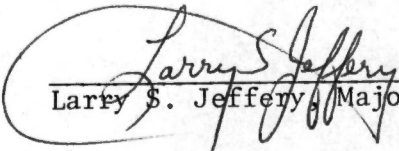
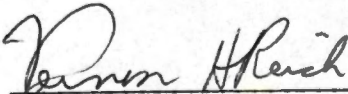


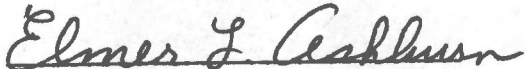
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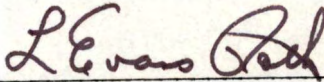

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INFLUENCE OF SOIL TYPES ON SOYBEAN RESPONSE
TO VARIOUS RATES OF CHLORBROMURON,
LINURON, AND METRIBUZIN

A Thesis

Presented for the

Master of Science

Degree

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John Robert Holowid

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ABSTRACT

Tennessee farmers and researchers have experienced occasional soybean (Glycine max) injury when chlorbromuron [3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea], linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea], and metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazine-5(4H) one] have been applied for preemergence weed control in soybeans. The activity of these herbicides on various soils needs to be understood in order to obtain effective weed control without causing soybean injury. Field studies were conducted during 1976, at three locations in Tennessee on seven soil types. The objectives of this study were to determine soybean response to various rates of chlorbromuron, linuron, and metribuzin, to determine the maximum rate that can be applied to a specific soil without reducing soybean yield and to correlate the most effective rate of chlorbromuron, linuron, and metribuzin for weed control and soybean tolerance to the physical properties of a soil.

The herbicides were applied preemergence at the following rates: chlorbromuron at 1.7, 2.3, 2.8, and 3.4 kg/ha; linuron at 0.6, 0.8, 1.1, and 1.7 kg/ha; and metribuzin at 0.3, 0.4, 0.6, and 0.8 kg/ha. The soils studied were Captina clay loam, Sequatchie sandy loam, Sequatchie loam, Hartsells loam, Falaya-Collins silt loam, Ocklochonee loam, and Loring silty clay loam. The experimental design was a modified factorial arrangement of a randomized complete block design with four replications. Data were obtained on soybean vigor reduction, stand reduction, plant height, forage weight and yield on the four East Tennessee soils. No

data on plant height and forage weight were obtained on the three West Tennessee soils.

Early chlorbromuron injury, as noted by soybean vigor and stand reduction ratings taken early in the growing season, was later expressed in reduced soybean yields on all rates applied on Falaya-Collins silt loam (0.3-1.5x the highest recommended rate). Rates greater than 1.7 kg/ha caused early injury and reduced yields on Ocklochonee loam (1-1.5x the highest recommended rate) and Loring silty clay loam (0.8-1.2x recommended rate) and rates greater than 2.3 kg/ha caused early injury and reduced yields on Sequatchie loam (1.2-1.5x highest recommended rate). None-to-slight injury occurred at the highest rate of chlorbromuron on Captina clay loam (1.2x highest recommended rate) and Sequatchie sandy loam (2x highest recommended rate) but no reduction in yield occurred. No injury or yield reduction occurred on Hartsells loam (0.5-1.0x recommended rate).

Early linuron injury at the 1.7 kg/ha rate occurred on Sequatchie sandy loam and Sequatchie loam (1.3x highest recommended rate for both) but no reduction in yield occurred. Yields were reduced when the 1.7 kg/ha rate was applied on Falaya-Collins silt loam and Ocklochonee loam (1.3x recommended rate for both). No injury occurred at any of the rates used on Captina clay loam (0.4-1.1x highest recommended rate), Hartsells loam (0.3-0.7x highest recommended rate), and Loring silty clay loam (0.4-1.1x highest recommended rate).

Early metribuzin injury and reduced yields occurred when the 0.8 kg/ha rate was applied on Falaya-Collins silt loam (2x Du Pont's recommended rate

and 1.3x Chemagro's highest recommended rate) and on Loring silty clay loam (1.1 Chemagro's and 1.4x Du Pont's recommended rate). Early injury with no yield reduction occurred at the 0.4 and 0.6 kg/ha rates on Falaya-Collins silt loam (1-1.5x Du Pont's recommended rates and 1x Chemagro's recommended rate), at 0.6 and 0.8 kg/ha rates on Ocklochonee loam (1.5-2x Du Pont's recommended rates and 1-1.3x Chemagro's highest recommended rates), and at 0.4 and 0.6 kg/ha on Loring silty clay loam (0.7-1x Du Pont's recommended rate and 0.6-0.9x Chemagro's recommended rates). Injury on Captina clay loam occurred at the 0.6 and 0.8 kg/ha rates (1-1.4x Du Pont and 0.9-1.1x Chemagro's recommended rates), on Sequatchie sandy loam at 0.8 kg/ha (both companies do not recommend use) and at the 0.8 kg/ha rate on Sequatchie loam (2x Du Pont and 1.3x Chemagro's recommended rates). No injury or yield reduction occurred at any of the rates used on Hartsells loam. However, at the 0.4 kg/ha rate, yields were found to be increased over the check. This rate was 0.7x that recommended by Du Pont and 0.6x that recommended by Chemagro.

Correlations between soil properties, injury, and yield show that organic matter content and pH have the greatest effect on buffering , phytotoxic effects. Similarly, the stepwise multiple regression analysis procedure showed that organic matter and pH accounted for most of the variation of all of the variables studied.

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CHAPTER I

INTRODUCTION

Tennessee farmers and researchers have experienced occasional soybean injury when chlorbromuron, linuron, and metribuzin have been applied for preemergence weed control in soybeans [Glycine max (L.)]. These herbicides, for most effective results, should be applied at a certain rate depending on the soil type and its percentage of organic matter. Tennessee, while short in latitude, covers considerable longitudinal distance and, consequently, offers a variety of soil types that differ in texture, organic matter, cation-exchange capacity, and other characteristics. By knowing the appropriate rate for his soil type, the farmer could increase profits by reducing crop injury and hence yield loss, and also by avoiding the waste resulting from over-application or under-application of the chemicals.

Chlorbromuron is sold under the name of "Maloran" by Ciba-GEIGY and "Bromex" by Nor Am. It is used for the control of annual grasses and broadleaf weeds occurring in soybean crops. The general recommended rates of application of chlorbromuron range from 1.1 to 4.5 kg/ha. It is not recommended for use on soils containing less than 1% organic matter. At present it is not included on the recommended list of soybean herbicides for Tennessee, because it has caused moderate to severe soybean injury in some years.

Linuron is manufactured and labeled as "Lorox" by Du Pont and is commonly used on soybeans. It selectively controls germinating and

newly established grass and broadleaf weeds in soybeans. The general effective rates for applying this herbicide as a preemergence treatment in soybeans are from 0.6 to 3.4 kg/ha, with specific rates recommended for different soil types and varying organic matter content. It is readily adsorbed by soils high in clay and organic matter content and it is noted that clays with a high cation-exchange capacity adsorb more linuron than those with a low exchange capacity. Linuron has been observed to cause some injury to soybeans grown in Tennessee, specifically to those grown on the lighter West Tennessee soils.

Metribuzin is a herbicide sold under the names of "Sencor" by Chemagro and "Lexone" by Du Pont. Soybeans have shown tolerance to this herbicide while many annual grasses and broadleaf weeds have been controlled. This herbicide has been used successfully against cocklebur (Xanthium strumarium) in Tennessee. The effective rates of metribuzin for use with soybeans are 0.3 to 1.1 kg/ha. Soils high in clay or organic matter adsorb metribuzin resulting in reduced effectiveness against deep germinating weeds. Chemagro recommends applying "Sencor" at rates of 0.4 to 0.6 kg/ha for all silt loam soils containing up to 2% organic matter, whereas Du Pont recommends "Lexone" only at the 0.4 kg/ha rate on silt loam soils containing 0.5 to 2% organic matter.

The objectives of this experiment were:

1. To determine soybean response to various rates of chlorbromuron, linuron, and metribuzin when applied to several different soil types.
2. To determine the maximum rate that can be applied to a specific soil without reducing soybean yield.

3. To correlate the most effective rate of chlorbromuron, linuron, and metribuxin for weed control and soybean tolerance to the physical properties of a soil.

CHAPTER II

LITERATURE REVIEW

The activity of soil-applied herbicides is dependent on the availability of the herbicide to plants. Availability, in turn, is dependent on a number of interrelated factors which include soil properties. Many experiments have been conducted to determine the type and importance of various factors which influence herbicide activity in the soil.

I. FACTORS INFLUENCING HERBICIDE ACTIVITY IN SOIL

Bailey and White (4,5) reviewed literature pertaining to the adsorption and desorption of organic herbicides by soil colloids. Through the use of multiple regression analysis and simple correlation analysis, it has been shown that herbicide adsorption, and consequently phytotoxicity reduction, is positively and highly correlated with organic matter content and the cation-exchange capacity of soils. Many authors (9,11,15,18,24,33,34,36,37,39) have shown that organic matter is the most important factor in herbicide adsorption. Of the soil colloids, organic matter, montmorillonite, and vermiculite clays have high cation-exchange capacities and surface areas. These are thus considered to be major factors in herbicide adsorption. On the other hand, illite, kaolinite, and chlorite clays have low cation-exchange capacities and surface areas and therefore are not considered to be as

important (4). Kaolinite is one of the dominant clay minerals in Southeastern United States (8).

Scott and Weber (31) conducted an experiment using cucumber (Cucumis sativus L.) seedlings as a bioassay indicator to determine differences in phytotoxicity as influenced by herbicide adsorption on montmorillonite, kaolinite, and a peaty muck soil (66% O.M.). When montmorillonite and kaolinite were increased, an additive effect in reduced prometone [2-methoxy-4, 6-bis(isopropylamino)-S-triazine] phytotoxicity resulted. The cucumber seedlings on peaty much showed no visible phytotoxicity. Approximately 16-20 times as much kaolinite as montmorillonite was required to obtain a significant reduction in prometone phytotoxicity.

In a study involving various adsorbents and herbicides, Harris and Warren (17) were able to completely recover herbicides adsorbed onto bentonite, but could not recover all, of any of the herbicides studied, when they were adsorbed onto a muck soil. This study indicated that adsorption onto organic matter may not be a completely reversible process, and thus a portion of the herbicide is made unavailable to plants.

Ashton (2) studied the lateral movement of four substituted urea herbicides and three triazine herbicides in three soils when furrow irrigation water was applied. He found that for each herbicide studied, lateral movement was greatest in Yolo sandy loam, intermediate in Sacramento clay, and least in Staten Island peaty muck. In each soil, herbicide movement increased with increasing herbicide water solubility.

Ashton and Crafts (3) stated that water solubility is one property used in achieving selectivity with the urea herbicides. For example,

in order to control deep-rooted weeds in shallow-rooted crops, one would use a urea herbicide with high water solubility on a soil of low adsorption capacity.

Many authors (6,11,13,17,26,30,33,39) have studied the relationship between the pH of the soil solution and herbicide phytotoxicity. For most herbicides, phytotoxicity increases as the pH is increased. Harris and Warren (17) varied the pH of solutions containing bentonite and muck. They found that when the pH was lowered, adsorption of prometon onto bentonite increased, whereas no increase was observed with the muck. Frissel and Bolt (13) noted that adsorption of herbicides onto illite, kaolinite, and montmorillonite clays increased as the pH decreased.

Wiese and Davis (41) observed differences in soybean injury when fenuron [(3-phenyl-1, 1-dimethylurea)], and monuron [3-(p-chlorophenyl)-1, 1-dimethylurea] were applied in varying amounts of water to wet and dry Pullman silty clay loam. The herbicides moved deeper into a tube of the soil when applied in 500 c.c. of water to prewetted soil, than when applied to dry soil. Soybean injury was greater when the herbicides were applied to an initially dry soil. This was attributed to higher herbicide concentration near the soil surface where the young soybean roots were located. Bailey and White (4) state that high soil moisture tends to keep herbicides in solution. In soils with extremely low moisture, the herbicides may crystallize and thus be made unavailable to plants.

Temperature of the soil solution may affect herbicidal activity by its effect on herbicide solubility (4). As the temperature increases,

herbicide solubility increases and adsorption decreases. Harris and Warren (17) found that adsorption of various herbicides onto bentonite was greater at 0°C than at 50°C. Desorption occurred when samples allowed to equilibrate at 0°C were heated to 50°C. This effect was probably due to the exothermic properties of adsorption and endothermic properties of desorption as reported by Burnside in a leaching study of Nebraska soils (9).

Rainfall affects herbicide activity by leaching herbicides deeper into the profile. Leaching may be deeper with increasing amount and frequency of rainfall, but rains of low intensity tend to leach herbicides to a deeper depth than those of high intensity (5). Coble and Schrader (10) found that metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)one] injury to soybeans [Glycine max (L.) Merr.] was more severe when rain occurred within ten days after treatment than when no rain occurred. Injury differences between rainfall regimes decreased as organic matter increased, indicating that less leaching occurred due to herbicide adsorption.

II. UREA HERBICIDES

As a family, the urea herbicides are primarily applied to the soil where they are absorbed by the roots of plants. Translocation occurs from the roots to the leaves via the apoplastic system. Symptoms of phytotoxicity include chlorosis, wilt, and petiole and stem collapse. Inhibition of photosynthesis is believed to be the primary mechanism of action of these herbicides (3,14).

Ashton and Crafts (3) stated that urea herbicides are relatively non-selective, but selectivity may be achieved by taking advantage of water solubility and adsorptive properties in conjunction with soil characteristics. Geissbuhler (14) generalized urea adsorption as being lowest in sandy soils, intermediate in clay loams, and highest in organic soils with a high humus content. Weber, Weed, and Sheets (39) reviewed pesticide activity in the soil and related urea herbicide movement in soil to soil properties. Fine-textured soils high in clay, and those soils high in organic matter require higher rates than coarser-textured soils to achieve the same level of phytotoxicity.

Dubey and Freeman (12) observed that increasing organic matter and cation-exchange capacity caused a reduction in linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] phytotoxicity in ryegrass (Lolium multiflorum Lam Tifton No. 1) and that clay content of the soil was not related. When organic matter was held constant, a change in the cation-exchange capacity did not show any effect on linuron phytotoxicity.

Sherburne and Freed (34) reported that correlations of pH, percent silt, and percent clay with the amount of monuron adsorbed were not significant. Organic matter had a high correlation with monuron adsorption, however. Yuen and Hilton (42) studied monuron and diuron [3-(3,4-Dichlorophenyl)-1, 1 dimethylurea] activity in several Hawaiian soils and observed that pH had little effect on adsorption. Adsorption was found to increase when high-carbon materials were added to the soils. Sheets (32) cited literature on the disappearance of the urea herbicides from soil and concluded that phytotoxicity reduction is proportional to the degree of adsorption on clay and organic colloids.

Savage (29), using cucumber as a bioassay indicator, concluded that chlorbromuron [3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea] was strongly adsorbed to soil colloids. Chlorbromuron is thus very immobile in soils high in clay and/or organic matter content.

The urea herbicides in general are not volatile but they may be degraded by sunlight. Herbicidal activity may be reduced if applications are followed by several hot, dry days (38). Hill et al. (19) studied the disappearance of diuron and monuron from eleven soil types and their findings support the previous citation. They concluded that volatilization is minimal but photodecomposition may be a major pathway of disappearance if little rainfall occurs after application and the chemicals remain on the soil surface.

Many authors (12,14,29,32) have investigated the importance of microbial degradation of the urea herbicides. Sheets and Crafts (33) determined that urea phytotoxicity to oats (Avena sativa L., kanota) was lost more rapidly in non-autoclaved soil than in autoclaved soil. Soils with conditions favorable for growth of microorganisms, such as high temperature, moisture, and organic matter content, tend to have rapid urea degradation. The study by Savage (29) using chlorbromuron supported these observations.

Slack et al. (35) compared chlorbromuron and linuron for controlling weeds in soybeans. They applied both herbicides preemergence at rates of 0.5, 0.75, 1.0, 1.25, 1.5, and 2.0 lb/A to a silt loam soil. They found linuron to have 1.5 to 2 times the activity of chlorbromuron in controlling various weeds used as indicators.

Akins et al. (1) found chlorbromuron to reduce soybean stand and vigor at Knoxville, Spring Hill, and Jackson, Tennessee. As a result of early injury, yields at Jackson were reduced by 20%. Jeffery et al. (20) noticed a slight reduction (2%) of soybean vigor following preemergence applications and noted chlorbromuron as being very effective in controlling prickly sida (Sida spinosa L.). They also stated that chlorbromuron is in limited use in Tennessee due to low organic matter content in Tennessee soils. EPA registration limits use of chlorbromuron to soils containing more than 1% organic matter.

III. TRIAZINE HERBICIDES

The triazine herbicides are adsorbed primarily by the roots of plants and are translocated via the apoplastic system to the shoots and leaves. Absorption tends to increase with increasing root temperatures and herbicide concentration in the soil. Symptoms of triazine toxicity are foliar chlorosis followed by necrosis. Inhibition of growth of all plant organs may be observed and this has been attributed to the lack of photosynthate caused by blockage of photosynthesis. At low concentrations, the triazines may stimulate growth and cause an increase in chlorophyll content of the leaves (3).

Weber, Weed, and Ward (40) studied the adsorption of seven s-triazine herbicides by organic matter at different pH levels. All of the compounds studied were adsorbed in the greatest amounts at pH levels in the vicinity of their respective pKa values. That is, that pH at which 50% of the herbicide is dissociated. They found that these compounds were

adsorbed less in calcareous soils, which are near neutral in reaction, than acidic soils. It was concluded that liming of acidic soils would counteract adsorption and therefore increase the weed killing effectiveness of these herbicides. This was supported by the work of Best et al. (6) who showed that liming Bladen silt loam soil (5.5% O.M.) from pH 5.5 to 7.5 significantly increased the activity of both atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-S-triazine] and prometryne [2,4-bis(isopropylamino)-6-(methylthio)-s-triazine]. They stated that acidic hydrogen is probably responsible for most triazine adsorption in soils, thus liming should decrease adsorption and therefore increase triazine activity. Lavy (25) reported that triazine adsorption increases with increasing organic matter and clay content, and with decreasing pH.

McGlamery and Slife (26) studied the adsorption and desorption of atrazine as affected by pH, temperature, and concentration. pH was found to be more effective in influencing adsorption than was temperature or concentration. As the pH decreased, adsorption increased on Drummer clay loam and humic acid. When pH was increased, nearly complete desorption occurred from the soil whereas very little desorption occurred from the humic acid.

Savage (30) compared the sorption properties of 16 Mississippi Delta soils for metribuzin. Metribuzin adsorption was correlated with the clay, organic matter, and water content of the soil. An increase in organic matter or clay resulted in an increase in adsorption. When clay was increased as organic matter was increased, the level of adsorption due to organic matter additions was less. Adsorption decreased when high

levels of clay were combined with high levels of organic matter as compared to adsorption at the same organic matter level with no clay. Savage postulated that the clay colloid has a negative effect on the adsorbing capacity of organic matter. He attributed this to a possible competition between clay and organic matter for adsorption sites which causes a net decrease in sites available for herbicide adsorption.

Ladlie et al. (21,22,23) discussed the importance of soil pH in influencing metribuzin activity in corn (Zea mays L.) and soybeans. They found that the number of dead corn and soybean plants and crop injury ratings increased while plant height and yields decreased with increasing soil pH. The pH range from 5.0 to 5.4 was determined to be the dividing line between slight and severe injury (21). When a sand culture was used, no difference in the reduction in dry weight of the plants was found as the pH changed. Adsorption was found to increase gradually as the soil pH decreased toward the pKa of metribuzin. This effect was considered to be the primary reason for a decrease in phytotoxicity to corn and soybeans, overruling the possibility of metribuzin disappearance due to microbial degradation (22). Metribuzin degradation was found to become slower as pH decreases. This may be due to increased adsorption making the herbicide less available to microbial attack (23).

Coble and Schrader (10) found soybean tolerance to metribuzin to be affected by soil organic matter, herbicide rate, rainfall, and planting depth. Injury to soybeans was found to be less severe when rainfall was delayed after treatment. They also found that injury was less severe

to soybeans planted 2.5 cm deep as compared to those planted at a 1.3 cm depth. They concluded that soybean tolerance to metribuzin is a function of position and that soil organic matter, herbicide rate, and rainfall after treatment play a major role in the relative position of the herbicide to the soybean plant.

Royster and Kerr (28) found differences in sensitivity among soybean cultivars to metribuzin. They found that on a Tiptonville sandy loam, 'Essex,' 'Dare,' 'Pickett 71,' 'Forrest,' and 'Davis' cultivars were less sensitive to metribuzin at 0.4 and 0.8 kg/ha than was the cultivar 'Tracy.'

CHAPTER III

METHODS AND MATERIALS

I. FIELD RESEARCH

This study was conducted on three soil types at the Knoxville Plant Science Farm (KPS), on one soil type at the Plateau Experiment Station near Crossville (PES), and on three soil types at the Milan Field Station (MFS). The three soil types used at KPS were Sequatchie sandy loam, Sequatchie loam, and Captina clay loam. Hartsells loam was used at PES and Falaya-Collins silt loam, Ocklochonee loam, and Loring silty clay loam were used at MFS. All soils varied in characteristics and were suitable for soybean production. Prior to seedbed preparation, plot areas were tested and fertilized according to need. Sequatchie sandy loam, Sequatchie loam, and Captina clay loam all received 450 kg/ha of 6-12-12 at KPS. Hartsells loam at PES received 225 kg/ha of 0-14-42. At MFS, Falaya-Collins silt loam received 225 kg/ha of 10-20-20+B, Ocklochonee loam received 560 kg/ha 10-20-20+B, and Loring silt loam received 678 kg/ha of 10-10-10+B. All fertilizers were applied broadcast.

Planting dates were within the range of recommended planting dates for soybeans at each experimental area. Experiments at KPS were planted June 11, the experiment at PES was planted June 8, and at MFS, the experiment on Ocklochonee was planted June 8 whereas the experiments on the Falaya-Collins and Loring soils were planted June 9. At PES, the 'Essex' variety of soybeans was planted. 'Forrest' variety was planted at all other locations.

The experimental design was a randomized complete block design with a modified factorial arrangement of treatments, consisting of chlorbromuron, linuron, and metribuzin applied preemergence broadcast. Subplots within each main treatment consisted of four rates of each herbicide. These rates consisted of chlorbromuron applied at 1.7, 2.3, 2.8, and 3.4 kg/ha, linuron at 0.6, 0.8, 1.1, and 1.7 kg/ha, and metribuzin applied at 0.3, 0.4, 0.6, and 0.8 kg/ha. This experiment was replicated four times at KPS and MFS and three times at PES. Subplots were four rows wide with the exception of the experiment on Captina clay loam, where they were three rows wide. Subplot size was 4.0 x 8.4 m on Sequatchie loam, 4.0 x 7.5 m on Sequatchie sandy loam, and 4.0 x 9.0 m on Captina clay loam at the KPS. At the MFS, all plots were 4.0 x 9.0 m and at the PES, the plots were 4.0 x 9.0 m. Replications were separated by 6 m alleys at the MFS whereas the other experiments had no alleys.

Rows were spaced one meter apart at all locations. Yield data were obtained from 6.0 m of one of the center rows at the three Knoxville locations. At Crossville, yield data were obtained from 4.8 m of the two center rows of each plot. At the Milan Field Station, yield data were obtained from 9.0 m of the two middle rows of each plot.

Visual ratings of vigor reduction and stand reduction and soybean yields were used as criteria for measuring crop response to chlorbromuron, linuron, and metribuzin at all of the locations. Soybean height and forage weight were additional criteria used as indicators at KPS and PES. Visual ratings of percent vigor reduction and stand reduction were made

on a 0 to 100 scale, with 0 being no vigor or stand reduction and 100 being complete kill of all plants. The degree of vigor and stand reduction was based on a comparison with the untreated check in the replication. Observations of the Knoxville experiments were made approximately two and six weeks after planting, at Crossville, two and four weeks after planting, and at Milan, three and five weeks after the planting date.

Plant heights were taken within the week prior to harvest. The measurements were taken from the center row of each plot on Captina clay loam and from the two inside rows of each plot at all other East Tennessee locations.

The soybeans were manually harvested at KPS on November 18, and at PES November 23. Forage weights were obtained by cutting the soybean plants at ground level and weighing before threshing. The plants were then threshed to obtain soybean yields. At MFS, the soybeans grown on Ocklochonee and Falaya-Collins soils were combine harvested November 2, and those grown on the Loring soil were harvested November 4. Soybean weight and moisture content were taken on the beans harvested at Milan. Those beans harvested at Crossville and Knoxville were allowed to air dry for one week, then moisture and weights were taken. All yields were converted to 13.0% moisture.

II. LABORATORY RESEARCH

Soil Characterization

Soil samples were taken during the 1976 growing season at the Knoxville Plant Science Farm, the Plateau Experiment Station, and the

Milan Field Station. At all sites, samples were taken at random across the plots at a depth from 0 to 15 cm and then pooled. Bulk density samples were later taken in November 1976 from the 0 to 15 cm depth range at all experimental sites.

The samples used for soil characterization were air dried, crushed to pass through a 2 mm. sieve, and stored in pint-size ice cream containers. All soils were characterized during the late summer and fall of 1976 in the laboratory.

The percentages of sand, silt, and clay sized fractions were determined by the pipette method (27). Organic matter was determined by using the Walkley-Black organic carbon analysis method (7) and converting percent carbon to percent organic matter. Soil pH was determined by mixing a 1:1, soil to water suspension, in which glass electrodes were emersed. The pH was then read on a Beckman pH meter. Bulk density was determined using the core method described by Black (7). Small and large pore space were determined by the difference method as discussed by Black (7).

Soil moisture content was determined by using the porous plate method for tensions of 1/3 bars, and the pressure membrane method for tensions of 15 bars (27). From these values, the available water holding capacity (percent by weight) was calculated.

The cation-exchange capacity was determined by using the ammonium saturation method as described by Black (7). Cations were replaced from the soil samples by leaching with 1N ammonium acetate (NH_4OAc). The ammonium ions were then replaced on the exchange complex by sodium

ions by leaching with 10% acidified NaCl. The leachate was then analyzed for ppm. of NH_4^+ by the alkaline-phenol ammonium-nitrogen analysis method set up on the Technicon Auto Analyzer using alkaline-phenol and sodium hypochlorite as the color producing reagents.

CHAPTER IV

RESULTS AND DISCUSSION

I. FIELD RESEARCH

Chlorbromuron

Captina clay loam. All rates of chlorbromuron reduced soybean vigor on June 25 and July 23 (Table 1). No differences existed between individual treatments. All rates reduced soybean stand on both dates with the exception of those soybeans treated with 1.7 kg/ha and observed on June 25. On July 23, soybeans treated with 2.8 and 3.4 kg/ha showed a significant reduction in stand over those treated with the lower rates. Chlorbromuron did not affect soybean height, but rates exceeding 2.3 kg/ha reduced forage weight. Early injury did not influence soybean yield.

The manufacturer's recommended rates for chlorbromuron on this soil are 1.7 to 2.8 kg/ha. Early injury resulted from the 1.7 kg/ha rate. In spite of this early injury, soybean yield reduction did not occur even where chlorbromuron was applied at 3.4 kg/ha. Apparently rainfall was not sufficient to cause leaching in this heavy soil. The 1.8% organic matter content probably accounted for much chlorbromuron adsorption, in spite of the high pH which would promote desorption. The soybeans were able to survive in the treated soil and recovered from early injury.

Sequatchie sandy loam. All treatments, with the exception of the 2.3 kg/ha rate reduced soybean vigor during the June 25 rating (Table 2).

Table 1. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Captina Clay Loam, Knoxville Plant Science Farm, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor			Stand			Height (cm)	Forage Weight (kg/ha)	Soybean Weight (kg/ha)
		Reduction			Reduction					
		June 25	July 23	(%)	June 25	July 23	(%)			
Chlorbromuron	1.7	45 bcd	30 bc		21 abcd	31 bc		71 ab	10774 bcd	2096 abc
	2.3	69 abc	33 bc		34 abc	33 b		74 ab	10101 bcd	1921 abc
	2.8	76 ab	64 a		40 ab	55 a		65 b	7492 d	1436 bc
	3.4	86 a	58 ab		46 a	59 a		65 b	7239 d	1381 c
Linuron	0.6	40 cd	11 cd		16 bcd	6 cd		76 ab	14529 ab	2474 a
	0.8	45 bcd	13 cd		19 abcd	9 bcd		84 a	13300 abc	2354 a
	1.1	49 bcd	28 cd		39 ab	20 bcd		82 ab	12677 abc	2444 a
	1.7	39 cd	16 cd		16 bcd	11 bcd		67 ab	13855 abc	2462 a
Metribuzin	0.3	21 de	8 cd		8 cd	5 d		84 a	16128 a	2608 a
	0.4	23 de	14 cd		14 bcd	6 cd		74 ab	15572 a	2617 a
	0.6	35 cd	19 cd		16 bcd	8 bcd		78 ab	12879 abc	2573 a
	0.8	41 cd	33 bc		25 abcd	14 bcd		74 ab	11364 bc	2149 ab
Check	0.0	0 e	0 d	0 d	0 d	0 d	82 ab	13855 abc	2100 abc	

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

Table 2. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Sequatchie Sandy Loam, Knoxville Plant Science Farm, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor Reduction (%)		Stand Reduction (%)		Height (cm)	Forage Weight (kg/ha)	Soybean Weight (kg/ha)
		Reduction (%)		Reduction (%)				
		June 25	July 23	June 25	July 23			
Chlorbromuron	1.7	34 bc	26 bcd	5 cd	10 bc	84 ab	10320 abc	2262 ab
	2.3	30 bcd	29 bc	16 bcd	16 bc	73 bc	10774 abc	2516 ab
	2.8	46 ab	33 b	28 ab	20 abc	76 abc	10404 abc	2552 ab
	3.4	70 a	51 a	48 a	40 a	67 c	7576 c	1754 b
Linuron	0.6	15 bcd	11 de	3 d	9 bc	88 a	12710 a	2970 a
	0.8	34 bc	29 bc	14 bcd	20 abc	82 ab	10909 abc	2531 ab
	1.1	18 bcd	20 bcd	0 d	6 bc	88 a	13266 a	3083 a
	1.7	41 abc	34 b	26 abc	25 ab	74 bc	9175 bc	2287 ab
Metribuzin	0.3	13 cd	10 de	0 d	3 bc	84 ab	12845 a	2642 ab
	0.4	15 bcd	15 cde	0 d	6 bc	80 ab	12795 a	2595 ab
	0.6	28 bcd	14 cde	0 d	5 bc	84 ab	12205 ab	2402 ab
	0.8	34 bc	23 bcd	0 d	8 bc	80 ab	11835 ab	2762 ab
Check	0.0	0 d	0 e	0 d	0 c	74 bc	10572 abc	2320 ab

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

By July 23, all rates of chlorbromuron reduced soybean vigor. The 2.8 and 3.4 kg/ha rates reduced soybean stand on June 25 whereas only the high rate reduced stand on July 23. In spite of this early injury, the soybeans recovered enough by harvest time to reveal no differences in height, forage weight, or yield when compared to the check plot.

The recommended rates for chlorbromuron on Sequatchie sandy loam are 1.1 to 1.7 kg/ha. All of the rates used in this study, with the exception of the lowest rate (1.7 kg/ha), were higher than the recommended rates. The 1.9% organic matter content of this soil, along with the low pH, probably tied up the herbicide on the exchange complex. This prevented leaching of the herbicide deep into the soybean root zone in spite of the coarse soil texture. Young soybeans recovered from early injury when their roots grew out of the treated zone of soil.

Sequatchie loam. All treatments severely reduced soybean vigor on both rating dates (Table 3). The 1.7 kg/ha treatment reduced soybean stand on June 25. By July 23, all treatments reduced stand with the highest rate of 3.4 kg/ha showing very severe reduction (88.8%). As a result of early injury, all of the rates reduced soybean height. Treatments exceeding the 1.7 kg/ha rate reduced forage weight, with the 3.4 kg/ha rate causing the greatest reduction. The 2.8 and 3.4 kg/ha treatments reduced yield.

The manufacturer's recommended rates for chlorbromuron on Sequatchie loam are 1.4 to 2.3 kg/ha. This soil had the lowest amount of organic matter of the East Tennessee soils and was intermediate in clay content. Early injury at all rates probably were the result of adsorption and

Table 3. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Sequatchie Loam, Knoxville Plant Science Farm, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor Reduction (%)		Stand Reduction (%)		Height (cm)	Forage Weight (kg/ha)	Soybean Weight (kg/ha)
		Reduction (%)		Reduction (%)				
		June 25	July 23	June 25	July 23			
Chlorbromuron	1.7	43 cd	45 cd	14 cd	34 bc	69 bc	9090 abcd	1899 abc
	2.3	46 cd	60 bc	21 bcd	49 b	58 cd	6364 cd	1137 bcd
	2.8	69 ab	70 ab	34 b	80 a	45 d	5051 d	863 cd
	3.4	85 a	91 a	56 a	89 a	11 e	673 e	98 d
Linuron	0.6	11 fg	11 ef	3 e	4 d	92 a	10488 ab	2226 ab
	0.8	29 def	20 ef	3 e	13 d	83 ab	12121 a	2450 a
	1.1	15 efg	13 ef	3 e	6 d	90 a	11414 ab	2400 a
	1.7	55 bc	51 bcd	25 bc	51 b	66 bc	7121 bcd	1488 abc
Metribuzin	0.3	11 fg	16 ef	0 e	6 d	86 a	11364 ab	2222 ab
	0.4	29 def	33 de	3 e	13 d	77 ab	10185 abc	2152 ab
	0.6	28 def	19 ef	4 e	9 d	81 ab	9343 abcd	1885 abc
	0.8	36 cde	45 cd	9 de	23 cd	69 bc	7458 bcd	1584 abc
Check	0.0	0 g	0 f	0 e	0 d	88 a	11111 ab	2060 ab

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

slow leaching of the herbicide which kept it near the soil surface, in the root zone of the young soybeans. Yield reduction resulting from the higher rates of chlorbromuron may be attributed to the saturation of the exchange complex by the herbicide. With such saturation, excess herbicide molecules do not have binding sites and are thus available in the soil solution to plants and to leaching.

Hartsells loam. No rate of chlorbromuron reduced vigor on June 22 (Table 4). On July 6, the 2.8 kg/ha rate reduced vigor. No stand reduction occurred, and similarly, neither soybean height, forage weight, nor yield was reduced.

Chlorbromuron is recommended at 2.3 to 3.4 kg/ha rates on Hartsells loam. All rates used in this study were within the recommended range. The high organic matter content of this soil (2.8%) probably adsorbed much of the herbicide and reduced its availability to the plants.

Falaya-Collins silt loam. All rates greatly reduced soybean vigor on both June 29 and July 13 (Table 5). Severe vigor reduction occurred where treatments exceeded 1.7 kg/ha. Rates exceeding 1.7 kg/ha reduced stand on June 29, and by July 13, all of the treatments reduced stand. All of the treatments reduced yield and soybeans treated with 2.8 and 3.4 kg/ha produced no yield.

The recommended rates of chlorbromuron on Falaya-Collins silt loam were 1.4 to 2.3 kg/ha. This soil, while having the highest percentage of organic matter (1.0%) of the West Tennessee soils, also had the highest pH (6.2%). Considerable rainfall during the month of June,

Table 4. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Hartsells Loam, Plateau Experiment Station, Crossville, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor Reduction (%)		Stand Reduction (%)		Height (cm)	Forage Weight (kg/ha)	Soybean Weight (kg/ha)
		June 22	July 6	June 22	July 6			
Chlorbromuron	1.7	7 ab	0 c	3 a	2 a	79 b	14421 bcd	2841 bc
	2.3	7 ab	2 bc	5 a	3 a	79 b	14947 abcd	2901 abc
	2.8	5 ab	12 a	2 a	2 a	81 ab	14494 bcd	3009 abc
	3.4	7 ab	7 abc	3 a	2 a	84 ab	14179 cd	3037 abc
Linuron	0.6	5 ab	2 bc	3 a	0 a	81 ab	15084 abcd	2956 abc
	0.8	10 a	2 bc	5 a	0 a	81 ab	15579 abc	2878 bc
	1.1	8 ab	10 ab	7 a	8 a	81 ab	15084 abcd	2775 c
	1.7	5 ab	3 bc	3 a	3 a	86 a	16347 a	3003 abc
Metribuzin	0.3	5 ab	3 bc	5 a	2 a	84 ab	15894 ab	3148 ab
	0.4	7 ab	2 bc	3 a	2 a	86 a	16526 a	3216 a
	0.6	10 a	7 abc	10 a	3 a	84 ab	15231 abcd	3107 ab
	0.8	0 b	0 c	0 a	0 a	84 ab	16315 a	3153 ab
Check	0.0	0 b	0 c	0 a	0 a	81 ab	13926 cd	2876 bc

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

Table 5. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Falaya-Collins Silt Loam, Milan Field Station, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor Reduction (%)		Stand Reduction (%)		Soybean Weight (kg/ha)
		June 29	July 13	June 29	July 13	
Chlorbromuron	1.7	38 cd	50 d	18 de	39 cd	1744 bc
	2.3	76 ab	84 ab	61 bc	84 ab	169 d
	2.8	87 ab	84 ab	80 ab	93 a	0 d
	3.4	98 a	95 a	91 a	99 a	0 d
Linuron	0.6	3 e	5 fg	0 e	0 e	3218 a
	0.8	14 de	19 efg	5 e	6 e	2818 ab
	1.1	18 de	25 ef	6 e	11 e	2436 ab
	1.7	62 bc	68 bcd	53 c	65 bc	939 cd
Metribuzin	0.3	4 de	0 g	0 e	0 e	2694 ab
	0.4	18 de	28 e	6 e	3 e	2942 ab
	0.6	33 cde	54 cd	13 de	16 de	2064 abc
	0.8	65 abc	75 abc	36 cd	56 c	518 d
Check	0.0	0 e	0 g	0 e	0 e	3201 a

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

along with a low organic matter content, intermediate clay content, and high pH, probably caused chlorbromuron to leach into the soil. With leaching, the soybeans could not grow out of the treated soil and thus were subjected to continuing injury.

Ocklochonee loam. Treatments exceeding 1.7 kg/ha reduced soybean vigor on June 29 (Table 6). Severe reduction occurred in soybeans treated with 2.3 and 3.4 kg/ha. All treatments reduced vigor on July 13 and severe reduction occurred where rates exceeded 1.7 kg/ha. Similarly treatments exceeding 1.7 kg/ha reduced soybean stand on June 29 and July 13 and later reduced yield.

The manufacturer does not recommend the use of chlorbromuron on soils containing less than 1.0% organic matter. Therefore, it is not condoned for use on Ocklochonee loam (0.9% O.M.). The Ocklochonee loam, while slightly lower in organic matter content than Falaya-Collins silt loam, had a slightly lower pH. At low pH, herbicides have been shown to be more highly adsorbed (16). This effect may account for slightly less injury and yield reduction when compared to the Falaya-Collins soil.

Loring silty clay loam. All treatments reduced vigor on June 29 (Table 7). Reduced vigor occurred on July 13, with complete kill of soybeans at the 3.4 kg/ha rate. Treatments exceeding 1.7 kg/ha reduced soybean stand on both dates with complete kill of soybeans at the 3.4 kg/ha rate on July 13. All treatments with the exception of the 1.7 kg/ha rate reduced yield. The 3.4 kg/ha treatment produced no yield.

Chlorbromuron is not recommended for use on this soil due to its low percentage of organic matter (0.8%). Loring silty clay loam is the

Table 6. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Ocklochonee Loam, Milan Field Station, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor Reduction (%)		Stand Reduction (%)		Soybean Weight (kg/ha)
		June 29	July 13	June 29	July 13	
Chlorbromuron	1.7	19 d	29 bc	9 d	9 d	2785 a
	2.3	66 ab	75 a	54 b	67 a	947 bc
	2.8	55 bc	66 a	41 b	51 ab	1004 bc
	3.4	84 a	70 a	78 a	64 ab	257 c
Linuron	0.6	1 d	3 cd	1 d	0 d	2859 a
	0.8	9 d	10 cd	1 d	3 d	2927 a
	1.1	14 d	9 cd	0 d	3 d	2431 ab
	1.7	68 ab	55 a	53 b	56 ab	1569 abc
Metribuzin	0.3	9 d	8 cd	0 d	0 d	3042 a
	0.4	44 c	26 cd	4 d	3 d	2300 ab
	0.6	68 ab	53 ab	13 cd	16 cd	2865 a
	0.8	74 ab	69 a	33 bc	39 bc	2049 ab
Check	0.0	0 d	0 d	0 d	0 d	3298 a

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

Table 7. Parameters of Soybean Response to Chlorbromuron, Linuron, and Metribuzin Applied at Various Rates on Loring Silty Clay Loam, Milan Field Station, 1976^a

Herbicide	Rate ai (kg/ha)	Vigor			Stand		Soybean Weight (kg/ha)
		Reduction (%)			Reduction (%)		
		June 29	July 13		June 29	July 13	
Chlorbromuron	1.7	51 bc	45 cd		31 bc	39 bc	2296 a
	2.3	83 ab	88 a		55 b	85 ab	467 b
	2.8	83 ab	85 a		52 b	79 ab	314 b
	3.4	99 a	100 a		95 a	100 a	0 b
Linuron	0.6	6 de	4 e		0 c	1 c	3117 a
	0.8	18 cde	19 cde		8 c	8 c	2963 a
	1.1	18 cde	15 de		5 c	9 c	2636 a
	1.7	21 cde	24 cde		8 c	11 c	2776 a
Metribuzin	0.3	18 cde	26 cde		0 c	1 c	3183 a
	0.4	45 bcd	45 cd		6 c	10 c	2616 a
	0.6	45 bcd	50 bc		5 c	10 c	2196 a
	0.8	84 ab	78 ab		39 bc	49 bc	954 b
Check	0.0	0 e	0 e		0 c	0 c	2843 a

^aMeans within columns with similar letters are not significantly different at the 5% level by Duncan's multiple range test.

finest textured soil of those West Tennessee soils studied. Severe early injury along with slight yield reduction, when compared with the Falaya-Collins soil may be attributed to the fine texture of this soil. The herbicide might not have been greatly adsorbed due to the low organic matter and intermediate pH (5.9), and leaching might have been hindered due to the clay content of the soil. The soybeans were able to recover when treated with the low rate by growing out of the treated soil.

The effect of chlorbromuron on soybean response appears to be dependent on the amount of organic matter present in the soil in East Tennessee. This effect is illustrated in Figure 1. Hartsells loam (2.8% O.M.) shows no decrease in yield, whereas Sequatchie loam (1.2% O.M.) shows considerable yield reduction. The severity of early injury also increases with decreasing organic matter content in soils.

The organic matter content of the three West Tennessee soils was nearly the same, ranging from 0.8 to 1.0%. Consequently, with such a narrow range, soybean response to chlorbromuron, as affected by soil organic matter, was not as evident. Injury along with yield reduction, increased with increasing pH in the West Tennessee soils. This effect was noted by several authors (6,11,13). In general, soybean injury in West Tennessee was more severe and this may be attributed to low organic matter content coupled with high pH. Also, the soils of West Tennessee had higher available water holding capacities which would affect herbicide solubility and thus availability for plant uptake. Soybean yield responses to the various rates of chlorbromuron on the various soils of West Tennessee are shown in Figure 2. Table 8

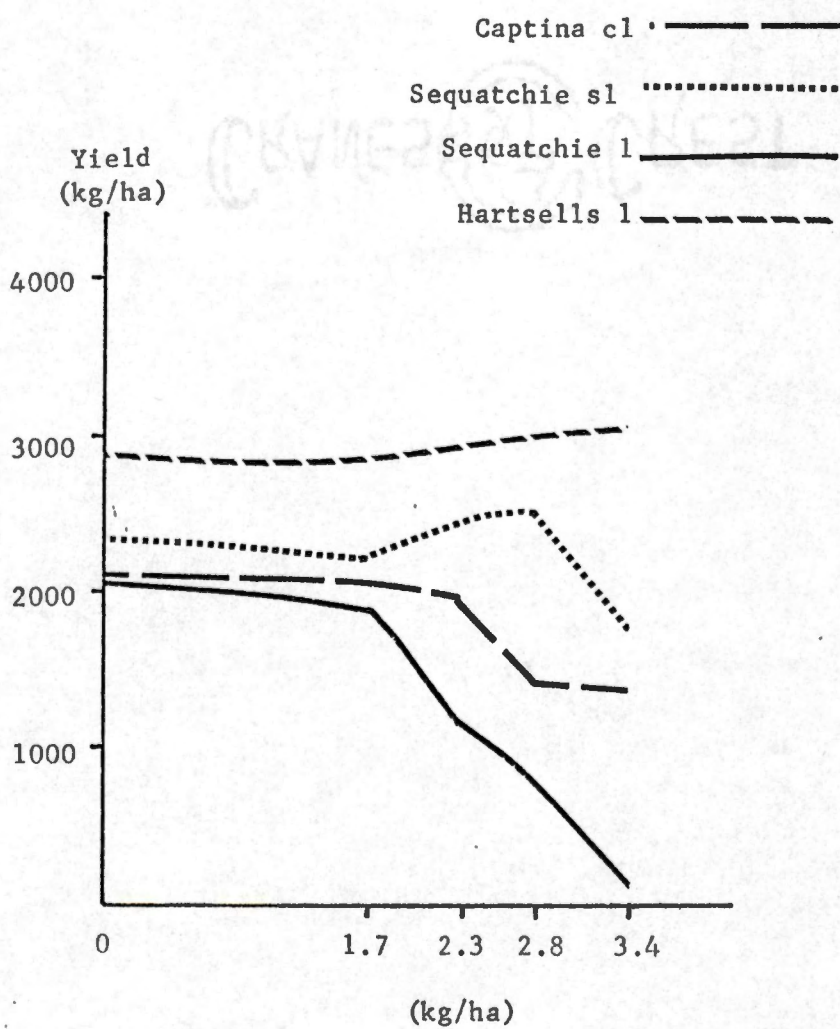


Figure 1. Influence of various rates of chlorbromuron on soybean yields on Captina Clay Loam, Sequatchie Sandy Loam, Sequatchie Loam, and Hartsells Loam.

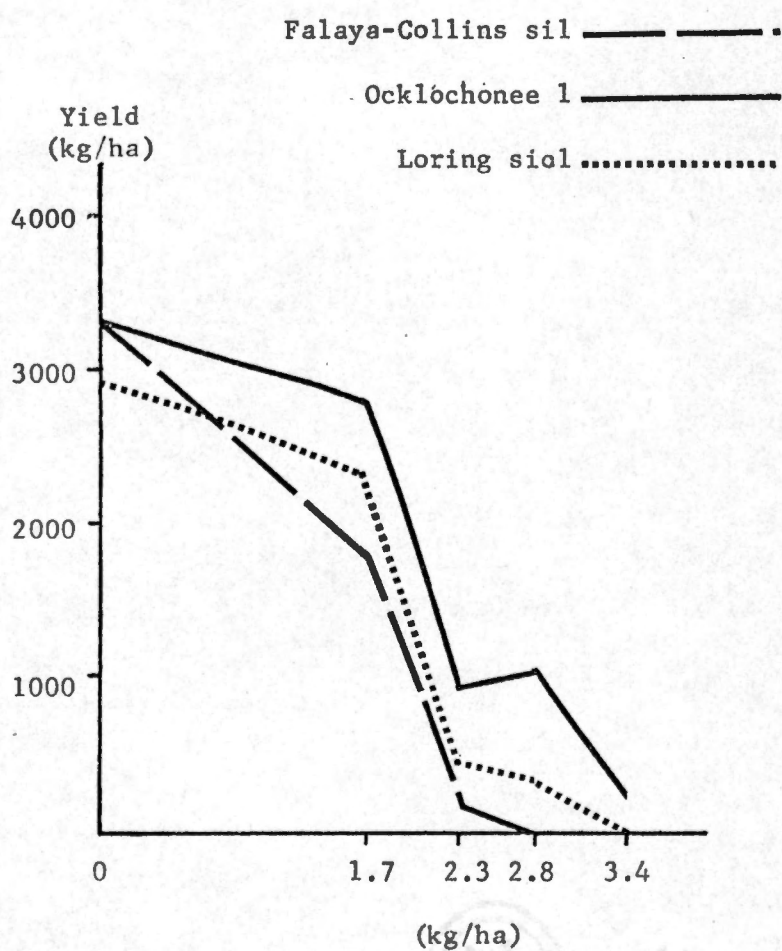


Figure 2. Influence of various rates of chlorbromuron on soybean yields on Falaya-Collins Silt Loam, Ocklochonee Loam, and Loring Silty Clay Loam.

Table 8. Ratio in Terms of "x" of Rates of Chlorbromuron Applied to a Given Soil Type to Manufacturer's Recommended Rate for the Given Soil Type

Soil Type	Recommended Rate per Soil Type (a.i. kg/ha)	Rate Applied (a.i. kg/ha)			
		1.7	2.3	2.8	3.4
Captina Clay Loam	2.8	0.6*	0.8	1.0	1.2
Sequatchie Sandy Loam	1.7	1.0	1.4	1.6	2.0
Sequatchie Loam	2.3	0.7	1.0	1.2	1.5
Hartsells Loam	3.4	0.5	0.7	0.8	1.0
Falaya-Collins Silt Loam	2.3	0.7	1.0	1.2	1.5
Ocklochonee Loam	(2.3)**	0.7	1.0	1.2	1.5
Loring Silty Clay Loam	(2.8)**	0.6	0.8	1.0	1.2

*Ratio in terms of "x" of rates applied to recommended rates.

**Rate for soil type disregarding organic matter less than 1%; therefore, herbicide is not recommended.

illustrates the ratio in terms of "x" of rates of chlorbromuron applied to a given soil type to manufacturer's recommended rate for the given soil type.

Linuron

Captina clay loam. All treatments of linuron reduced soybean vigor on June 25 (Table 1, page 20). By July 23, the soybeans showed no signs of reduced vigor and had recovered from earlier injury. The 1.1 kg/ha rate reduced soybean stand on June 25, however, this reduction was not discernible on July 23. In general, the soybeans were tolerant to linuron on this soil and no reduction in soybean height, forage weight, or yield occurred.

The manufacturers recommend linuron at 0.8 to 1.5 kg/ha on this soil. All rates used in this study exceeded the recommended range of rates, yet early injury was slight and yields were not reduced.

In spite of a high soil pH (6.4) which would tend to promote herbicide desorption, considerable amounts of organic matter and clay along with low rainfall in June probably kept linuron from leaching out of the surface soil. Soybean roots grew in a soil zone that was relatively free of linuron.

Sequatchie sandy loam. The 0.8 and 1.7 kg/ha rates reduced soybean vigor on June 25 (Table 2, page 21). By July 23, all treatments reduced vigor with the exception of the 0.6 kg/ha rate. The 1.7 kg/ha rate reduced soybean stand on both June 25 and July 23. Soybeans exhibited a positive growth response where the 0.6 and 1.1 kg/ha treatments were

applied, the height of the soybeans in these treatments being significantly greater than the check. In spite of this response, no differences in forage weight or yield were found.

Linuron is recommended at 0.7 to 1.3 kg/ha on Sequatchie sandy loam. Considerable organic matter and low pH probably caused linuron adsorption. Soybeans grew out of the treated soil and recovered from early injury.

Sequatchie loam. The 1.7 kg/ha rate reduced soybean vigor on both rating dates (Table 3, page 23). Vigor reduction noted at the 0.8 kg/ha rate on June 25 was not evident on July 23. The 1.7 kg/ha rate reduced soybean stand on both dates. Early injury from the 1.7 kg/ha rate resulted in reduced soybean height. No reductions in forage weight or yield were obtained from any of the treatments used.

The recommended rates of linuron for this soil are 0.7 to 1.3 kg/ha. Early injury was most severe where the 1.3 kg/ha rate was exceeded. In spite of the low organic matter content of Sequatchie loam (1.2%), the pH of the soil was also low (5.0). This probably accounted for linuron adsorption and thus deterred late injury to the soybeans.

Hartsells loam. The 0.8 kg/ha rate reduced soybean vigor on June 22 (Table 4, page 25). These soybeans recovered by July 6, but by this time, soybeans treated with 1.1 kg/ha showed reduced vigor. None of the treatments reduced soybean stand, height, or yield. A slight increase in forage weight occurred where soybeans received the 1.7 kg/ha treatment.

The manufacturers recommend linuron at 1.3 to 2.3 kg/ha on this soil. All of the rates used were below the highest recommended rate

and consequently early injury was only slight. The high amount of organic matter in this soil apparently adsorbed considerable amounts of the herbicide from the soil solution, accounting for the lack of significant soybean response.

Falaya-Collins silt loam. The 1.1 kg/ha rate reduced soybean vigor on July 13 (Table 5, page 26). The 1.7 kg/ha rate reduced soybean vigor and stand on June 29 and July 13 and later reduced yield.

Linuron is recommended at 0.7 to 1.3 kg/ha on this soil. Early injury and yield reduction occurred at the 1.7 kg/ha rate which exceeded recommendation. This soil, while the highest in organic matter of the West Tennessee soils studied, has the highest pH. Apparently, rates exceeding 1.1 kg/ha saturated the exchange complex of the soil and thus more linuron was available in solution at the high rates. Linuron in solution is subject to leaching and soybean uptake.

Ocklochonee loam. The 1.7 kg/ha rate reduced soybean vigor on both June 29 and July 13 (Table 6, page 28). Similarly, this rate reduced soybean stand on both dates. In spite of this early injury, no reduction in yield occurred as a result of any of the treatments.

Ocklochonee loam has characteristics similar to Falaya-Collins silt loam and thus has the same recommended rates of linuron (0.7 to 1.3 kg/ha). Early injury and yield reduction occurred where linuron exceeded the highest recommended rate. In spite of a slightly lower organic matter content than the Falaya-Collins soil, the pH was also slightly lower. This allowed for more adsorption and consequently less yield reduction at the highest rate.

Loring silty clay loam. Linuron did not reduce either soybean vigor, stand, or yield on this soil (Table 7, page 29).

The manufacturer's recommended rates of linuron on this soil are 0.8 to 1.5 kg/ha.

The 1.7 kg/ha rate which exceeds the recommended rates did not cause injury or reduce yield. The low pH of this soil may have caused considerable adsorption of linuron in spite of the low organic matter content of the soil. This would make linuron unavailable to the soybeans and would thus account for the lack of injury.

The influence of linuron on soybean response, like chlorbromuron, appears to be affected most by organic matter in East Tennessee soils. Soil pH appears to have some effect in the West Tennessee soils. Figures 3 and 4 show soybean yield responses to the various rates of linuron on the various soils. In general, yields are more greatly reduced in soybeans grown in West Tennessee soils. This may be attributed to the lower organic matter content and generally higher pH of these soils. These factors are conducive to keeping linuron in the soil solution where it is available for plant uptake and leaching. Table 9 illustrates the ratio in terms of "x" of rates of linuron applied to a given soil type to manufacturer's recommended rate for a given soil type.

Metribuzin

Captina clay loam. The highest rate of metribuzin (0.8 kg/ha) reduced soybean vigor on both June 25 and July 23 (Table 1, page 20).

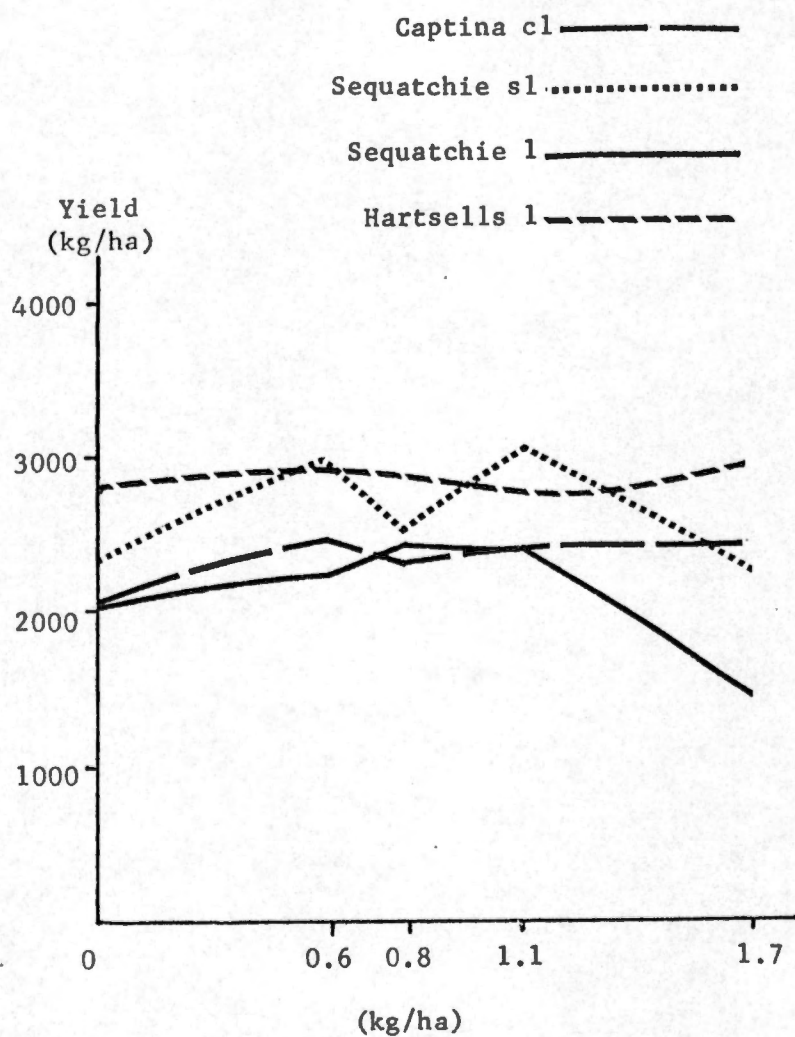


Figure 3. Influence of various rates of linuron on Captina Clay Loam, Sequatchie Sandy Loam, Sequatchie Loam, and Hartsells Loam.

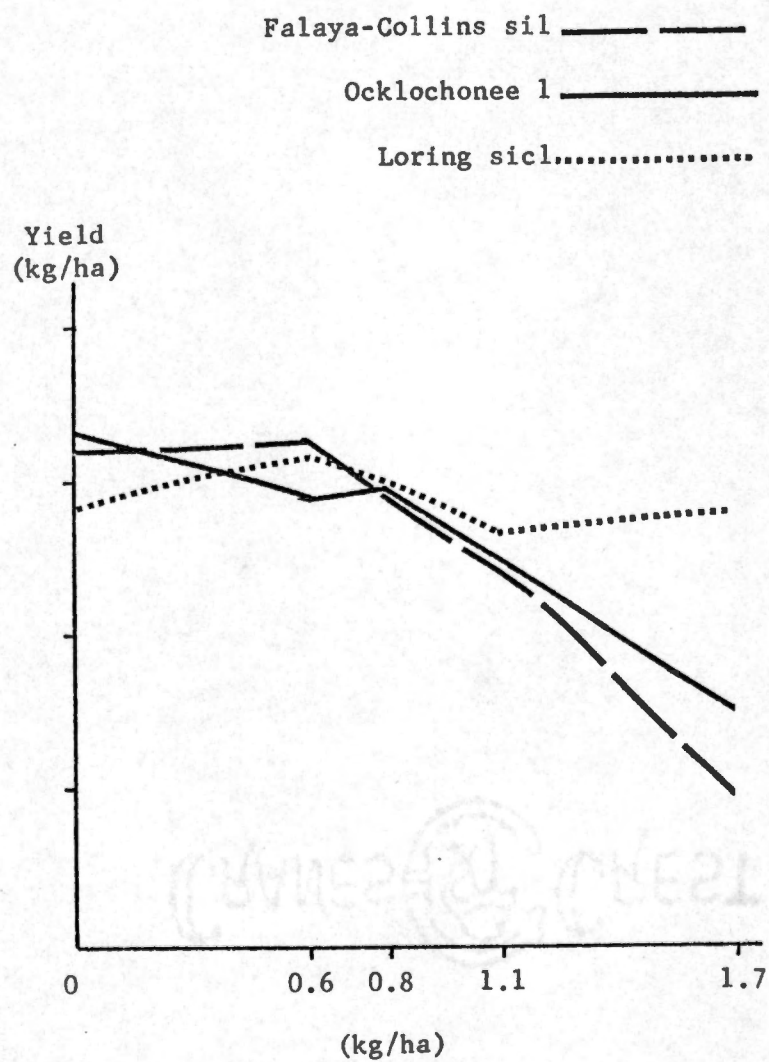


Figure 4. Influence of various rates of linuron on soybean yields on Falaya-Collins Silt Loam, Ocklochonee Loam, and Loring Silty Clay Loam.

Table 9. Ratio in Terms of "x" of Rates of Linuron Applied to a Given Soil Type to Manufacturer's Recommended Rate for the Given Soil Type

Soil Type	Recommended Rate per Soil Type (a.i. kg/ha)	Rate Applied (a.i. kg/ha)			
		0.6	0.8	1.1	1.7
Captina Clay Loam	1.5	0.4*	0.5	0.7	1.1
Sequatchie Sandy Loam	1.3	0.5	0.6	0.8	1.3
Sequatchie Loam	1.3	0.5	0.6	0.8	1.3
Hartsells Loam	2.3	0.3	0.3	0.5	0.7
Falaya-Collins Silt Loam	1.3	0.5	0.6	0.8	1.3
Ocklochonee Loam	1.3	0.5	0.6	0.8	1.3
Loring Silty Clay Loam	1.5	0.4	0.5	0.7	1.1

*Ratio in terms of "x" of rates applied to recommended rates.

None of the treatments affected soybean stand. Early injury was not severe, and consequently, the soybeans recovered without exhibiting reductions in height, forage weight, or yield.

Du Pont recommends "Lexone" at 0.6 kg/ha and Chemagro recommends "Sencor" at 0.6 to 0.7 kg/ha on Captina clay loam. No injury occurred in soybeans grown within recommended rates. The amount of organic matter was probably high enough to adsorb most of the metribuzin, thereby counteracting the effect of high pH on desorption. This would tend to keep the herbicide near the soil surface, allowing the soybean roots to grow out in an untreated area and thus recover from early injury.

Sequatchie sandy loam. The 0.8 kg/ha rate reduced soybean vigor on both June 25 and July 23 (Table 2, page 21). No stand reduction was observed at any rate. Similarly, none of the rates caused reductions in soybean height, forage weight, or yield.

Neither Du Pont nor Chemagro recommends the use of metribuzin on a coarse soil such as Sequatchie sandy loam. Slight early injury resulted where metribuzin was applied at 0.8 kg/ha, however, no reduction in yield occurred. The amount of organic matter may have been sufficient to hold the herbicide near the soil surface and away from the soybean root zone. Apparently, rainfall was not sufficient enough to cause leaching of the herbicide into the root zone.

Sequatchie loam. All rates exceeding 0.3 kg/ha reduced soybean vigor on June 25 (Table 3, page 23). By July 23, soybeans treated with 0.6 kg/ha had recovered whereas those treated with 0.4 and 0.8 kg/ha

had not. Metribuzin did not reduce stand at any of the rates. The highest rate (0.8 kg/ha) reduced height but not forage weight or yield.

Du Pont recommends "Lexone" at 0.4 kg/ha on this soil whereas Chemagro recommends "Sencor" at 0.4 to 0.6 kg/ha. Some early crop injury resulted but no yield reduction occurred. A low pH (5.0) and fairly high organic matter content probably promoted adsorption of the herbicide. With this, it could not affect the soybeans as a result of leaching or being in solution.

Hartsells loam. On June 22, the 0.6 kg/ha rate of metribuzin slightly reduced soybean vigor (Table 4, page 25). By July 6, the soybeans in this treatment recovered and no other differences in vigor were observed. No reductions were found in soybean stand and height. Forage weight showed slight increases over the check in the 0.3, 0.4, and 0.8 kg/ha treatments. The 0.4 kg/ha treatment produced greater yield when compared to the check.

The recommended rates for "Lexone" is 0.6 kg/ha and "Sencor" is 0.6 to 0.7 kg/ha on this soil. Early injury was slight and the 0.4 kg/ha rate caused an increase in yield. Ashton and Crafts (3) reported that low concentrations of triazine herbicides may cause increases in plant growth. Adsorption by soil organic matter probably caused a reduction in the concentration of metribuzin in the soil solution which would account for this effect.

Falaya-Collins silt loam. The 0.8 kg/ha rate severely reduced soybean vigor on June 29 (Table 5, page 26). By July 13, all treatments

exceeding 0.3 kg/ha reduced vigor, with severe injury occurring at the 0.6 and 0.8 kg/ha rates. The 0.8 kg/ha treatment reduced stand on June 29 which became more severe by July 13. The 0.8 kg/ha rate reduced soybean yield.

"Lexone" is recommended at 0.4 kg/ha and "Sencor" is recommended at 0.4 to 0.6 kg/ha on this soil. The high pH of this soil may have caused desorption of metribuzin at the high rates. The desorbed herbicide, being in the soil solution, would then be subject to leaching and consequently available to cause soybean injury on a continuing basis. Leached herbicides are not only in a position to be intercepted by deeper roots, but also decompose at a slower rate due to a lower temperature and reduced oxygen environment (14).

Ocklochonee loam. Treatments exceeding the 0.3 kg/ha rate reduced soybean vigor on June 29 (Table 6, page 28). On July 13, only the 0.6 and 0.8 kg/ha rates caused a reduction in vigor. The 0.8 kg/ha rate reduced stand on both dates. None of the treatments reduced yield.

The recommended rate of "Lexone" is 0.4 kg/ha and "Sencor" is 0.4 to 0.6 kg/ha on this soil. Early soybean injury occurred in the recommended range of rates but yields were not affected. This may be attributed to the increased adsorption effect caused by low pH and a slow percolation rate due to the low percentage of large and small pores in Ocklochonee loam. Slow percolation would retard leaching of the herbicide into the root zone where it could be taken up by the soybeans.

Loring silty clay loam. All treatments exceeding the 0.3 kg/ha rate caused vigor reduction on June 29 and July 13 (Table 7, page 29). No stand reduction occurred on either date. The 0.8 kg/ha rate reduced soybean yield.

"Lexone" is recommended at 0.6 kg/ha and "Sencor" at 0.6 to 0.7 kg/ha on this soil. Early soybean injury occurred in the recommended rate range but yields were not reduced. In spite of the fine texture, this soil was found to have the highest percentage of large pores of the West Tennessee soils studied. Leaching of this herbicide might have been the principle cause of soybean injury and yield reduction at the high rate. The low organic matter content of this soil would also be conducive to leaching.

The influence of metribuzin on soybean response was affected by soil organic matter in East Tennessee (Figure 5). Higher amounts of organic matter resulted in lower crop injury. In West Tennessee soils, metribuzin activity appears to be influenced somewhat by pH. Figure 6 illustrates soybean yield response to various rates of metribuzin on the West Tennessee soils. As the pH increases, herbicide desorption from soil colloids increases, freeing the herbicide to move through the soil in solution. Coble and Schrader (10) state that soybean tolerance to metribuzin is positional, i.e., the closer metribuzin is to the soybean root zone, the more injury may result. Table 10 illustrates the ratio in terms of "x" of rates of metribuzin applied to a given soil type to manufacturer's recommended rate for the given soil type.

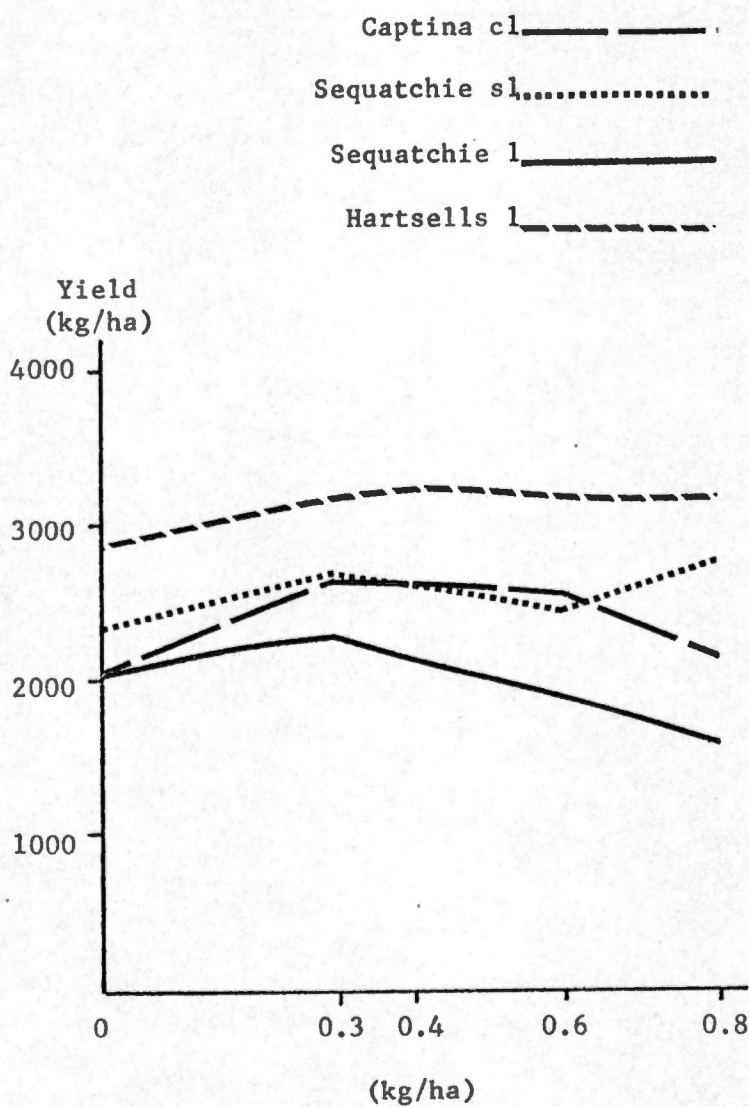


Figure 5. Influence of various rates of metribuzin on Captina Clay Loam, Sequatchie Sandy Loam, Sequatchie Loam, and Hartsells Loam.

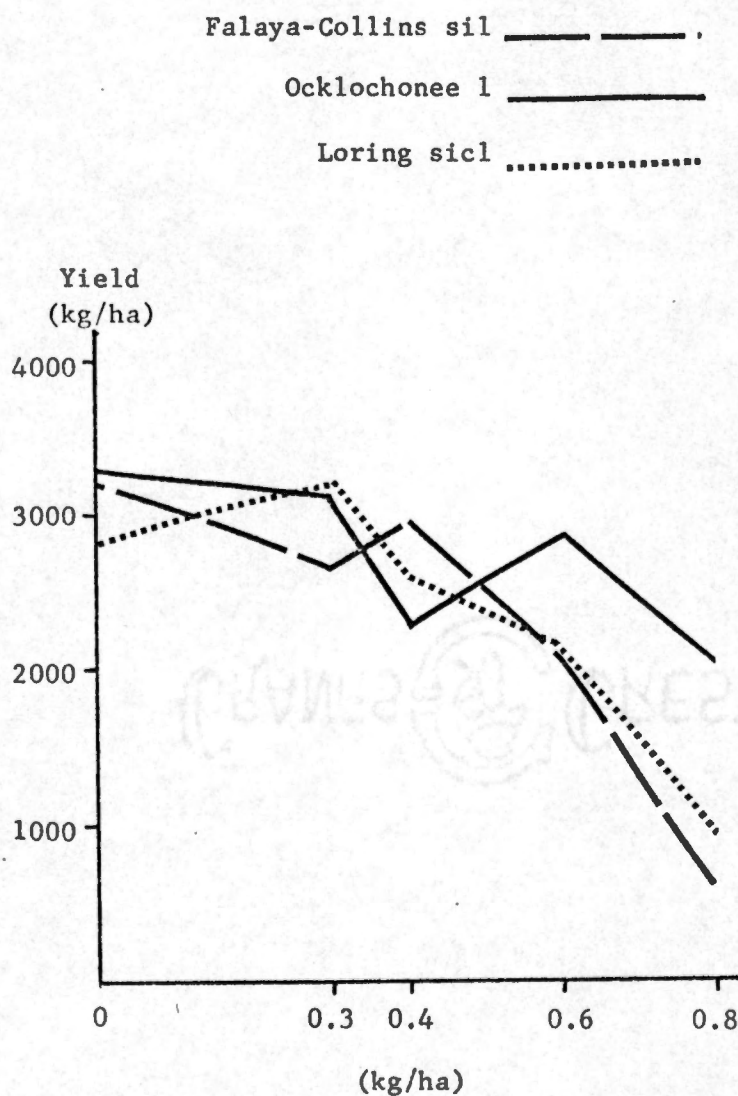


Figure 6. Influence of various rates of metribuzin on Falaya-Collins Silt Loam, Ocklochonee Loam, and Loring Silty Clay Loam.

Table 10. Ratio in Terms of "x" of Rates of Metribuzin Applied to a Given Soil Type to Manufacturer's Recommended Rate for the Given Soil Type

Soil Type	Recommended Rate per Soil Type (a.i. kg/ha)		Rate Applied (a.i. kg/ha)					
			0.3		0.4		0.6	
	Du Pont	Chemagro	Du P.*	Chm.**	Du P.	Chm.	Du P.	Chm.
Captina Clay Loam	0.6	0.7	0.5	0.4	0.7	0.6	1.0	0.9
Sequatchie Sandy Loam	-	-						
Sequatchie Loam	0.4	0.6	0.8	0.5	1.0	0.7	1.5	1.0
Hartsells Loam	0.6	0.7	0.5	0.4	0.7	0.6	1.0	0.9
Falaya-Collins silt Loam	0.4	0.6	0.8	0.5	1.0	0.7	1.5	1.0
Ocklochonee Loam	0.4	0.6	0.8	0.5	1.0	0.7	1.5	1.0
Loring Silty Clay Loam	0.6	0.7	0.5	0.4	0.7	0.6	1.0	0.9
							1.4	1.1
							2.0	1.3
							1.4	1.1
							2.0	1.3
							2.0	1.3
							1.4	1.1

*Ratio in terms of "x" of rates applied to Du Pont's recommended rates.

**Ratio in terms of "x" of rates applied to Chemagro's recommended rates.

Weed Control

All of the herbicide treatments demonstrated excellent control of the weeds specified on their labels on each of the soils but Hartsells loam. At this location, all of the treatments failed to control weeds and mechanical methods were used to reduce weed-crop competition. The high soil organic matter content may be the key to this effect on Hartsells loam. Adsorption of the herbicides so decreased their availability to the weeds that no phytotoxicity was expressed.

II. LABORATORY RESEARCH

Soil Characterization

Results of characterization of the Captina clay loam, Sequatchie sandy loam, Sequatchie loam, and Hartsells loam soils are given in Table 11. The results of characterization of the Falaya-Collins silt loam, Ocklochonee loam, and Loring silty clay loam soils are given in Table 12. Each of the soil series used and their classifications are given in Table 13.

In general, the East Tennessee soils contained more organic matter than the West Tennessee soils. Hartsells loam, at the Plateau Experiment Station, contained the highest percentage of organic matter (2.8%). This high value may be attributed to heavy yearly additions of manure and corn-plant residues at this site. In contrast, Loring silty clay loam had the lowest amount of organic matter at 0.8%.

The West Tennessee soils were generally higher in pH than those of East Tennessee with the exception of the Captina clay loam.

Table 11. Selected Soil Properties of Captina Clay Loam, Sequatchie Sandy Loam, and Sequatchie Loam Soils on the Knoxville Plant Science Farm and Hartsells Loam on the Plateau Experiment Station

Properties	Soil (0-15cm)			
	Captina Clay Loam	Sequatchie Sandy Loam	Sequatchie Loam	Hartsells Loam
Organic Matter (percent)	1.8	1.9	1.2	2.8
pH	6.4	4.9	5.0	5.2
Cation-Exchange Capacity (me/100g)	7.5	4.4	7.3	8.4
Textural Components (percent)				
Sand	30.3	73.2	37.3	49.9
Silt	39.0	10.2	36.8	33.0
Clay	30.7	16.6	25.9	22.1
Large Pores (percent)	14.1	11.2	9.7	17.4
Small Pores (percent)	32.8	36.5	34.9	29.9
Bulk Density (g/cm ³)	1.4	1.4	1.4	1.3
Moisture @ Field Capacity (percent/w)	21.7	10.8	19.1	18.2
Available Water Holding Capacity (cm/cm)	0.20	0.10	0.15	0.14

Table 12. Selected Soil Properties of Falaya-Collins Silt Loam, Ocklochonee Loam, and Loring Silty Clay Loam Soils on the Milan Field Station

Properties	Soil (0-15cm)		
	Falaya-Collins Silt Loam	Ocklochonee Loam	Loring Silty Clay Loam
Organic Matter (percent)	1.0	0.9	0.8
pH	6.2	5.9	5.6
Cation-Exchange Capacity (me/100g)	10.0	5.1	7.0
Textural Components (percent)			
Sand	13.4	40.3	7.4
Silt	66.2	41.2	57.4
Clay	20.4	18.5	35.2
Large Pores (percent)	10.6	9.0	11.9
Small Pores (percent)	36.7	30.8	35.8
Bulk Density (g/cm ³)	1.3	1.4	1.3
Moisture @ Field Capacity (percent/w)	26.0	17.2	21.3
Available Water Holding Capacity (cm/cm)	0.27	0.18	0.12

Table 13. Soil Series and Their Classification

Soil Series	Classification
Captina	Typic Fragiudult, fine-silty, mixed, mesic
Collins	Aquic Udifluvent, coarse-silty, mixed, acid, thermic
Falaya	Aeric Fluvaquent, coarse-silty, mixed, acid, thermic
Hartsells	Typic Hapludult, fine-loamy, siliceous, thermic
Loring	Typic Fragiudalf, fine-silty mixed, thermic
Ocklochonee	Typic Udifluvent, coarse-loamy, siliceous, acid, thermic
Sequatchie	Humic Hapludult, fine-loamy, siliceous, thermic

Falaya-Collins silt loam had the highest cation-exchange capacity (10.0me/100g) and Sequatchie sandy loam had the lowest (4.4me/100g).

The clay content of the soils studied ranged from 35.2% for Loring silty clay loam to 16.6% for Sequatchie sandy loam.

Hartsells loam had the largest percentage of large pore space and Ocklochonee loam had the lowest. Falaya-Collins silt loam had the highest percentage of small pore space and Hartsells loam had the smallest.

The bulk density of each soil was nearly the same and the available water holding capacity was in the range expected for a given texture.

Correlations to determine the relationship between soil properties and soybean response were calculated. The r values are not given because, overall, they were quite low. However, organic matter had a high negative correlation to the rating variables and was highly and positively correlated to the height, forage weight, and soybean yield variables. Similarly, an attempt was made to run multiple regression analysis on soil properties and soybean responses. The Stepwise procedure and the Maximum R square procedure in SAS 76 resulted in low R^2 values. Organic matter was again found to have the most effect on herbicidal activity and was given as the best single variable. Organic matter and pH were found to be the best two-variable model. These results, although the values were not high, were similar to those reported by several researchers (9,11,15). The low r and R^2 values may be attributed to having only one set of soil property data for each location. Each set was run against fifty-two sets of soybean response data. A suggestion for future studies

of this type would be to obtain a separate set of soil data for each plot in each location. By doing this, more effective correlation and multiple regression analysis results should be obtained.

CHAPTER V

SUMMARY AND CONCLUSIONS

Research was carried on to:

1. Determine soybean response to various rates of chlorbromuron, linuron, and metribuzin when applied to several soil types.
2. Determine the maximum rate that can be applied to a specific soil without reducing soybean yield.
3. Correlate the most effective rate of chlorbromuron, linuron, and metribuzin for weed control and soybean tolerance to the physical properties of a soil.

The field experiment was conducted at three locations on seven soil types in 1976. Additional soil characterization work was carried on in the laboratory. Data on percent vigor reduction, percent stand reduction, plant height, forage weight, and soybean yield were collected for soybeans grown at the Knoxville Plant Science Farm and the Plateau Experiment Station. At Milan Field Station, data were collected on all parameters except plant height and forage weight.

The data generally showed that both early and late soybean injury became more severe with increasing rates of chlorbromuron on all soils except Hartsells loam. The lowest rate of 1.7 kg/ha did not cause early injury or yield reduction on any of the soils except Falaya-Collins silt loam. The 2.3 kg/ha rate did not cause significant early injury or yield reduction on any of the East Tennessee soils. It did cause yields to be reduced on each of the three West Tennessee soils. The 2.8 kg/ha rate

caused no injury or yield reduction on Captina clay loam and Hartsells loam. Early injury was slight on Sequatchie sandy loam but yields were not reduced. Early injury and yield reduction occurred on Sequatchie loam and on all three West Tennessee soils. The highest rate (3.4 kg/ha) did not cause injury or yield reduction on Captina clay loam or Hartsells loam. Severe early injury occurred on Sequatchie sandy loam and early injury and yield reduction occurred on Sequatchie loam. Chlorbromuron caused early injury and yield reduction on all three of the West Tennessee soils when 3.4 kg/ha was applied.

Linuron at 0.6, 0.8, and 1.1 kg/ha caused no early soybean injury or yield reduction on any of the soils studied. The 1.7 kg/ha rate caused injury and yield reduction in soybeans grown on Falaya-Collins silt loam and Ocklochonee loam. Injury without yield reduction occurred on Sequatchie sandy loam and Sequatchie loam. No injury or yield reduction occurred on Captina clay loam, Hartsells loam, or Loring silty clay loam.

Metribuzin applied at 0.3 kg/ha caused no early injury or yield reduction on any of the soils. Similarly, no injury or yield reduction occurred when the 0.4 kg/ha rate was used on Captina clay loam, Sequatchie sandy loam, Sequatchie loam, and Ocklochonee loam. Early injury and yield reduction occurred on Falaya-Collins silt loam and Loring silty clay loam. Metribuzin at 0.4 kg/ha caused an increase in yield in soybeans grown on Hartsells loam. The 0.6 kg/ha rate did not cause early injury or yield reduction in soybeans grown on Sequatchie sandy loam, Sequatchie loam or Hartsells loam. Soybeans grown on Captina clay loam, Falaya-Collins silt loam, Ocklochonee loam and Loring silty clay loam were injured by the 0.6 kg/ha rate but recovered enough so that yields

were not reduced. The 0.8 kg/ha rate caused early injury to soybeans grown on all of the soils but Hartsells loam. Yields were reduced by the 0.8 kg/ha rate of metribuzin applied on Falaya-Collins silt loam and Loring silty clay loam.

The maximum rate at which chlorbromuron may be applied without reducing yield varied from soil to soil. None of the rates used on Captina clay loam, Sequatchie sandy loam, or Hartsells loam reduced yield. On Sequatchie loam, the 2.3 kg/ha rate was the maximum rate that could be applied without a yield reduction. On Ocklochonee loam and Loring silty clay loam, the 1.7 kg/ha rate was the maximum and on Falaya-Collins silt loam, each of the rates caused a reduction in yield.

Linuron can be safely applied at all rates studied without yield reduction on all of the East Tennessee soils studied. Similarly, no reduction in yield was found at any rate on Loring silty clay loam. The 1.1 kg/ha rate is the maximum rate that can be applied on Falaya-Collins silt loam and Ocklochonee loam without reducing soybean injury.

Metribuzin did not reduce yields at the highest rate (0.8 kg/ha) on any of the East Tennessee soils, although slight early injury was shown to occur. In West Tennessee, 0.6 kg/ha was the maximum rate that could be applied without reducing yield on Falaya-Collins silt loam and Loring silty clay loam. None of the rates caused yield reduction on Ocklochonee loam.

Soil organic matter was the soil property most highly correlated with the herbicidal activity of chlorbromuron, linuron, and metribuzin. Correlations and multiple regression analysis between soil properties

and soybean responses, although values were not high, showed that organic matter was the most influential variable. Soil pH was also found to be important and to some extent, clay.

The soils of East Tennessee contained more organic matter, and this appeared to influence early injury and yield. As the organic matter content of a soil increased, herbicidal toxicity decreased. Weed control was also found to be affected in a similar manner. Hartsells loam, a soil with 2.8% organic matter, rendered every treatment useless and no weed control resulted, along with no soybean injury.

In the soils of West Tennessee, pH appears to influence herbicidal activity more than the organic matter content of the soil. West Tennessee soils are relatively low in organic matter, having 1% or less. With such a low range of organic matter present, the influence of pH is more noticeable. Injury occurred on West Tennessee soils to a greater degree as the pH increased.

Along with organic matter and pH, clay does influence herbicide activity. In Southeastern United States, kaolinite is the predominant clay mineral. This type of clay does not compete well with organic matter in the adsorption of herbicides due to its low surface area and cation-exchange capacity. In this study, clay probably had the most influence on deterring herbicide leaching.

The lack of a rainfall within seven to ten days after treatment application might have caused a reduction in herbicide phytotoxicity of all treatments. Hill et al. (19) stated that ureas may disappear via photo-decomposition if little rainfall occurs after application, and

Coble and Schrader (10) reported that metribuzin injury to soybeans was more severe when rain occurred within ten days after treatment than when no rain occurred. In years where rain occurs soon after treatment, one may expect crop injury to be more severe than that reported in this study.

Rates of chlorbromuron, linuron, and metribuzin should be within those rates recommended by the manufacturers for a given soil texture and organic matter content. If soils contain a low amount of clay and organic matter and have a high pH, then a lower rate of the three herbicides should be used to avoid crop injury.

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APPENDIX

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Table A-1. Rainfall for the Soybean Growing Season at the Knoxville Experiment Station, 1976^a

	May	June	July	August	September	October
1	1.98		0.25			0.38
2	0.74	0.25			0.74	
3		0.48			0.15	
4		0.15	4.22			
5			0.66		0.28	
6						
7	1.52			3.00		1.14
8				0.23		1.80
9			0.84			4.01
10					0.30	
11	0.71					
12	1.37					
13			0.48			
14	0.18					
15	5.08					
16	0.74		0.28	2.31		
17	0.58		1.50			0.36
18	0.61					
19	0.48	2.36				0.05
20		1.88				
21		0.15			1.09	0.76
22			2.21			
23						
24	0.64					0.30
25						1.14
26					0.20	3.35
27		1.35		0.46	0.69	
28	0.08			1.22	2.92	
29	3.15	0.18				
30	1.17	1.75		1.22	1.27	0.66
21			1.68			1.73
Total	19.03	8.55	12.12	8.43	7.64	15.86

^aData is given in cm.

Table A-2. Rainfall for the Soybean Growing Season at the Plateau Experiment Station, Crossville, 1976^a

	May	June	July	August	September	October
1	1.96	0.84			0.15	0.15
2	0.08	0.86			2.67	
3		1.55			0.15	
4		0.03	5.03			
5		0.25	2.34			
6						0.89
7	1.85		0.10	0.15		1.35
8	0.05					0.13
9						1.14
10			0.05		0.66	
11	0.20					
12						
13			1.35			
14	1.27					
15	3.68	0.51				
16	0.03		0.33	0.51		
17	0.36	0.25	1.09			0.28
18	0.84					
19	0.08	1.88				
20		1.91				1.88
21		4.60			1.78	0.23
22		0.05				
23	2.16	0.13	2.59			
24	0.15					1.04
25			0.03			3.56
26		1.14				2.87
27		0.18		0.36	0.86	
28	0.46	0.30	2.21	0.15	2.84	
29	3.76	1.60		4.88	0.15	
30	0.10	1.17	0.15		2.46	0.81
31			0.25			1.07
Total	18.03	17.25	15.52	6.05	11.72	15.40

^aData is given in cm.

Table A-3. Rainfall for the Soybean Growing Season at the Milan Field Station, 1976^a

	May	June	July	August	September	October
1	0.28	0.15		1.32		
2		3.81			0.23	
3	0.41	0.46	2.11			
4		0.08	3.25		1.19	
5			0.05		T	
6		T	T			0.79
7	1.93		0.30	0.08		
8					T	
9					0.30	
10					1.04	
11	0.13					
12						
13						
14	7.32					
15	2.41		0.74	0.10		
16	1.07	1.52	T			
17	0.25	0.25	1.83			T
18	0.99					
19		1.22				
20					0.05	2.44
21					T	T
22						
23						
24		2.46				4.32
25	T	1.24				3.81
26		0.15		0.05		0.38
27		T			1.30	
28	1.35		2.06		0.08	
29	1.45	1.60		8.15	0.71	
30		0.08	1.14		0.25	1.73
31						0.10
Total	17.59	13.02	11.48	9.70	5.15	13.57

^aData is given in cm.

VITA

John Robert Holowid was born in Meadville, Pennsylvania on July 30, 1953. He attended grammar school in Meadville and graduated from Saegertown Area High School in May 1971. While in high school, he worked for neighboring dairy farmers and was an exchange-student to Brazil.

In September of 1971 he entered the University of Pittsburgh in Pittsburgh, Pennsylvania, and in April 1975, he received his Bachelor of Science degree in Biology.

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