 was evidence of possible toxicity indicated. Some decrease in weed control at Knoxville and virtually complete loss of activity at Jackson between 5 and 12 weeks after application in 1963 indicated a rapid disappearance of amiben (Tables II and III, Appendix A). Poor weed control was also displayed by the 1X rate in 1962. The common morningglory was a severe problem on amiben plots at Knoxville in 1963, while crabgrass was serious at Jackson. No injury to oats in the field following amiben treatments was detected (Table IV, Appendix A). The high rates of amiben may have caused some injury to corn; however, the corn injury ratings may include some effects of poor weed control (Tables V and VI, Appendix A).

Persistence of amiben has been described as short like 2,4-D (4). Results of this study support that comparison. Like 2,4-D, there was no evidence that amiben accumulated in the soil.



[a]Data for this date are based upon observations rather than actual weights.

Figure 17. Fresh weights of oat seedlings from bioassays following three annual applications of amiben at three rates on Cumberland loam at Knoxville.

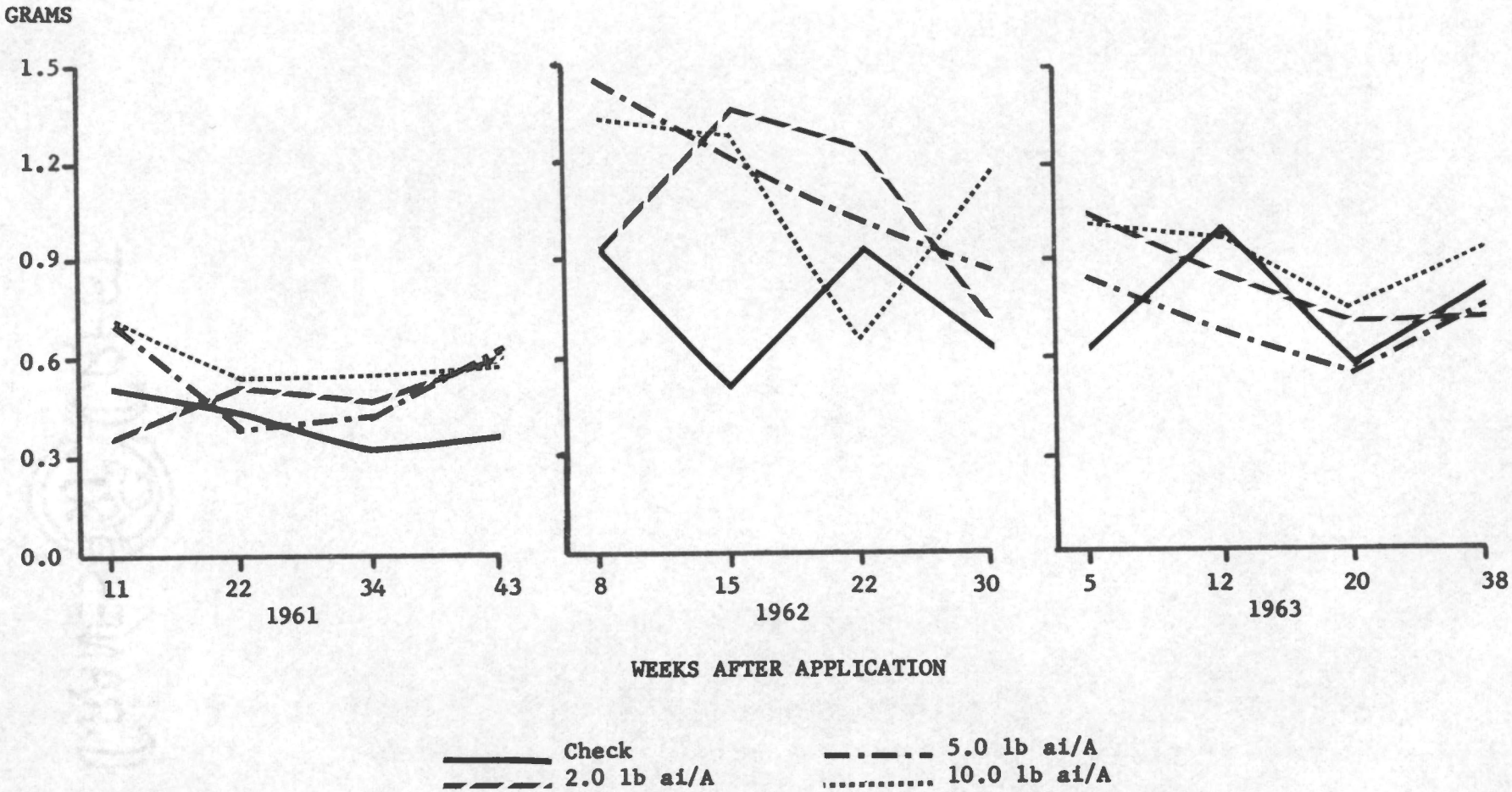


Figure 18. Fresh weights of oat seedlings from bioassays following three annual applications of amiben at three rates on Collins silt loam at Jackson.

CHAPTER V

SUMMARY AND CONCLUSIONS

In order to study the persistence of several preemergence herbicides under field conditions, plots were established in 1961 on the Main Experiment Station at Knoxville and on the West Tennessee Experiment Station at Jackson. Treatments of 1, 2.5, and 5 times the recommended rates of application were replicated three times on Cumberland loam at Knoxville and Collins silt loam at Jackson (Table I, page 23). The plots were treated for 3 successive years.

Oats and cucumbers were used for bioassays conducted periodically with soil samples from the plots. Fresh weights of the seedlings were recorded 4 weeks after planting. Results of the bioassays were supplemented by ratings of weed control and corn injury during the summer and injury to oats seeded in the fall and spring whenever possible.

Results showed simazine, atrazine, and diuron to be the only materials of appreciable persistence. Bioassays indicated that toxicity from the 1X rate of application of simazine and atrazine generally disappeared within 20 weeks. No significant injury from the 1X rate occurred to fall-seeded oats. The 5X rate of the two materials often persisted throughout the sampling period. Little or no residual toxicity from the 1X rate of diuron was detected. Fall-seeded oats were injured only by the 5X rate of application at Knoxville.

The study indicated that simazine, atrazine, and diuron at

very high rates of application could persist throughout a year; and that accumulation of simazine and atrazine might be possible. The evidence lends support to the hypothesis by Burnside et al. (6) that such materials which are slowly decomposed might accumulate at lower levels in the soil where decomposition is slow. However, little danger of residual toxicity or accumulation appeared with the recommended rates of application.

LITERATURE CITED

LITERATURE CITED

1. Alexander, M. and Aleem, M. I. H. Effect of chemical structure on microbial decomposition of aromatic herbicides. Jour. Agr. Food Chem. 9:44-47. 1961.

2. Ashton, Floyd M. and Sheets, T. J. The relationship of soil adsorption of EPTC to oats injury in various soil types. Weeds 7 (1):88-90. 1959.

3. Audus, L. J. The decomposition of 2,4-D and 2-methyl-4-chlorophenoxyacetic acid in the soil. Jour. Sci. Food Agr. 3:268-274. 1959.

4. Behrens, Richard. Soil residues from herbicides. Agr. Chem. 17 (7):34+. 1962.

5. Burnside, O. C. and Behrens, R. Phytotoxicity of simazine. Weeds 9 (1):145-157. 1961.

6. _____, Fenster, C. R., and Wicks, G. A. Dissipation and leaching of monuron, simazine, and atrazine in Nebraska soils. Weeds 11 (3):209-213. 1963.

7. _____, Schmidt, E. L., and Behrens, R. Dissipation of simazine from the soil. Weeds 9 (3):477-484. 1961.

8. Burschel, Peter and Freed, V. H. The decomposition of herbicides in soils. Weeds 7 (2):157-161. 1959.

9. Davis, D. E. Some factors that affect the phytotoxicity of water-soluble DNBP. Weeds 3 (4):227-234. 1956.

10. DeRose, H. Robert and Newman, Arthur S. The comparison of the persistence of certain plant growth regulators when applied to the soil. Soil Sci. Soc. Amer. Proc. 12:222-226. 1947.

11. Dowler, Clyde, Baughman, N. M., and Veatch, Collins. The effect of soil type, soil pH, and simulated rainfall on the distribution of DNBP in the soil. Weeds 6 (3):281-288. 1958.

12. Feight, J. J. and Slife, Fred. You can whip residue problems. Hoard's Dairyman 108 (8):503. April 25, 1963.

13. Fink, Rodney J. and Fletchall, O. Hale. Forage crop establishment in soil containing atrazine and simazine residues. Weeds 11 (2):81-83. 1963.

14. Foy, Chester L. Volatility and tracer studies with alkylamino-s-triazines. Weeds 12 (2):103-108. 1964.

15. Frissel, M. J. and Bolt, G. H. Interaction between certain ionizable organic compounds (herbicides) and clay minerals. Soil Sci. 94:284-291. 1962.

16. Gantz, R. L. and Slife, F. W. Persistence and movement of CDAA and CDEC in soil and the tolerance of corn seedlings to these herbicides. Weeds 8 (4):599-606. 1960.

17. Gast, A. Contributions to the knowledge of the behavior of triazines in soil. Paper read at the XIV Annual Symposium for Crop Protection, Gent, Belgium. May, 1962.

18. Glasstone, Samuel. Textbook of Physical Chemistry. D. Van Nostrand Company, Inc. New York, Toronto, and London, Ed. 2, 1320 pp. 1946.

19. Gramlich, J. V., Couch, R. W., Sikka, H. C., Davis, D. E., and Funderburk, H. H., Jr. Preliminary report on atrazine metabolism by microorganisms. Proc. SWC 17:356. 1964.

20. Gysin, H. Triazine herbicides; their chemistry, biological properties and mode of action. Geigy Industrial Chemicals, Technica 5:17-28. Nov., 1963.

21. Hamilton, Robert H. and Moreland, Donald E. Simazine: degradation by corn seedlings. Sci. 135 (3501):373-374. 1962.

22. Hanks, Robert W. Removal of 2,4-dichlorophenoxyacetic acid and its calcium salt from six different soils by leaching. Bot. Gaz. 108:186-191. 1946.

23. Harris, C. I. and Warren, G. F. Adsorption and desorption of herbicides by soil. Weeds 12 (2):120-126. 1964.

24. Harris, Vernon C. Weed control in cotton over a ten-year period by the use of more promising materials and techniques. Proc. SWC 13:31. 1960.

25. Hill, G. D. and McGahen, J. W. Further studies on soil relationships of the substituted urea herbicides for pre-emergence weed control. Proc. SWC 8:284-293. 1955.

26. _____, _____, Baker, H. M., Finnerty, D. W., and Bingeman, C. W. The fate of substituted urea herbicides in agricultural soils. Agron. Jour. 47:93-104. 1955.

27. Hilton, H. Wayne and Yuen, Quan H. Adsorption of several pre-emergence herbicides by Hawaiian sugar cane soils. Agr. Food Chem. 11:230-234. 1963.

28. Hollingsworth, Everett B. Cotton response to two substituted ureas and CIPC and their persistence and movement in soil. Proc. SWC 8:294-304. 1955.

29. Holstun, J. T., Jr. and Loomis, W. E. Leaching and decomposition of 2,2-dichloropropionic acid in several Iowa soils. Weeds 3 (4): 205-217. 1956.

30. Jones, Larry B. and Andrews, Henry. Effect of rate of application upon the persistence in the soil of several preemergence herbicides. Proc. SWC 17:374-376. 1964.

31. Jordan, L. S., Day, B. E., and Clerx, W. A. Photodecomposition of triazines. Weeds 12 (1):5-6. 1964.

32. Kearney, P. C., Sheets, T. J., and Smith, J. W. Volatility of seven s-triazines. Weeds 12 (2):83-87. 1964.

33. Klingman, Glenn C. Weed Control as a Science. John Wiley and Sons, Inc. New York and London, 421 pp. 1961.

34. Kries, Olive H. Persistence of 2,4-dichlorophenoxyacetic acid in soil in relation to content of water, organic matter, and lime. Bot. Gaz. 108:510-525. 1947.

35. Leopold, A. C., van Schaik, P., and Neal, Mary. Molecular structure and herbicide adsorption. Weeds 8 (1):48-54. 1960.

36. Lillie, D. T. and Aldrich, R. J. Monuron does not build up in the soil, study reveals. New Jersey Agr. Exp. Sta., New Jersey Agriculture 38 (4):10-12. 1956.

37. Martin, James P. Influence of pesticide residues on soil microbiological and chemical properties. Residue Review 4:96-129. 1963.

38. Newman, Arthur S., DeRose, Robert H. and DeRigo, Herbert T. Persistence of isopropyl-N-phenyl carbamate in soils. Soil Sci. 66:393-397. 1948.

39. _____ and Downing, C. R. Herbicides and the soil. Jour. Agr. Food Chem. 6 (5):352-353. 1958.

40. Ogle, R. E. and Warren, G. F. Fate and activity of herbicides in soils. Weeds 3 (4):257-273. 1954.

41. Rahn, E. M. and Baynard, Robert E., Jr. Persistence of monuron in asparagus soils. Weeds 6 (4):432-440. 1958.

42. Rauser, Wilfred E. and Switzer, Clayton M. Effects of leaching on the persistence of amiben toxicity in various soils. Amchem Products, Inc., The Hormolog 4 (1):13-14. 1963.

43. _____ and _____. Factors contributing to the loss of amiben phytotoxicity in soils. Weeds 10 (1):62-64. 1962.

44. Reid, James J. Soil organisms destroy herbicides. Pennsylvania Agr. Exp. Sta., Sci. for the Farmer 10 (4):14. 1963.

45. Richards, R. F. Field studies of the residual effects of several herbicides. Proc. SWC 8:154-157. 1956.

46. _____. Simazine and related triazines - a progress report. Proc. SWC 11:86-89. 1958.

47. Rodgers, E. G. Leaching characteristics of certain herbicides in selected soils. Contribution to Regional Project S-18. Jl. 1963.

48. _____. Leaching of four triazines in three soils as influenced by varying frequencies and rates of simulated rainfall. Proc. SWC 15:268. 1962.

49. Scudder, W. T. Persistence of simazine residues in two central Florida soils. Proc. SWC 12:187. 1959.

50. Sheets, T. J. Persistence of herbicides in soils. Proc. WWCC 19:37-42. 1962.

51. _____. Photochemical alteration and inactivation of amiben. Weeds 11 (3):186-190. 1963.

52. _____. Review of disappearance of substituted urea herbicides from soil. Agr. Food Chem. 12 (1):30-33. 1964.

53. _____. The comparative toxicities of four phenylurea herbicides in several soil types. Weeds 6 (4):413-424. 1958.

54. _____ and Crafts, A. S. The phytotoxicity of four phenylurea herbicides in soil. Weeds 5 (2):93-101. 1957.

55. _____ and Danielson, L. L. Herbicides in soils. ARS 20-9:170-181. 1960.

56. Sigler, William V., Jr. Residual effects of soil sterilants. Masters thesis. The University of Tennessee. 68 pp. 1960.

57. Splittstoesser, Walter E. and Derscheid, Lyle A. Effects of environment upon herbicides applied preemergence. Weeds 10 (4):304-307. 1962.

58. Sweet, R. D., Feddema, Leonard, Crabtree, Garvin, and Baker, Donald. Longevity of several herbicides in soils. Proc. NEWCC 12:17-24. 1958.

59. Switzer, Clayton M. and Rauser, Wilfried E. Effectiveness and persistence of certain herbicides in soil. Proc. NEWCC 14:329-335. 1960.

60. Talbert, Ronald E. and Fletchall, O. Hale. Inactivation of simazine and atrazine in the field. Weeds 12 (1):33-37. 1964.

61. _____ and _____. The adsorption of some triazine herbicides in soils. Proc. SWC 17:373. 1964.

62. Thiegs, B. J. Microbial decomposition of herbicides. The Dow Chemical Company, Down to Earth. 18 (2):7-10. 1962.

63. Upchurch, R. P. and Mason, D. D. The influence of soil organic matter on the phytotoxicity of herbicides. Weeds 10 (1): 9-14. 1962.

64. _____ and Pierce, W. C. The leaching of monuron from Lakeland sand soil. Part I. The effect of soil temperature, organic matter, soil moisture, and amounts of herbicide. Weeds 6 (1):24-33. 1958.

65. Warren, G. F. Adsorption of amiben in soils. Amchem Products, Inc., The Hormolog 4 (1):15-16. 1963.

66. _____. Rate of leaching and breakdown of several herbicides in different soils. Proc. NCWCC 11:5. 1954.

67. _____. The relative adsorption of several herbicides by widely differing soils. Proc. NCWCC 13:5. 1956.

68. Weldon, L. W. and Timmons, F. L. Penetration and persistence of diuron in soil. Weeds 9 (2):195-203. 1961.

69. _____ and _____. Photochemical degradation of diuron and monuron. Weeds 9 (1):111-116. 1961.

70. Whiteside, Jean S. and Alexander, M. Measurement of microbiological effects of herbicides. Weeds 8 (2):204-213. 1960.

APPENDIXES

APPENDIX A

FIELD RATINGS AND BIOASSAY WEIGHTS

TABLE II

AVERAGE WEED CONTROL RATINGS AT KNOXVILLE FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES: 0 = NO CONTROL; 10 = COMPLETE CONTROL

		Weeks After Application							
		1961		1962		1963			
	Rate ai-ae	14		15		5		12	
Herbicide	lb/A	Grass	Bdlv	Grass	Bdlv	Grass	Bdlv	Grass	Bdlv
Check	---	0.3	8.7	0.0	5.3	1.3	3.7	0.0	1.0
2,4-D,	1.5	8.7	8.0	5.0	3.3	5.0	6.8	0.7	3.7
PGBE	3.75	9.3	9.0	4.3	7.3	6.0	6.3	0.7	2.7
Esters	7.5	9.7	9.0	4.3	6.0	6.0	6.7	2.0	3.7
2,4-D, Alk-	1.5	9.3	8.7	4.0	2.0	5.0	5.7	0.0	1.0
anolamine	3.75	9.7	9.7	6.3	6.0	6.0	7.0	1.0	4.3
Salts	7.5	10.0	10.0	6.0	6.3	6.3	8.0	0.7	6.0
Diuron	1.0	8.3	8.0	3.7	3.3	8.0	7.7	6.0	3.7
	2.5	9.3	8.7	7.0	3.3	9.3	9.0	8.3	6.0
	5.0	10.0	9.3	9.0	8.3	9.7	8.7	10.0	7.3
Simazine	2.0	10.0	9.3	6.3	7.0	9.0	8.0	7.7	5.3
	5.0	10.0	9.7	9.0	9.0	10.0	9.7	9.7	9.0
	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Atrazine	2.0	9.3	9.0	5.3	5.7	9.3	8.7	7.7	6.3
	5.0	10.0	10.0	8.7	10.0	10.0	10.0	10.0	10.0
	10.0	10.0	10.0	10.0	10.0	10.0	9.3	10.0	10.0
DNBP	6.0	2.0	9.7	0.0	9.7	6.0	9.3	1.7	8.0
	15.0	8.3	10.0	4.7	5.3	8.3	9.3	5.3	7.7
	30.0	9.7	10.0	7.7	10.0	9.7	10.0	8.0	10.0
DCPA	4.0	9.0	8.7	3.3	0.0	7.0	5.3	5.7	0.0
	10.0	9.3	9.3	8.7	6.7	8.0	8.3	7.0	5.7
	20.0	10.0	10.0	10.0	9.3	8.7	8.3	9.7	6.7
Amiben	2.0	7.7	9.3	3.3	6.3	8.0	4.7	6.3	2.0
	5.0	9.3	10.0	7.3	2.3	9.0	4.0	8.0	0.0
	10.0	9.7	9.7	10.0	2.7	9.7	6.3	10.0	1.7

TABLE III

AVERAGE WEED CONTROL RATINGS AT JACKSON FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES: 0 = NO CONTROL; 10 = COMPLETE CONTROL

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961 16 Grass	1961 16 Bdlv	1962 22 Grass	1962 22 Bdlv	1963 5 Grass	1963 5 Bdlv	1963 12 Grass	1963 12 Bdlv
Check	---	8.3	10.0	0.0	9.3	0.0	6.3	0.0	6.0
2,4-D,	1.5	9.3	10.0	1.3	7.7	0.0	8.7	0.0	5.3
PGBE	3.75	9.7	9.7	1.7	8.7	0.0	5.3	0.0	5.7
Esters	7.5	9.3	10.0	1.3	9.3	0.7	6.7	0.0	7.7
2,4-D, Alk-	1.5	9.2	10.0	0.0	8.7	0.0	7.7	0.0	7.7
anolamine	3.75	9.7	10.0	0.3	9.3	0.7	7.3	0.0	7.7
Salts	7.5	9.2	10.0	0.7	9.7	0.0	8.0	0.0	9.0
Diuron	1.0	10.0	10.0	7.7	9.3	6.3	8.3	0.7	7.0
	2.5	10.0	10.0	9.7	9.7	8.7	10.0	6.7	8.7
	5.0	10.0	10.0	10.0	10.0	9.3	10.0	9.3	10.0
Simazine	2.0	10.0	9.7	8.3	9.0	8.0	10.0	7.0	9.7
	5.0	10.0	10.0	7.0	10.0	8.7	10.0	9.3	10.0
	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Atrazine	2.0	10.0	10.0	8.3	9.0	7.0	10.0	5.0	10.0
	5.0	10.0	10.0	9.3	9.0	8.0	10.0	7.3	10.0
	10.0	10.0	10.0	9.7	9.0	9.0	9.3	8.7	10.0
DNBP	6.0	10.0	10.0	0.7	9.7	1.3	7.0	0.0	6.0
	15.0	10.0	10.0	3.7	9.7	2.6	8.3	0.0	7.0
	30.0	10.0	10.0	5.7	9.3	5.0	9.7	0.0	8.7
DCPA	4.0	9.5	10.0	5.3	8.3	8.7	9.7	8.7	8.0
	10.0	8.7	10.0	3.7	6.3	9.0	9.3	9.0	8.7
	20.0	8.7	10.0	6.0	8.3	9.7	9.0	9.0	7.7
Amiben	2.0	9.0	10.0	1.3	3.3	0.7	7.7	0.0	5.3
	5.0	9.5	10.0	6.3	4.7	4.7	4.0	0.0	2.0
	10.0	10.0	10.0	8.3	7.3	5.7	6.3	0.7	3.3

TABLE IV

AVERAGE OAT INJURY RATINGS AT KNOXVILLE AND JACKSON FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES: 0 = NO INJURY; 10 = COMPLETE KILL

		Knoxville				Jackson			
		Year of Application							
		1961	1962		1963	1961		1962	1963
		Spring seeded	Fall seeded	Spring seeded	Fall seeded	Fall seeded	Spring seeded	Fall seeded	Fall seeded
	Rate ai-ae	Date of Rating							
Herbicide	lb/A	5/3/62	1/8/63	5/4/63	1/31/64	3/23/62	4/19/62	12/18/62	3/17/64
Check	---	1.3	0.0	2.3	0.0	0.0	0.7	0.0	0.0
2,4-D,	1.5	1.0	0.0	1.0	0.0	0.3	0.0	0.3	0.0
PGBE	3.75	0.3	0.0	0.7	0.0	0.0	0.0	0.7	0.0
Esters	7.5	1.0	0.0	0.7	0.3	0.0	0.3	0.3	0.0
2,4-D, Alk-	1.5	1.0	0.0	0.3	0.3	0.3	0.3	0.0	0.7
anolamine	3.75	1.0	0.0	0.0	0.0	0.3	0.3	0.7	0.0
Salts	7.5	0.7	0.0	1.0	0.0	0.0	1.3	0.7	0.0
Diuron	1.0	0.3	0.0	1.7	0.0	0.0	1.0	0.0	0.0
	2.5	1.0	0.0	1.0	0.7	0.3	1.3	1.3	0.0
	5.0	3.7	1.3	7.7	4.0	0.0	0.0	0.0	0.0
Simazine	2.0	0.7	1.3	0.0	0.0	0.3	0.7	0.7	0.3
	5.0	1.0	0.0	2.3	1.3	3.0	1.7	0.7	1.0
	10.0	7.7	4.7	8.7	8.0	9.7	8.7	6.7	4.0

TABLE IV (continued)

		Knoxville				Jackson			
		Year of Application							
		1961	1962		1963	1961		1962	1963
		Spring seeded	Fall seeded	Spring seeded	Fall seeded	Fall seeded	Spring seeded	Fall seeded	Fall seeded
	Rate ai-ae	Date of Rating							
Herbicide	lb/A	5/3/62	1/8/63	5/4/63	1/31/64	3/23/62	4/19/62	12/18/62	3/17/64
Atrazine	2.0	1.0	0.0	2.0	1.7	0.0	0.3	0.0	0.7
	5.0	3.7	2.3	4.7	4.0	0.0	1.3	0.0	2.5
	10.0	3.3	3.0	6.7	6.0	2.0	0.3	2.7	5.7
DNBP	6.0	0.3	0.0	0.0	0.0	0.0	0.3	0.7	0.0
	15.0	0.7	0.0	0.3	0.0	0.7	0.7	1.3	0.0
	30.0	0.3	0.7	4.7	0.3	1.0	0.0	0.0	1.0
DCPA	4.0	0.3	0.7	1.7	0.0	1.0	1.3	0.7	3.7
	10.0	0.3	0.0	0.0	0.0	1.7	1.3	0.3	5.7
	20.0	1.0	1.0	0.3	6.0	4.7	3.0	0.3	9.7
Amiben	2.0	0.0	1.0	0.0	0.0	0.7	0.0	0.0	0.0
	5.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.0	0.7	0.0	0.0	0.0	0.0	0.0	1.3	0.0

TABLE V

AVERAGE CORN INJURY RATINGS AT KNOXVILLE FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES: 0 = NO INJURY; 10 = COMPLETE KILL

		Weeks After Application				
	Rate ai-ae	1961	1962	1963		
Herbicide	lb/A	14	15	5	12	20
Check	---	6.3	2.0	2.0	5.7	4.0
2,4-D,	1.5	1.0	2.7	2.7	4.0	1.7
PGBE	3.75	2.7	4.7	3.3	2.0	1.0
Esters	7.5	3.7	6.0	3.3	2.0	0.7
2,4-D, Alk-	1.5	2.3	2.3	2.0	4.3	1.3
anolamine	3.75	2.7	4.7	3.3	3.3	0.0
Salts	7.5	2.3	7.3	4.3	5.3	0.7
Diuron	1.0	3.0	5.3	3.3	2.3	0.0
	2.5	2.7	4.3	6.0	5.0	0.0
	5.0	7.0	6.7	8.3	8.3	6.3
Simazine	2.0	2.3	2.7	2.3	2.0	0.0
	5.0	4.7	2.3	2.3	1.7	0.0
	10.0	4.0	1.7	2.3	1.0	0.0
Atrazine	2.0	1.0	3.3	1.3	1.7	0.0
	5.0	1.7	2.7	2.0	2.0	0.0
	10.0	1.7	3.7	4.0	3.0	0.0
DNBP	6.0	3.7	3.0	4.3	4.0	2.0
	15.0	3.7	6.0	4.0	4.3	1.0
	30.0	5.0	6.7	8.0	7.3	4.3
DCPA	4.0	3.0	2.7	2.7	1.7	0.0
	10.0	0.7	2.7	2.3	2.3	0.0
	20.0	2.3	2.7	2.3	1.7	0.0
Amiben	2.0	3.0	4.3	2.0	3.0	1.0
	5.0	2.3	4.7	5.0	1.7	1.0
	10.0	2.7	6.7	6.0	4.3	1.7

TABLE VI

AVERAGE CORN INJURY RATINGS AT JACKSON FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES: 0 = NO INJURY; 10 = COMPLETE KILL

Herbicide	Rate ai-ae lb/A	Weeks After Application 1961 16	1962 22	1963 5	1963 12	1963 18
Check	---	0.3	1.7	0.3	5.0	5.0
2,4-D,	1.5	1.0	2.0	2.7	5.7	4.3
PGBE	3.75	1.3	3.0	1.3	4.0	3.3
Esters	7.5	2.3	2.0	2.7	5.3	4.3
2,4-D, Alk-	1.5	0.7	1.3	1.7	5.0	4.0
anolamine	3.75	2.3	3.3	0.3	4.7	3.3
Salts	7.5	1.3	3.3	2.7	6.3	5.3
Diuron	1.0	0.7	1.0	3.3	2.7	1.3
	2.5	4.0	3.0	8.7	7.7	8.3
	5.0	8.3	7.3	9.7	9.3	9.7
Simazine	2.0	0.0	1.3	0.0	0.0	0.0
	5.0	1.0	3.3	2.7	1.0	1.0
	10.0	1.3	0.0	5.0	1.7	1.0
Atrazine	2.0	0.0	1.7	0.0	0.7	0.7
	5.0	1.7	2.3	0.0	0.7	0.0
	10.0	1.0	2.3	2.7	0.0	0.7
DNBP	6.0	0.7	3.7	4.7	7.0	6.7
	15.0	2.7	5.7	5.0	5.3	5.0
	30.0	7.7	7.7	7.7	7.7	7.3
DCPA	4.0	0.0	1.3	0.0	0.7	0.0
	10.0	0.3	2.0	1.0	2.0	1.0
	20.0	0.7	2.0	0.7	2.0	3.0
Amiben	2.0	1.7	2.3	1.7	5.0	4.3
	5.0	1.0	3.7	3.0	4.0	3.3
	10.0	3.7	5.7	4.3	4.0	4.0

TABLE VII

AVERAGE FRESH WEIGHTS IN GRAMS OF OAT SEEDLINGS FROM BIOASSAYS FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES AT KNOXVILLE

Herbicide	Rate ai-ae lb/A	Weeks After Application 1961 10	1961 21	1961 35	1961 42	1962 9	1962 16	1962 33	1962 43[a]	1963 5	1963 13[a]	1963 21	1963 37
Check	---	0.71	0.50	0.66	0.19	0.53	1.04	1.06	100	1.12	100	0.75	0.96
2,4-D,	1.5	0.62	0.47	0.56	0.41	0.75	1.10	1.27	100	0.56	100	0.83	0.93
PGBE	3.75	0.87	0.53	0.49	0.41	0.62	1.15	1.14	100	1.21	100	0.99	0.92
Esters	7.5	0.78	0.43	0.53	0.37	0.41	1.21	1.20	100	0.87	100	0.69	0.88
2,4-D, Alk-	1.5	0.51	0.51	0.60	0.41	0.88	1.15	0.86	100	1.21	100	0.84	0.69
anolamine	3.75	0.69	0.50	1.70	0.36	1.41	1.20	0.96	100	1.43	100	0.81	0.97
Salts	7.5	0.71	0.50	0.70	0.38	0.93	1.26	0.88	100	1.34	100	0.81	0.74
Diuron	1.0	0.61	0.56	0.57	0.43	0.61	1.05	1.09	100	0.90	100	0.87	1.01
	2.5	0.50	0.43	0.70	0.06	0.43	0.71	0.96	100	0.23	50	0.69	0.90
	5.0	0.00	0.13	0.48	0.00	0.00	0.74	0.57	90	0.00	33	0.74	0.86
Simazine	2.0	0.39	0.37	0.60	0.35	0.46	1.08	0.96	100	0.87	100	0.92	0.85
	5.0	0.00	0.17	0.50	0.07	0.09	0.95	0.92	100	0.00	100	0.62	0.93
	10.0	0.00	0.07	0.07	0.04	0.00	0.70	0.46	90	0.00	13	0.27	0.38

TABLE VII (continued)

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961 10	1961 21	1961 35	1961 42	1962 9	1962 16	1962 33	1962 43[a]	1963 5	1963 13[a]	1963 21	1963 37
Atrazine	2.0	0.20	0.51	0.55	0.25	0.57	0.76	1.05	90	0.40	50	0.93	0.70
	5.0	0.00	0.21	0.27	0.16	0.00	0.62	0.56	67	0.00	50	0.61	0.69
	10.0	0.00	0.24	0.32	0.02	0.00	0.65	0.58	67	0.00	13	0.52	0.62
DNBP	6.0	0.68	0.41	0.76	0.23	0.41	1.33	0.81	100	1.11	100	0.88	0.78
	15.0	0.80	0.63	0.64	0.15	0.89	1.04	0.83	100	1.37	100	0.98	0.60
	30.0	0.54	0.52	0.57	0.45	0.68	0.70	0.83	100	1.02	100	0.99	0.75
DCPA	4.0	0.72	0.43	0.62	0.40	1.09	1.28	0.86	100	0.78	100	0.90	0.62
	10.0	0.52	0.37	0.43	0.43	0.89	0.90	0.86	100	0.91	100	1.23	0.74
	20.0	0.19	0.31	0.37	0.26	0.69	0.62	1.13	100	0.94	90	0.86	0.92
Amiben	2.0	0.66	0.42	0.61	0.34	0.98	1.11	1.12	100	1.31	100	0.87	0.81
	5.0	0.52	0.43	0.57	0.33	1.38	0.98	0.90	100	1.22	100	0.74	0.65
	10.0	0.56	0.46	0.61	0.52	0.86	1.04	0.94	100	0.89	100	0.90	0.98

[a]Visual ratings expressed as percentages of the untreated check.

TABLE VIII

AVERAGE FRESH WEIGHTS IN GRAMS OF OAT SEEDLINGS FROM BIOASSAYS FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES AT JACKSON

Herbicide	Rate ai-ae lb/A	Weeks After Application 1961 11	1961 22	1961 34	1961 43	1962 8	1962 15	1962 22	1962 30	1963 5	1963 12	1963 20	1963 38
Check	---	0.50	0.44	0.32	0.36	0.93	0.50	0.93	0.63	0.61	0.99	0.56	0.80
2,4-D,	1.5	0.54	0.58	0.47	0.58	1.09	0.94	1.00	0.81	0.78	1.08	0.73	0.77
PGBE	3.75	0.73	0.46	0.55	0.53	0.85	0.95	1.10	1.22	0.88	0.79	0.65	0.45
Esters	7.5	0.86	0.40	0.42	0.40	1.28	0.53	1.23	0.78	0.83	0.90	0.53	0.67
2,4-D, Alk-	1.5	0.40	0.42	0.46	0.40	1.06	0.42	0.89	0.97	0.80	0.96	0.61	0.59
anolamine	3.75	0.51	0.54	0.35	0.45	1.26	0.69	0.98	0.82	0.85	0.73	0.63	0.76
Salts	7.5	0.40	0.43	0.45	0.55	0.85	0.80	1.06	0.78	0.78	0.92	0.66	0.84
Diuron	1.0	0.57	0.48	0.33	0.41	1.24	0.24	0.69	0.75	0.71	0.87	0.59	0.54
	2.5	0.25	0.46	0.44	0.36	0.05	0.29	0.35	1.01	0.04	0.31	0.62	0.65
	5.0	0.00	0.30	0.12	0.21	0.00	0.00	0.12	0.87	0.11	0.11	0.20	0.13
Simazine	2.0	0.31	0.49	0.35	0.35	0.09	0.32	0.95	0.93	0.10	0.73	0.71	0.67
	5.0	0.03	0.44	0.44	0.25	0.01	0.00	0.66	0.64	0.25	0.34	0.59	0.60
	10.0	0.02	0.27	0.15	0.11	0.00	0.13	0.02	0.19	0.04	0.07	0.30	0.63

TABLE VIII (continued)

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961 11	1961 22	1961 34	1961 43	1962 8	1962 15	1962 22	1962 30	1963 5	1963 12	1963 20	1963 38
Atrazine	2.0	0.24	0.55	0.52	0.55	0.24	0.59	1.07	0.63	0.15	0.62	0.72	1.21
	5.0	0.06	0.18	0.28	0.48	0.00	0.28	1.00	0.95	0.12	0.23	0.52	0.48
	10.0	0.00	0.45	0.31	0.34	0.00	0.08	0.43	0.71	0.00	0.04	0.15	0.43
DNBP	6.0	0.59	0.51	0,50	0.50	1.29	1.08	0.97	0.78	0.71	0.93	0.49	0.84
	15.0	0.71	0.53	0.29	0.46	2.03	1.02	1.16	1.02	1.06	0.86	0.62	0.38
	30.0	0.52	0.66	0.40	0.51	1.19	0.75	1.30	1.15	0.71	0.80	0.64	0.76
DCPA	4.0	0.59	0.44	0.47	0.57	0.88	0.69	0.78	0.80	0.37	0.45	0.47	0.65
	10.0	0.40	0.32	0.40	0.61	0.43	0.88	0.88	1.01	0.17	0.39	0.45	0.24
	20.0	0.21	0.57	0.50	0.42	0.53	0.31	0.55	0.58	0.30	0.18	0.33	0.30
Amiben	2.0	0.36	0.50	0.47	0.60	0.93	1.37	1.25	0.70	1.05	0.84	0.69	0.71
	5.0	0.72	0.39	0.42	0.62	1.46	1.22	1.02	0.88	0.84	0.67	0.54	0.74
	10.0	0.71	0.53	0.55	0.58	1.33	1.28	0.66	1.16	1.00	0.97	0.74	0.92

TABLE IX

AVERAGE FRESH WEIGHTS IN GRAMS OF CUCUMBER SEEDLINGS FROM BIOASSAYS FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES AT KNOXVILLE

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961 10	1961 21	1961 35	1961 42	1962 9	1962 16	1962 33	1962 43[a]	1963 5	1963 13[a]	1963 21
Check	---	2.37	1.85	1.58	1.59	3.50	2.27	1.87	100	5.17	100	2.62
2,4-D,	1.5	1.87	2.05	2.09	2.21	1.98	1.77	2.21	100	5.20	100	2.37
PGBE	3.75	2.26	1.76	2.57	1.20	1.98	2.53	2.07	100	6.96	100	1.46
Esters	7.5	3.34	1.77	2.03	1.74	3.28	1.32	1.54	100	5.09	100	2.03
2,4-D, Alk-	1.5	1.92	1.42	1.40	2.04	4.31	1.12	2.70	100	5.71	100	2.28
anolamine	3.75	1.98	1.44	2.07	2.17	1.70	1.44	2.68	100	6.64	100	1.49
Salts	7.5	1.52	1.76	2.33	2.64	3.87	1.29	2.25	100	6.69	100	2.12
Diuron	1.0	2.47	1.81	2.24	1.79	3.58	2.28	1.77	100	3.61	100	2.84
	2.5	0.72	1.38	1.62	0.35	1.63	1.77	1.38	100	0.46	33	1.32
	5.0	0.00	0.12	1.22	0.00	0.00	1.07	0.92	90	0.00	33	1.32
Simazine	2.0	1.20	1.93	1.87	2.19	3.12	1.03	2.18	100	4.26	100	2.32
	5.0	0.00	1.01	1.33	0.78	0.88	2.15	1.78	100	0.00	100	2.30
	10.0	0.00	0.00	0.25	0.29	0.00	1.24	1.77	9	0.00	0	1.19

TABLE IX (continued)

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961 10	1961 21	1961 35	1961 42	1962 9	1962 16	1962 33	1962 43[a]	1963 5	1963 13[a]	1963 21
Atrazine	2.0	1.81	1.60	2.32	2.00	2.65	2.47	0.44	90	1.85	33	1.89
	5.0	0.00	1.51	0.48	1.27	0.00	2.00	1.69	67	0.00	0	1.68
	10.0	0.00	0.78	1.21	0.47	0.00	1.82	1.66	67	0.00	0	0.37
DNBP	6.0	1.79	1.81	1.70	2.18	2.42	1.31	2.01	100	6.05	100	2.72
	15.0	2.19	2.04	2.04	2.12	5.15	1.38	2.31	100	5.19	100	2.08
	30.0	1.34	1.93	1.94	1.46	1.35	1.18	1.91	100	5.19	100	1.98
DCPA	4.0	1.57	1.42	1.74	2.06	3.26	1.90	1.96	100	6.41	100	2.11
	10.0	1.80	1.48	1.99	2.46	4.35	2.70	1.49	100	3.75	100	1.72
	20.0	2.65	1.38	2.24	1.90	3.93	2.34	1.98	100	6.44	90	1.71
Amiben	2.0	1.68	2.31	2.25	1.89	3.82	1.36	2.17	100	5.67	100	2.30
	5.0	1.98	1.63	1.69	2.11	5.07	1.79	1.69	100	5.54	100	2.50
	10.0	1.65	2.14	1.37	2.19	3.72	1.69	1.63	100	5.10	100	1.83

[a]Visual ratings expressed as percentages of the untreated check.

TABLE X

AVERAGE FRESH WEIGHTS IN GRAMS OF CUCUMBER SEEDLINGS FROM BIOASSAYS FOLLOWING THREE ANNUAL APPLICATIONS OF HERBICIDES AT THREE RATES AT JACKSON

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961 11	1961 22	1961 34	1961 43	1962 8	1962 15	1962 22	1962 30	1963 5	1963 12	1963 20
Check	---	3.19	1.56	2.15	2.07	5.85	2.27	2.59	2.83	3.90	4.66	2.77
2,4-D,	1.5	3.31	2.19	1.85	2.62	5.81	0.90	2.61	2.06	4.05	3.10	2.51
PGBE	3.75	2.60	2.94	2.15	2.70	5.98	4.29	3.23	3.32	4.31	4.29	2.65
Esters	7.5	3.39	1.92	2.06	2.55	4.95	3.23	2.54	1.72	3.70	4.22	2.67
2,4-D, Alk-	1.5	2.81	0.70	1.67	2.41	8.42	3.20	1.93	2.09	4.32	4.44	3.14
anolamine	3.75	3.73	2.40	1.78	1.61	8.53	3.52	1.80	1.66	4.37	4.88	2.17
Salts	7.5	3.29	1.76	1.70	2.32	4.45	2.80	2.06	2.83	3.80	4.10	2.46
Diuron	1.0	1.82	2.62	1.93	2.65	5.97	1.08	1.89	1.88	2.55	4.66	2.61
	2.5	1.24	1.86	2.20	1.67	0.42	0.40	0.42	2.01	0.00	0.73	1.25
	5.0	0.00	0.72	0.78	1.06	0.00	0.00	0.15	1.89	0.00	0.00	0.81
Simazine	2.0	2.09	2.09	1.71	2.96	0.26	4.54	2.25	2.63	1.07	4.43	3.16
	5.0	0.14	1.97	2.30	2.49	0.00	0.00	1.31	1.59	1.58	3.14	2.14
	10.0	0.00	1.67	1.22	1.03	0.00	1.46	0.00	0.00	0.00	0.28	0.10

TABLE X (continued)

Herbicide	Rate ai-ae lb/A	Weeks After Application: 1961				1962				1963		
		11	22	34	43	8	15	22	30	5	12	20
Atrazine	2.0	1.94	2.51	2.36	2.61	2.37	4.39	2.79	3.44	0.00	3.35	2.38
	5.0	0.22	1.77	1.84	2.70	0.00	3.73	2.54	2.43	0.00	1.46	1.64
	10.0	0.00	2.44	1.97	2.19	0.00	0.00	1.92	0.79	0.00	0.00	0.33
DNBP	6.0	2.52	2.24	2.04	2.57	6.27	4.94	1.72	1.73	3.61	4.51	2.23
	15.0	4.64	2.94	1.76	2.37	8.26	4.72	1.98	1.51	4.45	4.40	2.94
	30.0	3.65	2.77	2.17	2.13	5.94	3.42	2.22	1.98	3.05	4.20	2.44
DCPA	4.0	2.81	2.36	1.51	2.47	5.43	5.70	2.09	2.17	4.04	4.54	2.93
	10.0	3.07	3.08	2.32	2.54	6.38	4.74	1.49	3.20	4.63	3.99	2.38
	20.0	2.37	2.58	2.47	2.56	6.94	3.68	3.56	3.17	5.00	2.87	2.92
Amiben	2.0	2.52	2.60	2.13	2.36	6.41	3.60	2.68	2.36	5.10	3.80	2.45
	5.0	2.33	2.29	2.32	2.03	8.63	4.74	3.07	1.48	3.73	4.92	2.22
	10.0	3.68	1.81	2.38	2.52	6.36	3.68	1.99	3.50	4.04	4.88	2.36

APPENDIX B

RAINFALL DATA

TABLE XI

RAINFALL DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT KNOXVILLE, 1961

	Jan.-Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.
1			0.09							
2			0.06					0.12	1.00	
3			0.12						0.90	
4							0.21			
5		0.07	0.36							
6		0.09	0.25		0.30					
7		0.97	0.03		0.10	0.05				
8		1.09			0.09	0.79	0.27			
9		1.06	0.08	0.99	0.80		0.17	0.03		
10				0.18	0.40		0.83			
11				0.15			1.18			
12			0.98	0.75		0.20				
13		0.04	0.12	0.10	0.95	0.36		0.07		
14					0.48			0.02	1.00	
15					0.22	0.70				
16			0.50	0.46	0.70	0.43		0.05		
17		0.12				0.71				
18				0.10		0.41				
19				0.47						
20		0.52				1.40				
21			0.21		0.48					
22					0.14					
23				0.12						
24		0.65				0.08	0.45			
25		0.60	0.21			0.25	0.28			
26				0.38	0.09					
27				0.11	0.08	0.08	0.84	0.36		
28										
29										
30										
31		0.90							0.78	
Total	6.91	6.11	3.01	3.81	4.83	5.46	4.23	0.65	3.68	9.94
1921-50 average	9.27	4.83	3.64	3.58	3.47	4.74	3.43	2.53	2.63	7.41

Annual total 48.63

1921-50 average 45.53

TABLE XII

RAINFALL DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT JACKSON, 1961

	Jan.-Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.
1			0.48	0.80			0.83	0.17	1.80	
2				0.02				0.56		
3			0.08			0.78			0.19	
4		0.20			0.27					
5		0.32								
6		2.12		0.66	0.33	0.06		0.11		
7		0.57		0.21	0.22	0.39				
8		0.54			0.08		0.49	0.10		
9			0.28	0.72	2.00		0.38			
10			0.15							
11										
12		0.03	1.31		0.80	0.15			0.06	
13		0.49	0.10		0.02	0.75				
14					0.90	0.10		0.26		
15			0.83	0.28	0.09	0.01	0.05			
16			1.10		0.02	0.31				
17						0.11				
18		0.49								
19						0.17				
20							0.16			
21		0.43			0.02	0.12	0.02			
22		0.02		0.53		0.16				
23			0.05	1.22			0.95			
24		0.02				0.29	0.45			
25						0.08	0.33			
26			0.38	0.23		0.24				
27		0.16								
28		0.48								
29										
30		0.21								
31		0.45				0.08				
Total	9.15	6.53	4.76	4.67	4.75	3.80	3.66	1.20	2.05	14.03
1931-55 average	11.29	5.56	4.60	4.21	4.09	4.63	3.65	3.58	2.60	8.75

Annual total. 54.60

1931-55 average 52.96

TABLE XIII

RAINFALL DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT KNOXVILLE, 1962

	Jan.-Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.
1		0.20	0.20							
2									0.08	
3							0.19		0.89	
4							0.50	0.04	0.41	
5				0.16	1.08	1.07		0.63		
6			0.12		0.05	0.01	0.09			
7			0.16		0.06	0.01	0.75		0.09	
8			0.02			0.45			0.86	
9		0.22	0.13			0.10				
10		0.04	0.05							
11			0.62	0.94				0.17		
12			1.65		0.92					
13			0.50		0.74					
14							0.34			
15										
16								1.10		
17								2.05		
18										
19										
20		0.15		0.11	0.18					
21		0.75							0.21	
22		0.30								
23		0.05								
24			0.01		0.63					
25				0.02		0.87				
26		0.97				2.70		0.20		
27						0.09		0.53		
28					1.08					
29					0.03	0.13				
30				0.58	0.02					
31		0.62		0.18		0.05			0.32	
Total	11.69	3.30	3.46	1.99	4.79	5.48	1.87	4.72	2.86	7.94
1921-50 average	9.27	4.83	3.64	3.58	3.47	4.74	3.43	2.53	2.63	7.41

Annual total. 48.10

1921-50 average 45.53

TABLE XIV

RAINFALL DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT JACKSON, 1962

	Jan.-Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.
1				1.55				0.50		
2					0.20		0.10	0.08	0.13	
3					1.04			0.03		
4					0.08			0.04		
5		0.04			0.02		0.28	1.87		
6			0.12			0.75				
7										
8										
9		0.84	0.46			0.47		0.11		
10			0.08					0.65		
11		0.50	1.75		0.06	0.11				
12		0.12	0.17							
13					0.22					
14								0.62	0.02	
15			0.06							
16								1.08		
17			0.16					0.08	0.06	
18										
19										
20		0.20			0.30					
21		0.57							0.07	
22									0.05	
23										
24					0.13	0.13				
25		0.30			0.31	0.34		0.29		
26		0.36			0.13		0.41	0.06		
27										
28			0.04							
29			0.38							
30		0.29		0.78		0.36	0.06			
31		1.26					0.34			
Total	14.18	4.48	3.22	2.33	2.49	2.16	1.19	5.41	0.33	3.48
1931-55 average	11.29	5.56	4.60	4.21	4.09	4.63	3.65	3.58	2.60	8.75

Annual total 39.27

1931-55 average 52.96

TABLE XV

RAINFALL DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT KNOXVILLE, 1963

	Jan.-Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.
1				0.08		0.60				
2		0.55								
3						0.08				
4								0.12		
5		0.10			0.08		0.11	0.35		
6		2.10		0.17	0.06					
7			0.48			1.71	0.11			
8					0.08	0.47	0.72			
9					0.22					
10										
11				0.02	0.14		0.48			
12		2.50								
13		0.34						0.15		
14				0.45	0.42	0.21	0.10	0.11		
15										
16		0.12		0.25	0.71					
17		0.27			0.10	0.15				
18				1.09						
19		0.05				0.05				
20		1.60	0.04		0.10		0.05			
21				0.12	0.65	1.25	0.13			
22				0.10	0.10					
23			0.22	0.03	0.12					
24						0.05				
25				0.05		0.03				
26		0.02		0.75		0.09				
27		0.05		0.35						
28			0.28	1.04		0.09				
29			0.83	0.82	0.08	1.14		1.22		
30			1.66		0.06	0.10	0.54	0.30		
31						0.70				
Total	10.11	7.70	3.51	5.32	2.92	6.72	2.24	2.25	0.00	6.32
1921-50 average	9.27	4.83	3.64	3.58	3.47	4.74	3.43	2.53	2.63	7.41

Annual total. 44.23

1921-50 average 45.53

TABLE XVI

RAINFALL DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT JACKSON, 1963

	Jan.-Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.
1		0.87								
2		0.12								
3						0.32				
4								0.06		
5		2.49								
6		0.07	0.17	0.35		0.37		0.03		
7			0.17							
8						0.61				
9		0.10								
10										
11		1.33								
12		0.81								
13								0.46		
14					0.04	0.98				
15										
16		0.60			1.60					
17		0.93	0.10		0.02	0.07				
18										
19										
20		0.07	0.42		0.20					
21					0.26					
22										
23				0.01						
24						0.18				
25			0.25	0.42						
26		0.14		2.70						
27				0.90	0.41	0.17	0.13	0.03		
28			0.73	0.35	0.11	0.46				
29			1.36	0.05			1.03	0.41		
30			0.69			0.30	0.01			
31						0.10				
Total	3.29	7.53	3.89	4.78	2.64	3.56	1.17	0.99	0.00	5.15
1931-55 average	11.29	5.56	4.60	4.21	4.09	4.63	3.65	3.58	2.60	8.75

Annual total. 33.00

1931-55 average 52.96