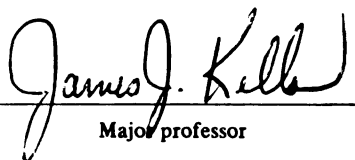




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VELVETLEAF (Abutilon theophrasti Medik.) CONTROL

AND OFF-TARGET INJURY WITH CLOMAZONE

By

Kurt David Thelen

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
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1987

ABSTRACT

VELVETLEAF (Abutilon theophrasti Medik.) CONTROL AND OFF-TARGET INJURY WITH CLOMAZONE

By

Kurt David Thelen

Field trials were conducted in 1985 and 1986 to evaluate velvetleaf control in soybeans [Glycine max (L.) Merr.] and off-target injury with clomazone [2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone]. Clomazone applied preplant incorporated or preemergence at 0.84 kg/ha provided 98% or greater velvetleaf control. Clomazone was also evaluated as an additional component in a preplant incorporated herbicide combination of trifluralin [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine] at 0.84 kg/ha plus metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one] at 0.28 kg/ha. The addition of clomazone at 0.28 kg/ha or higher significantly increased velvetleaf control compared to trifluralin plus metribuzin alone. Volatilization was detected up to 2 weeks after both surface and incorporated treatments of clomazone at 1.12 kg/ha. Volatilization was dependent on climatic conditions with rainfall increasing volatilization. There was consistently greater volatilization detected on the surface treated areas than on the incorporated areas. The rate of volatilization from surface applications was dependent on the amount of crop residue left on the

applications was dependent on the amount of crop residue left on the soil surface. The extent of volatilization detected was in the order of no-till > minimum-till > conventional-till. Wheat (Triticum aestivum L.) injury from clomazone carryover was found to be rate dependent and was greater following incorporated treatments. Physical spray particle drift following clomazone application was detected in the downwind direction at a distance of 15 m from the point of application.

[illegible]

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CHAPTER 1

REVIEW OF LITERATURE

VOLATILIZATION OF HERBICIDES

Volatilization of herbicides is a complex process that involves environmental, cultural, soil, and inherent chemical factors. Injury from the volatilization and subsequent movement of a herbicide is often difficult to distinguish from physical spray particle drift. The latter refers to the movement of airborne spray particles from the targeted area at the time of application, whereas volatilization refers to the vaporization and movement of the herbicide from the soil or leaf surface.

The importance of volatilization in applied herbicide losses can be paramount. Kearney and Kontson (48) observed that volatilization was the major mechanism of loss for butralin [4-(1,1-dimethylethyl)-N-(1-methylpropyl)-2,6-dinitrobenzenamine] and trifluralin [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine]. Draper and Crosby (21) found similar results in rice (Oryza sativa L.) fields with drepamon (S-benzyl N,N-di-sec-butylthiocarbamate). Cliath et al. (15) found volatilization was also the major mechanism of herbicide loss in irrigation applied EPTC (S-ethyl dipropyl carbamothioate) in alfalfa (Medicago sativa L.) fields.

Volatilization can enhance herbicide efficacy. Parochetti et al. (69) reported that absorption of vapors of dinitroaniline herbicides may be a more important mode of entry into plants than absorption from soil solutions. This is supported by the work of Harvey (39) who found the relative effectiveness of 12 dinitroaniline herbicides in controlling giant foxtail (Setaria faberi Herrm.) is related to their volatility and the influence of their vapors on germinating seedlings.

Volatilization of pesticides can adversely affect the environment and public health. Day et al. (18) found trifluralin contained up to 154 ppm of N-nitrosodi-n-propylamine volatile nitrosamines. Magee and Banes (58) have shown these nitrosamines to be carcinogenic in several animal species. Thus, they are now suspect human carcinogens (Lijinsky and Epstein (56)). Woodrow, et al. (95) report volatilization losses of beacon oil, a herbicide used in carrot crops, of over 90% within 3 hours after application. They concluded that these oil mixtures may contribute to the hydrocarbon emissions and ultimately to air pollution in some agricultural areas of California. Richards et al. (78) isolated 8 different herbicides from rainwater samples taken in Ohio. Injury to nontarget crop species is another adverse consequence of volatilization. Vapor injury to soybeans [Glycine max (L.) Merr.] from the volatilization of 2,4-D [(2,4-dichlorophenoxy)acetic acid] and dicamba (3,6-dichloro-2-methoxybenzoic acid) applied to corn is an example. Loss of weed control from excessive volatilization of thiocarbamate herbicides would also classify as a negative aspect of volatilization. Ogg (64) suggested that volatilization losses incurred during application and from wet

soils, account for the poor weed control sometimes observed with EPTC applied through sprinkler irrigation systems.

The importance of herbicide losses due to volatilization exemplifies the need for a greater understanding of the factors affecting the vapor loss of herbicides.

Environmental Factors

Environmental conditions present during and after herbicide application such as temperature, precipitation and wind speed affect volatilization. The initial moisture level of the soil is also a significant environmental factor affecting volatilization (2, 26, 49, 65, 70, 81). Increased temperature results in greater volatilization of herbicidal compounds (27, 30, 65). Parochetti and Hein (29) found the rate of trifluralin and benefin [N-butyl-N-ethyl-2,6-dinitro-4-(trifluoromethyl)benzenamine] volatilization to increase with increasing air and soil temperature. Behrens and Lueschen (3) discovered that increasing temperatures increased vapor injury to soybean plants exposed to dicamba treated corn (Zea mays L.) leaves. Volatilization losses of dichlobenil (2,6-dichlorobenzonitrile) were 10% at 30°C and 18% at 40°C 3 hours after application under laboratory conditions (71). The primary mechanism controlling this phenomenon is basic physical chemistry. By adding energy to the environment in the form of heat, the vapor pressure of the applied chemical is raised resulting in an increased rate of volatilization. Grover (27) demonstrated that the relationship between vapor pressure and rate of volatilization was a linear function. Thus, increased volatilization losses can be expected when applying herbicides at high ambient air

temperatures.

Precipitation also plays a role in volatilization, although the effect is not as well understood as is that of temperature. Halstead and Harvey (33) reported that rainfall following application reduced volatilization of clomazone [2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone]. However, later work by the researchers suggested an additional period of volatilization occurred following the application of 0.64 cm of irrigation to a dry soil treated 3 days prior with clomazone (32). Behrens and Lueschen found rainfall greatly reduced subsequent volatilization of dicamba (3). However, Oliver (65) found that the first addition of simulated rainfall in laboratory controlled experiments stimulated volatilization for a short time, but similar responses were not observed from subsequent rainfall applications. This indicated that initially the addition of water competes with the applied herbicide for adsorption sites on the soil. However, continued rainfall will result in the herbicide moving down through the soil profile with the water. This accounts for the initial burst of volatilization followed by a decrease in the rate of volatilization.

Perhaps the most important effect of precipitation is its effect on the moisture level of the soil before herbicide application. Halstead and Harvey (32) found the primary factor in the volatilization of clomazone to be the soil moisture level at the time application. Parochetti et al. (71) demonstrated that dichlobenil volatility increased as the soil moisture level increased from air dryness to field capacity; however, as soil moisture level increased to saturation, vapor losses remained similar to losses at field capacity. They also showed volatilization losses at field capacity were five

times greater than from air dry soil. Thus, volatilization appears to increase with increasing soil moisture levels, until the soil moisture reaches field capacity. Vapor loss in moist soil appears to be a function of the water and herbicide competing for adsorption sites on the soil. Spencer and Cliath (87) reported that vapor densities of dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa-hydro-1,4-endo,exo-5,8-dimethanonaphthalene) and lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer) in soil were greatly reduced when the soil water content decreased below about one molecular layer of water. The soil moisture level also appears to affect the movement of the applied herbicide to the soil surface. Evaporating water can accelerate volatilization of pesticides from soil via the wick effect as the pesticides are carried to the soil surface through upward water movement (88). This results in an increased herbicide concentration on the soil surface and thus greater volatilization. The work of Hance et al. (36) supports these findings as they have shown an increase in triallate [S-(2,3,3-trichloro-2-propenyl)bis(1-methylethyl)carbamothioate] volatility as soil water increases beyond that necessary to produce a monolayer in the soil. This process is not to be confused with codistillation which will be discussed in the Physical Properties section of this review.

Windspeed also affects herbicide volatilization from soils. Grover (27) found the rate of volatilization of the n-butyl ester of 2,4-D increased from 0.86 to 1.62 nmoles/cm/hr with each doubling of the flow rate of air passing over the soil surface. Increasing windspeed decreases the thickness of the still air space above the soil and also decreases the concentration or vapor density of the herbicide in the air above the soil. This accounts for the increased

volatilization loss associated with increased windspeed. Environmental conditions influence the volatilization of herbicides from soil and plant surfaces. Little can be done to control the environment; hence, we have little or no control over the climatic factors affecting volatilization after an herbicide has been applied. However, we can choose when and how to apply, thereby determining the environmental conditions at the time of application. This decision, which is a managerial or cultural determinant, also affects volatilization.

Cultural Practices

Volatilization of herbicides can be minimized if the proper management procedures are followed. Factors such as spray droplet size, rate of active ingredient, application method, tillage method and the use of spray additives can all be managed to reduce the risk of subsequent volatilization loss. Most herbicides have vapor pressures well below 10 mm Hg at 20°C, but their mode of application frequently presents a high potential for loss by evaporation (74).

Volatility and adsorption to soil or absorption into plant tissue are competing processes. Que Hee and Sutherland (76) found the rate of volatilization of iso and normal butyl esters of 2,4-D applied to pyrex glass and leaf surfaces increased directly with the available surface area/applied dose ratio (Q). As the Q ratio becomes larger, the rate of volatilization is greater than the rate of absorption. Spray droplets of 55 μ in diameter volatilized much faster than they were absorbed, whereas droplets of 255 μ in diameter were absorbed

faster than they volatilized. Que Hee and Sutherland concluded that the volatilization of both butyl esters of 2,4-D can largely be attributed to the fraction of spray droplets below 250 μ in diameter. Volatilization from surface applications is influenced by the rate of carrier water used with the herbicide. Parochetti et al. (71) found the greatest loss of soil applied diclobenil occurred during the first hour after application. They proposed that it is due to moisture added with the spray application. In addition to the volume of carrier water used, the concentration of herbicide applied also influences volatilization. Behrens and Lueschen (3) found that increasing the application rate of dicamba increased the injury to soybean bioassay plants. Vapor losses of trifluralin are directly related to rate of application (2).

Surface applications, soil incorporation, applying directly to crop surfaces or to crop residues are all examples of different application methods that can affect volatilization. Bardsley et al. (2) demonstrated that vapor loss of trifluralin decreased with subsurface placement in the soil. Halstead and Harvey (32) found soil incorporation significantly reduced volatilization of clomazone compared to preemergence surface applications. Smith and Wiese (84) found redroot pigweed (Amaranthus retroflexus L.) control using trifluralin decreased when incorporation was delayed. Similarly, Savage and Barrentine (82) found the persistence of trifluralin increased when applied by incorporation as contrasted to surface application. Oliver (65) found that only 4 to 6% of NDPA (N-nitrosodipropylamine) was volatilized when incorporated 7.5 cm in the soil compared to 50 to 60% volatilization when surface applied. Applying to crop and crop residue surfaces also affects volatilization.

Burt (10) found volatilization of atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] from soil to be less probable than volatilization from plant material. Boldt and Putnam (7) applied diclofop-methyl [methyl-2-[4-(2,4-dichlorophenoxy)phenoxy]propanoate] to living and dried leaf surfaces and found no difference in volatilization rates between these two surfaces. Halstead and Harvey (33) simulated crop residue in the field by covering plots with a layer of straw mulch. They reported that clomazone volatilization loss was greater from these mulch covered plots than from plots without a residue cover.

The use of spray additives or carriers other than water reduce volatilization. Ekins et al. (23) tested the spray additive Norback, a cross-linked polyacrylate and dacagin, a pseudo-plastic spray gel composed primarily of natural carbohydrates, for their effect on volatilization losses of the ethyl ester of 2,4-D from plant surfaces. Their results show decreased volatilization primarily due to fewer and larger spray droplets per unit area on the leaf surface. Linseed oil added to the spray mixture has been shown to reduce the volatilization of atrazine from leaf surfaces (60). Increased absorption into the plant, combined with the nonvolatile nature of linseed oil and high solubility of atrazine in linseed oil, contributed to the decreased volatilization. Verneti and Freed (92) proposed that vapor loss of EPTC and pebulate (S-propyl butylethylcarbamothioate) may be reduced by using oil as a carrier solvent instead of water.

Soils

Soil affects volatilization of herbicides through adsorption. The extent of adsorption that occurs in soil is related to the cation exchange capacity contributed by organic matter and clay. Volatilization losses are inversely related to the adsorptive potential of the soil for s-triazines (Kearney et al. (49)), prometryne (Talbert et al. (90)), dichlobenil (Parochetti et al. (71)), and propham (1-methylethyl phenylcarbamate) and chlorpropham (1-methylethyl-3-chlorophenylcarbamate), (Parochetti and Warren (72)). However, the literature is not as clear as to the effect soil adsorptive capacity has on the volatilization of dinitroaniline herbicides. Parochetti and Hein (70) found the volatilization of trifluralin decreased as cation exchange capacity increased. However, Parochetti et al. (69) were unable to find a decrease in vapor losses with increasing adsorptive capacity for substituted dinitroanilines.

The adsorptive capacity of soils can be divided into an organic fraction and a clay fraction. Walker (93) found that by adding small amounts of coextracted plant materials he could greatly reduce the rate of atrazine and linuron [$N'-(3,4\text{-dichlorophenyl})\text{-N-methoxy-N-methylurea}$] volatilization from aluminum planchets. Spencer (86) found the vapor density of dieldrin to be inversely related to organic matter content in 5 different soils tested. Osgerby (67) reported that it is now generally accepted that the best correlation between herbicide

adsorption and soil adsorptive capacity involves the soil organic matter content. He further reported that exceptions to this are largely where the herbicide exists in a pronouncedly ionic form and, consequently, the clay fraction can play a more significant role. In addition, Spencer found clay to be of minor importance in the adsorption of nonpolar compounds (86). Koren et al. (52) further support these findings with their work involving thiocarbamates. They found a correlation between adsorption and organic matter content but not for adsorption and clay content. They further propose that since organic matter content in the soil is the main factor affecting adsorption, it is obvious that any other soil property which is correlated with organic matter also may be correlated with adsorption.

Herbicide movement through the soil via the soil water is another soil factor affecting volatilization. Upward movement of water due to capillary flow and evaporation can accelerate volatilization by carrying herbicides to the soil surface where they may volatilize immediately or after remoistening of the soil (88). Acree et al. (1) and Bowman et al. (8) originally proposed that herbicides evaporated by co-distillation with evaporating water. This theory has now been widely refuted. Osgerby (67) stated that the main role of soil water in facilitating volatilization is to convey the herbicide to the soil surface, where the herbicide can evaporate. He further states that once moved to the surface, the herbicide evaporates by molecular diffusion and not by distillation. Guenzi and Beard (30) found lindane and DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane] evaporated from wet soil with no net water loss. These results would not be compatible with the codistillation theory.

Chemical and Physical Properties

Vapor pressure is the most important parameter governing the vapor behavior of herbicides and other pesticides. This statement proposed by Grover et al. (29) illustrates how important inherent chemical and physical properties of a herbicide are on the herbicides potential for volatilization loss. Although volatilization from the soil involves many soil, environmental, chemical and physical properties, Jacques and Harvey (46) found that, in general, as vapor pressure increased volatilization increased for dinitroaniline herbicides. Care must be taken when making herbicide comparisons based on vapor pressure. Hamilton (35) calculated the vapor pressures of three different 2,4-D esters. He found ten fold differences between his and published vapor pressures. Grover et al. (29) found his calculated vapor pressure for triallate was higher by a factor of 1.6 than that reported in the literature.

By changing the formulation of triallate from an emulsifiable concentrate to a granular form Hance et al. (36) reduced volatilization on a wet soil. Gray and Weierich (26) found very little loss of EPTC applied as granules to a dry soil. However, when the material was applied as a spray, about 20% of the applied EPTC was lost in the 10 minutes it took to dry. Granular and wettable powder formulations of clomazone have also been shown to result in less volatilization relative to emulsifiable concentrate formulations. However, granular

forms are not always less volatile. Parochetti and Warren (72) observed that two times as much protham volatilized from granular applications made to the soil than from spray formulations. Behrens and Lueshen (3) found the magnitude of volatilization suppression achieved in the laboratory with granular formulations was not enough to adequately eliminate dicamba vapor drift. Osgerby (67) proposed that soils act as a chromatography column and that it is to be expected that eventually the herbicide will become separated from the formulation additives, making any beneficial effect short-lived under field conditions. This led him to conclude that granular forms could enhance weed control in soils of low adsorptivity but that in highly adsorptive soils a decrease in the level of weed control could result.

Turner et al. (91) achieved a five fold decrease in the rate of volatilization of chlorprotham when applied in a microencapsulated form as compared to the emulsion form. Grover (28) found up to a 400 fold decrease in 2,4-D volatility using the amine salt formulation as opposed to the ester formulations. He also found a 56 fold increase in the rate of volatilization for the iso-propyl ester of 2,4-D over the iso-octyl ester. Que Hee and Sutherland (75) explain the latter phenomenon with their observation that the increase in volatilization associated with the different esters of 2,4-D are inversely related to chain length. In addition, they also found that the vapor drift for 2,4-D compounds can be essentially eliminated by the use of amine salts instead of esters.

VELVETLEAF COMPETITION AND CONTROL IN SOYBEANS

Velvetleaf originates from China where it was once an important fiber crop (55). It is believed to have been introduced into the United States from England, sometime before 1750. In England it was also cultivated as a fiber producing crop. Velvetleaf continued to be spread across the U.S. as a fiber crop throughout the 19th century, although there were conflicting reports regarding its benefits as a crop versus its detriments as a weed.

Today velvetleaf is a major weed affecting agricultural crops in the United States between the latitudes of 32° and 45° North. Spencer (85) estimates the economic loss associated with velvetleaf infestations in corn and soybeans in the United States to be 343 million dollars annually.

Ecology and Competition

The competitive nature of velvetleaf can be attributed to many biological factors. Chandler and Dale (14) found that velvetleaf produced an average of 17,000 seeds per plant. Dale (17) found no difference in germination rate, number of plants emerged and fresh weight per plant for velvetleaf seeds planted at depths from 1 to 7.5 cm.. Khedir and Roeth (50) reported similar findings from observations made in a continuous corn field located in Hamilton county Nebraska.

They found an average of 44 million viable velvetleaf seeds per hectare in 1977 and 57 million in 1978.

Velvetleaf competes aggressively with agronomic crops. Oliver (66) found that although soybeans are more competitive than velvetleaf during the early growth stages, by 8 to 10 weeks after emergence velvetleaf competition reduces soybean growth and development. He reported yield reductions of 27% in soybeans competing full season with velvetleaf at densities of one plant per 30 cm. of crop row for early plantings and reductions of 14% for later plantings. He theorized that the competitive difference was due to the short-day photoperiodic response of velvetleaf. This is supported by the work of Hagwood et al. (31) who found that velvetleaf emerging 21 and 23 days after soybean emergence did not reduce crop growth or yield. They also reported that velvetleaf densities ranging from 2.5 to 40 plants per m² caused reductions in the dry weight of soybean leaves, stems, roots, pods, and seeds. Dekker and Meggitt (19) also reported reductions in soybean dry weight and seed yield as well as a decrease in the number of flowering nodes per plant, with the presence of low populations of velvetleaf. They suggested that this evidence could support an hypothesis implicating selective interference by means of soybean reproductive organ abortion or one implicating interference with soybean water relations or both.

The response of the velvetleaf plant to soybean competition further exemplifies its competitive nature. Higgins et al. (43) found that velvetleaf plants under competition with soybeans developed less leaf area and less dry matter than velvetleaf grown in a monoculture. However, the velvetleaf responded to competition by increasing

reproductive growth relative to vegetative growth. Dekker and Meggitt (20) reported that velvetleaf has the adaptive ability of differential mortality at different plant populations. Soybeans lack this ability which results in smaller, less productive soybean plants. Velvetleaf can also be detrimental to soybeans by serving as a wild host for fungal parasites. Hepperby et al. (41) found both Colletotrichum dematium var. truncata and Phomopsis sojae isolated from velvetleaf to be highly pathogenic to soybean seeds and pods. They further stated that the role of velvetleaf as an inoculum source for seed decay should not be underestimated.

A differential response to chilling temperatures is another mechanism of velvetleaf competition. Patterson (73) reported that chilling reduced leaf production and leaf area expansion of velvetleaf. However, the weeds recovered more rapidly and more completely than cotton after cessation of the chilling treatment.

Allelopathy

Allelopathy has recently been identified as a possible component in velvetleaf competition. Colton and Einhellig (16) concluded from their work in this area that the allelopathic potential attributed to velvetleaf must be considered as a component in the weeds interference with field crops. Bhowmik and Doll (5) reported reductions in soybean shoot weights and root growth when grown in soil containing velvetleaf residues under greenhouse conditions. In the field, they reported 14% yield reductions from soybean plots containing velvetleaf residues. They also reported that under aerobic conditions the toxins appeared to

be degraded faster and caused less injury than under anaerobic conditions. Velvetleaf has been reported to reduce nitrogen uptake in soybeans and phosphorus uptake in corn (Bhowmik and Doll (5)). Colton and Einhellig (16) quantified leaf chlorophyll from soybean plants 7 days after treatment with velvetleaf extract dilutions and found reduction in chlorophyll a, chlorophyll b and total chlorophyll levels. They also stated that the collective data on diffusive resistance, leaf water potential and leaf water content demonstrate that inhibitors in velvetleaf cause a water stress in soybean plants which parallels reduced growth. Sterling and Putnam (89) found exudates from glandular trichomes of velvetleaf to be phytotoxic to cress (Lepidium sativum L. 'Curly') grown in petri dishes and in autoclaved soil. However, the glandular trichome exudates did not appear to play a role in the interference that velvetleaf imposes on crops in the field.

Although soybeans are sensitive to interference from velvetleaf they in turn compete by inhibiting velvetleaf growth. Rose and Burnside (79) found that exudates from the roots of soybeans grown in sand reduced the dry weight of 4-week old velvetleaf an average of 15%. Undiluted soybean extracts slowed germination and dry weight accumulation of 6-day old velvetleaf. The researchers also found the incorporation of 1% ground soybean dry matter into Sharpsburg silty clay loam inhibited germination and dry weight of greenhouse grown velvetleaf an average of 46% each. Benzyl isothiocyanate (BITC) extracted from mature papaya (Carica papaya) seeds at concentrations of 6×10^{-4} M has been shown to completely inhibit germination of velvetleaf seeds (Wolf et al. (94)). BITC applied to etiolated seedlings at concentrations of 4×10^{-4} caused complete histolysis.

However, the application of these naturally occurring allelopathic chemicals alone has not yet successfully controlled velvetleaf in field crops at the commercial level.

Velvetleaf Control

Higgins et al. (42) found that stress to soybeans was significantly reduced when velvetleaf competition was terminated within 5.5 weeks after emergence. This is supported by Oliver (66) who found that 8 to 10 weeks after weed and crop emergence, continued velvetleaf stress will result in soybean yield reduction. These findings demonstrate the advantage obtained by controlling velvetleaf populations in soybean fields. Mechanical cultivation, hand labor, and herbicides are all currently employed for velvetleaf control. Tillage used in conjunction with herbicides is the most common method of controlling velvetleaf in field crops.

Frye et al. (25) found that trifluralin at 0.75 kg/ha combined with metribuzen [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one] at 0.42 kg/ha was the most effective combination for controlling velvetleaf among the dinitroaniline metribuzin combinations he tested. They found velvetleaf control was greatly enhanced by combining 0.42 kg/ha of metribuzin with any of the currently used dinitroaniline herbicides. Ndon and Harvey (62) reported that of eight weed species studied, velvetleaf was the most tolerant to trifluralin. This explains the marked increase in velvetleaf control obtained by the addition of metribuzin. Hatzios (40) found that metribuzin at concentrations as low as 1 μ M inhibited the ability of isolated

velvetleaf cells to fix radio labelled CO_2 by 80% or more after as little as 30 minutes of incubation time. He also found that metribuzin inhibited lipid synthesis in the leaf cells of velvetleaf.

Cantwell and Slife (11) and Carlson et al. (13) reported excellent velvetleaf control with soil applications of imazethapyr [(+)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid]. Sanborn et al. (80) also achieved excellent control of velvetleaf with imazethapyr when applied at a rate of 0.07 kg/ha. Imazaquin [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid] was found to provide excellent control of velvetleaf when soil applied (Landwehr and Kapusta (53)). Nau et al. (61) reported 90% or greater velvetleaf control with soil incorporated treatments of imazaquin but control tended to be less with preemergence treatments. Sulfonyl urea herbicides have also been examined for velvetleaf control. Flanigan et al. (24) reported that a 1:16 ratio of chlorimuron ethyl [2-[[[4-chloro-6-methoxy-2-pyrimidinyl]amino]carbonyl]amino]sulfonyl]benzoic acid] and linuron provided excellent velvetleaf control applied preemergence at a rate of 0.56 kg/ha.

Kapusta (47) found that clomazone afforded complete control of velvetleaf when applied preemergence at a rate of 0.28 kg/ha. Halverson et al. (34) and Brown et al. (9) also reported excellent control of velvetleaf with clomazone. Ohman et al. (63) reported 88% velvetleaf control when clomazone was applied at 0.56 kg/ha. With the addition of metribuzin at 0.12 kg/ha, velvetleaf control increased to 94%. Bellman et al. (4) also examined clomazone in combination with other herbicides. They reported 90% or greater control when clomazone

was combined with metribuzin, linuron, or chloramben (3-amino-2,5-dichlorobenzoic acid).

Since the establishment of herbicides such as bentazon [3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide], acifluorfen [5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid]] and, more recently, the imadazalinones, postemergence herbicide applications have become an effective means of controlling broadleaf weeds in soybeans.

Ilnicki and Michieko (45) and Lange et al. (54) reported excellent velvetleaf control with postemergence applications of bentazon at 1.12 kg/ha. Bentazon at a rate of 1.12 kg/ha provided significantly greater velvetleaf control than a 0.6 kg/ha rate during each year of a 2 year field study (Harrison et al. (38)). The researchers also compared bentazon combinations when applied with petroleum oil concentrate or soybean oil concentrate. They reported that there was no difference between the oils in the ability to enhance velvetleaf control with bentazon. Owen (68) compared 10-34-0 fluid fertilizer with crop oil concentrate (COC) as an additive with bentazon acifluorfen herbicide combinations. He reported that the addition of the fluid fertilizer did not significantly improve velvetleaf control as compared to the addition of COC. Lueschen and Hoverstead (57) reported that 28% nitrogen solution, or COC plus 28% N solution, or ammonium sulfate, with bentazon-acifluorfen combinations controlled velvetleaf more effectively than did a 10-34-0 fluid fertilizer addition. However, Koppatschek et al. (51) reported that velvetleaf control could be improved when either 28% N solution, ammonium sulfate, or 10-34-0 were used in place of COC with bentazon-acifluorfen

herbicide combinations. Mohan and Rathmann (59) substituted 1 gallon of 28% N fertilizer solution for COC with bentazon-acifluorfen herbicide combinations and reported a significant increase in velvetleaf control.

Acifluorfen, used in conjunction with mefluidide [N-[2,4-dimethyl-5-[[trifluoromethyl)sulfonyl]amino]phenyl]acetamide], has been found to control velvetleaf. Hargroder et al. (37) applied mefluidide (0.14 to 0.28 kg/ha) to soybeans infested with velvetleaf. This was followed 7 days later by an application of acifluorfen. They reported 90% or greater control of 7 to 20 cm velvetleaf and 80% or greater control of 25 to 45 cm velvetleaf. Hook and Glenn (44) found that mefluidide plus ^{14}C -acifluorfen combinations resulted in greater ^{14}C penetration into the velvetleaf tissue compared to ^{14}C -acifluorfen applied alone. Penetration was increased the most when mefluidide was applied 3 days prior to treatment with acifluorfen.

Imazaquin has also been used for velvetleaf control in soybeans with poor to inconsistent results (53, 61). Shaner and Dobson (83) found that imazaquin did not penetrate velvetleaf foliage as well as it did soybean or cocklebur. They also found velvetleaf was more tolerant of imazaquin than cocklebur (Xanthium strumarium L.). Imazethapyr however, has provided good to excellent velvetleaf control when applied postemergence (13, 12). Foliar applications with sulfonylurea herbicides have also resulted in inconsistent velvetleaf control. Eiker et al. (22) reported that it generally required rates of 12 to 16 g/ha to control velvetleaf with chlorimuron ethyl. They found that even at these relatively high rates, velvetleaf control was variable.

Recent technological advances such as rope wick and roller applicators provide a means of preventing seed production in weeds that escape conventional control measures and overtop the soybean canopy. Biniak and Aldrich (6) reported nearly complete prevention of seed production in velvetleaf treated with glyphosate [N-(phosphonomethyl)glycine] applied using a rope wick roller. Reductions in both the number of capsules and the number of seeds per capsule accounted for the decline in seed production per plant. Retzner (77) examined the retention of pipe wick applied glyphosate by greenhouse grown velvetleaf. A 5% v/v solution of glyphosate resulted in 25 μg of the herbicide retained per cm^2 of leaf surface. This compares to 165 $\mu\text{g}/\text{cm}^2$ retained with a 30% solution. Even though the test plants retained more glyphosate at the high concentration, both concentrations were equally effective in providing velvetleaf control.

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CHAPTER 2

VELVETLEAF (Abutilon theophrasti Medik.) CONTROL IN SOYBEANS [Glycine max (L.) Merr.]

ABSTRACT

Field trials were conducted in 1985 and 1986 to evaluate the efficacy of herbicide applications in soybeans for velvetleaf (Abutilon theophrasti Medik.) control. Preplant incorporated treatments of metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4h)-one] at 0.42 kg/ha or a sequential application of metribuzin at 0.28 kg/ha applied preplant incorporated followed by the same treatment applied preemergence gave significantly greater velvetleaf control than a preplant incorporated treatment of metribuzin at 0.28 kg/ha on a clay loam soil in 1985 and a loam soil in 1986. Clomazone [2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone] applied preplant incorporated or preemergence at 0.84 kg/ha provided 98% or greater velvetleaf control. Clomazone was also evaluated as an additional component in a preplant incorporated herbicide combination of trifluralin [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzamine] (0.84 kg/ha) plus metribuzin (0.28 kg/ha). The addition of clomazone at 0.28 kg/ha or higher significantly increased velvetleaf control

compared to trifluralin plus metribuzin alone. Preemergence treatments of imazethapyr [(+)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid] at 0.105 kg/ha provided 100% velvetleaf control. Chlorimuron ethyl [2-[[[4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid] combined with linuron [N'-(3,4-dichlorophenyl)-N-methoxy-N-methylurea] at a 12:1 or 16:1 ratio or metribuzin at a 6:1 or 10:1 ratio provided significantly greater velvetleaf control than metribuzin or linuron applied alone. Postemergence treatments of bentazon [3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] (0.84 kg/ha) plus either acifluorfen [5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid] (0.28 kg/ha) plus crop oil concentrate (1.17 L/ha) or chloramben [2-chloro-N,N-di-2-propenylacetamide] (3.02 kg/ha) plus crop oil concentrate (2.34 L/ha) gave greater control of 2 to 5 cm tall velvetleaf than bentazon (0.84 kg/ha) plus crop oil concentrate (2.34 L/ha) alone. Bentazon in combination with 28% nitrogen solution (urea-ammonium nitrate) at 9.5 L/ha provided greater velvetleaf control than bentazon in combination with crop oil concentrate in 1986.

INTRODUCTION

Velvetleaf has become a major weed affecting soybean crops in the United States between the latitudes of 32° and 45° North. An estimated 1/3 of all soybeans grown in the United States are infested with velvetleaf. This amounts to approximately 23 million acres with an estimated minimum control cost of 229 million dollars annually (26). In Michigan, soybeans growers recently identified velvetleaf as the number one weed control problem in soybeans (12)

Velvetleaf competes aggressively with soybeans. This weed produces an average of 17,000 seeds per plant (5), and germinates equally well from planting depths ranging from 1 to 7.5 cm (6). Soybean yield reductions of up to 27% have been reported for velvetleaf densities of one plant per 30 cm of crop row (23). However, stress to soybean crops can be significantly reduced when velvetleaf competition is eliminated within 5 1/2 weeks after emergence (13).

There are currently a number of herbicides available for soil and foliar treatments to control velvetleaf in soybeans. Herbicide combinations of trifluralin and metribuzin have been shown to control velvetleaf (9). Imazaquin [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid] (21) and imazethapyr (3, 4, 25) also control velvetleaf when applied to the soil. Sulfonyl urea herbicides have also been examined for velvetleaf control. Chlorimuron ethyl and linuron at a 1:16 ratio applied at .56

kg/ha has been shown to effectively control velvetleaf (8). Clomazone alone (2, 10, 16, 22) or in combination with metribuzin (1, 22) or linuron or chloramben (1) has also been reported to provide excellent control of velvetleaf.

Postemergence applications of bentazon (15, 18) and bentazon-acifluorfen combinations (24) are effective in controlling velvetleaf. The use of fertilizer solution additives including 28% liquid nitrogen, di-ammonium phosphate (10-34-0), and ammonium sulfate $[(\text{NH}_4)_2\text{SO}_4]$ have been examined with bentazon and bentazon-acifluorfen combinations. There are conflicting reports in the literature regarding the ability of fertilizer solutions to enhance velvetleaf control and research in this area is currently inconclusive. However, of these additives 28% nitrogen solution or ammonium sulfate appear to provide a greater increase in velvetleaf control than does 10-34-0 (19, 20). Acifluorfen used in conjunction with mefluidide $[\text{N}-[2,4\text{-dimethyl-5-}[(\text{trifluoromethyl})\text{sulfonyl}]\text{amino}]\text{phenyl}]\text{acetamide}]$ has also been found to control velvetleaf (11, 14). Imazethapyr applied postemergence has provided good to excellent velvetleaf control. However, postemergence velvetleaf control with imazaquin or chlorimuron ethyl has been inconsistent (7, 17, 21).

The objectives of this study were to evaluate herbicide strategies for velvetleaf control in soybeans including preplant incorporated, preemergence, and postemergence herbicide treatments.

MATERIALS AND METHODS

Field trials were conducted in Ingham County in 1985 and in Clinton and Eaton County in 1986 to evaluate the efficacy of herbicide treatments for velvetleaf control in soybeans. All treatments were applied with a compressed air, tractor mounted sprayer using 730308¹ flat fan nozzles. Preplant incorporated and preemergence treatments were applied at a spray volume of 215 L/ha, and a pressure of 207 kPa. All postemergence treatments were applied at 345 kPa with a spray volume of 280 L/ha. In addition to fertilizer solutions, additives used with postemergence treatments included crop oil concentrate² (COC) and various surfactants^{3,4}.

Plot size was four 76 cm wide rows by 7.6 or 12 m long. The soybean variety used was Corsoy 79 at the Ingham and Eaton County sites

¹Spraying Systems Co., Wheaton IL.

²Herbimax - Registered trademark of Union Carbide Corp., manufactured for: Loveland Industries, Inc., Loveland, Colorado 80537 (83% light paraffinic distillate, odorless aliphatic petroleum solvent, 17% mono- and diesters of omega hydroxypoly oxyethylene).

³X-77 - Registered trademark of Chevron Chemical Company, San Francisco, CA 94120 (functioning agents: alkylaryl polyethylene, glycols, free fatty acids, and isopropanol).

⁴Triton Ag-98 - Manufactured by Rohm and Haas Company, Philadelphia, PA 19105

and SRF 250 at the Clinton County location. All trials were designed as a randomized complete block containing three replications.

Weed control and soybean injury were determined by visual observations. Evaluations were subjected to analysis of variance and treatment mean comparisons were made using Duncan's multiple range test at the 0.05 level of significance.

Ingham County. The site of the 1985 velvetleaf control study consisted of Capac and Colwood clay loam soils, with a pH of 6.5 and an organic matter content of 2.5%. The site was fallow the previous year and had a high natural population of velvetleaf. The field was moldboard plowed the fall of 1985, and disked once in early May of 1986. On May 23, the site was tilled with a danish-tine harrow equipped with rolling baskets⁵ and hand seeded to velvetleaf at a rate of 4.2 kg/ha. An additional pass with the harrow was done to incorporate the velvetleaf seed. The preplant incorporated treatments were then applied and immediately incorporated with a danish-tine harrow. The incorporation implement was adjusted to a depth of 7 cm. Preemergence treatments were applied May 23 immediately after planting. Postemergence applications were made 28 days after planting on June 20. The soybeans were in the 2nd trifoliate stage of development and the velvetleaf were in the 2 to 4 leaf stage, 2.5 to 5 cm tall at the time of application.

Clinton County. The soil at the 1986 velvetleaf control study was a Blount loam, with a pH of 7.1 and an organic matter content of 2.4%.

⁵Triple K-Kongskilde Mfg. Co. Canada.

The site contained soybeans the previous year and had a high natural population of velvetleaf. The field was moldboard plowed the fall of 1985 and the seed bed was prepared the spring of 1986 by disking and field cultivating. The preplant incorporated treatments were applied on May 31, 1986 and immediately incorporated as described above. The field was planted on May 31, and the preemergence treatments were applied immediately after planting. Postemergence applications were made on June 25, 1986. The soybeans were in the 1st trifoliate stage and the velvetleaf were in the 3 to 4 leaf stage and 5 cm tall at the time of application. All treatments at this site received a mechanical cultivation on July 3, 1986.

Eaton County. This study, also conducted in 1986 consisted of preemergence and postemergence treatments. The soil was a Capac-Marlette loam with a pH of 6.8 and an organic matter content of 3.1%. The soybeans were planted and the preemergence treatments were applied on May 13, 1986. Postemergence applications were made 36 days after planting on June 18, 1986. At this time the soybeans were in the third trifoliate stage and the velvetleaf were in the 4 to 5 leaf stage, 7 to 8 cm tall.

RESULTS AND DISCUSSION

Preplant incorporated treatments. Preplant incorporated treatments of trifluralin (0.84 kg/ha) plus metribuzin at 0.28 kg/ha provided 88% velvetleaf control in 1985 and 87% control in 1986 (Table 1). By increasing the rate of metribuzin to 0.42 kg/ha or by applying a

Table 1: Velvetleaf control in soybeans with preplant incorporated herbicide treatments.^a

Herbicide	Rate	Evaluation date ^b	
		7/11/85	7/21/86
	(kg/ha)	-----(% control)-----	
Trifluralin + metribuzin	0.84 + 0.28	88 b	87 b
Trifluralin + metribuzin	0.84 + 0.42	95 ab	95 a
Trifluralin + metribuzin + [metribuzin (PRE)]	0.84 + 0.28 + [0.28]	95 ab	95 a
Pendimethalin + imazethapyr	1.4 + 0.14	100 a	-
Pendimethalin + imazethapyr	1.4 + 0.07	-	100 a
Clomazone	0.84	100 a	99 a
Clomazone	1.12	100 a	100 a
Untreated	-	0 c	0 c

^a1985 data is from Ingham County, MI; 1986 data is from Clinton County, MI.

^bMeans within a column followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test.

sequential application of metribuzin at 0.28 kg/ha preplant incorporated followed by 0.28 kg/ha applied preemergence, a significant increase in velvetleaf control was observed.

Imazethapyr-pendimethalin herbicide combinations applied preplant incorporated provided excellent velvetleaf control (Table 1). In 1985, pendimethalin at 1.4 kg/ha plus imazethapyr at 0.14 kg/ha gave 100% velvetleaf control. In 1986, the rate of imazethapyr was reduced to 0.07 kg/ha which also provided 100% velvetleaf control.

Clomazone at 0.84 kg/ha or 1.12 kg/ha provided 98% or greater velvetleaf control when applied PPI or PRE in both years (Tables 1 and 2). Clomazone was also evaluated as an additional component in a preplant incorporated herbicide combination of trifluralin (0.84 kg/ha) plus metribuzin (0.28 kg/ha). The addition of clomazone at 0.28 kg/ha or higher significantly increased velvetleaf control compared to trifluralin plus metribuzin alone for both years of the study (Figures 1 and 2). In 1986, clomazone at 0.07 kg/ha significantly increased velvetleaf control with a visual rating of 94%. These results indicate that low rates of clomazone will effectively increase velvetleaf control when used in conjunction with standard herbicide combinations.

Preemergence treatments. Preemergence treatments of alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl)acetamide] (2.24 kg/ha) combined with metribuzin or chloramben were evaluated for velvetleaf control (Table 2). In 1985, metribuzin provided 95% velvetleaf control at 0.28 kg/ha and 100% control at 0.42 kg/ha. Optimal weather conditions present during the spring of 1985 appear to have contributed to the excellent control achieved with these treatments. In 1986, metribuzin at 0.42 kg/ha resulted in 90% velvetleaf control.

Table 2: Velvetleaf control in soybeans with preemergence herbicide treatments.^a

Herbicide	Rate	Evaluation date ^b	
		7/11/85	7/21/86
	(kg/ha)	----(% control)-----	
Alachlor + metribuzin	2.24 + 0.28	95 a	-
Alachlor + metribuzin	2.24 + 0.42	100 a	90 b
Alachlor + chloramben	2.24 + 2.02	97 a	93 ab
Alachlor + chloramben + metribuzin	2.24 + 2.02 + 0.42	100 a	96 ab
Alachlor + imazethapyr	2.24 + 0.105	100 a	100 a
Alachlor + imazaquin	2.24 + 0.14	-	98 ab
Alachlor + imazaquin	2.24 + 0.21	73 b	-
Clomazone	0.84	100 a	99 ab
Clomazone	1.12	100 a	100 a
Untreated	-	0 c	0 c

^a1985 data is from Ingham County, MI; 1986 data is from Clinton County, MI.

^bMeans within a column followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test.

Figure 1. Velvetleaf control with clomazone combined with trifluralin (0.84 kg/ha) plus metribuzin (0.28 kg/ha) PPI 1985. Lower data line represents the velvetleaf control obtained without the addition of clomazone.

JULY 21 1986
VELVETLEAF CONTROL
(%)

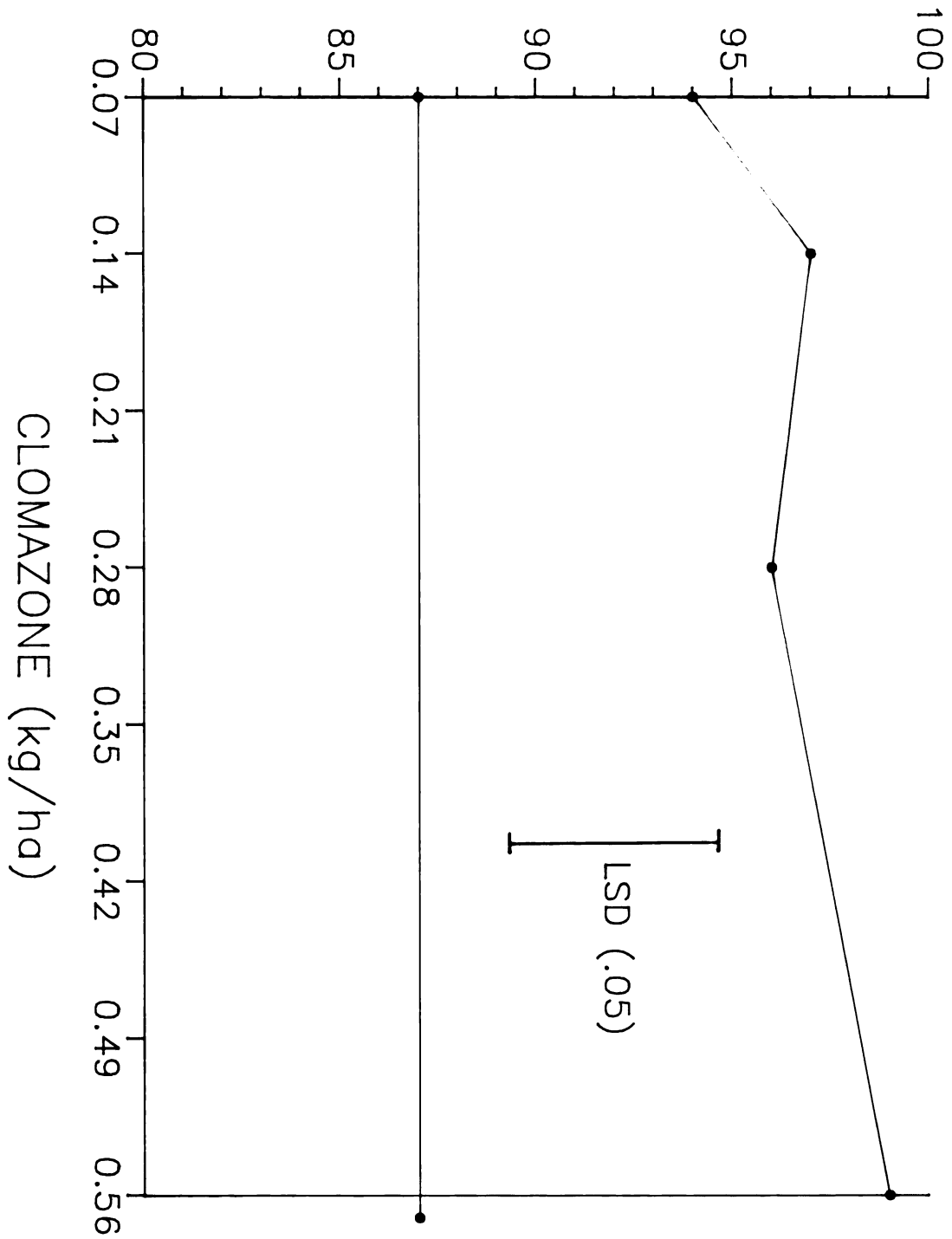
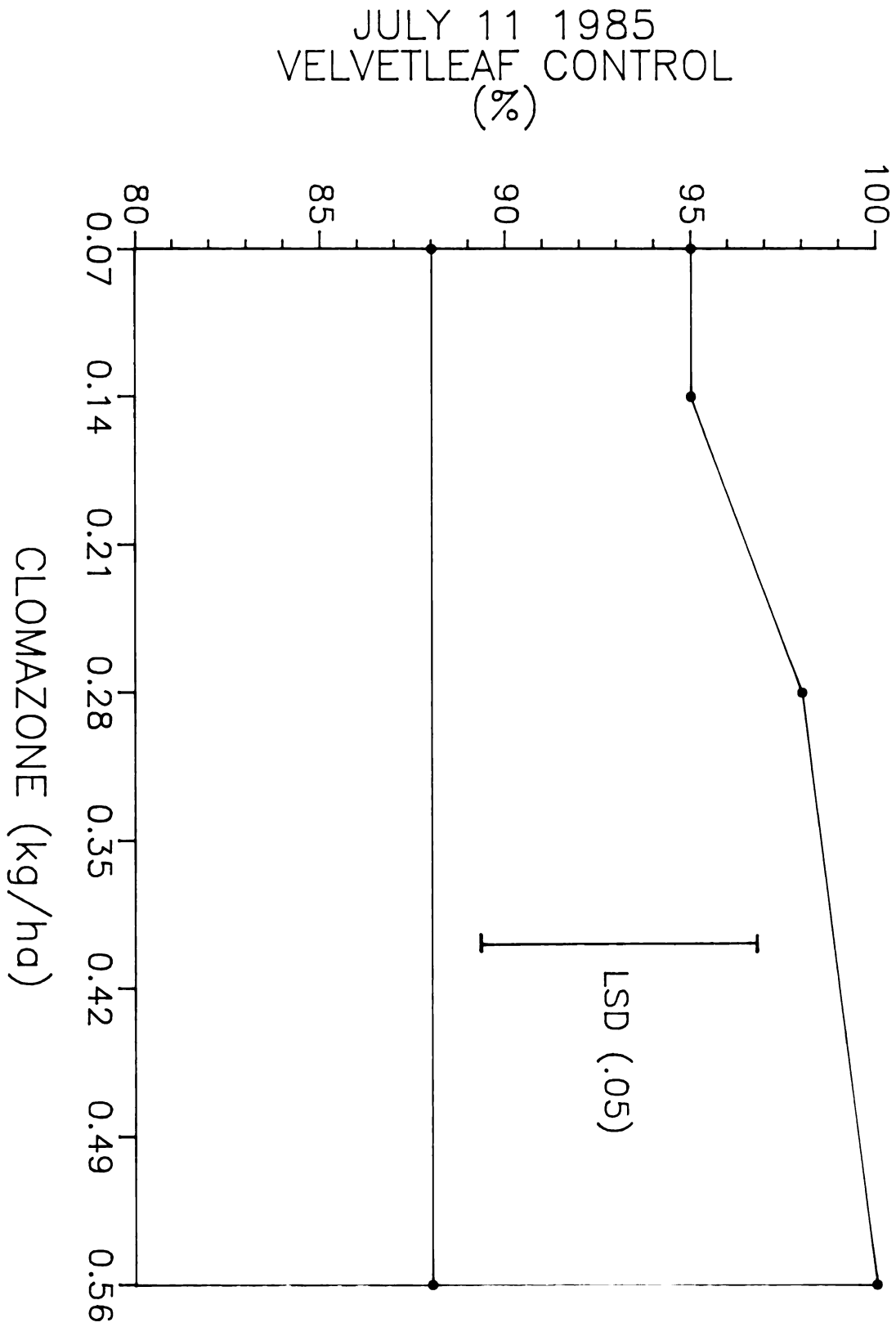


Figure 2. Velvetleaf control with clomazone combined with trifluralin (0.84 kg/ha) plus metribuzin (0.28 kg/ha) PPI 1986. Lower data line represents velvetleaf control without the addition of clomazone.



Chloramben (2.02 kg/ha) and chloramben (2.02 kg/ha) plus metribuzin (0.42 kg/ha) provided 93% or greater velvetleaf control (Table 2).

Imazethapyr at 0.105 kg/ha applied preemergence gave 100% control of velvetleaf in both years of the study (Table 2). The results obtained with imazaquin were inconsistent. In 1986, imazaquin at 0.14 kg/ha gave 98% velvetleaf control. However, in 1985 a higher 0.21 kg/ha rate of imazaquin provided only 73% velvetleaf control. A possible basis for this difference in control between years may be due to rainfall patterns. In 1985, approximately 2.4 cm of rainfall fell during the three week time period following application as compared to 12 cm of rainfall during the same period in 1986. These results suggest that imazaquin applied PRE requires relatively high rates of rainfall to provide the soil incorporation necessary to ensure effective velvetleaf control.

Clomazone herbicide combinations applied preemergence were evaluated for velvetleaf control. In 1985, clomazone (0.84 kg/ha) applied alone or in combination with metribuzin (0.188 kg/ha) or chloramben (1.0 kg/ha) or linuron (.42 kg/ha) or imazethapyr (0.14 kg/ha) or chlorimuron ethyl (8.76 g/ha) provided 100% velvetleaf control. In 1986 using similar rates these same herbicide combinations resulted in 99% or greater velvetleaf control (data not shown). Clomazone was also evaluated as a third component in standard herbicide combinations applied preemergence. However, no significant increase in velvetleaf control was obtained due to the excellent control achieved by the standard herbicide combinations applied alone (data not shown).

In 1986 preemergence applications of chlorimuron ethyl plus metribuzin or linuron were evaluated for velvetleaf control in Eaton

County, Michigan (Table 3). Metribuzin at 0.42 kg/ha provided 88% velvetleaf control. However, when combined with chlorimuron ethyl at ratios of 10:1 or 6:1 applied at 0.42 kg/ha, velvetleaf control was increased significantly to 100%. Similarly, linuron at 0.84 kg/ha provided 83% velvetleaf control. Linuron plus chlorimuron ethyl at ratios of 12:1 or 16:1 at 0.84 kg/ha significantly increased velvetleaf control to 100% and 98% respectively (Table 3).

Postemergence treatments. Postemergence control of velvetleaf was evaluated at all three locations. In Ingham County (1985) and Clinton County (1986) postemergence treatments were applied 28 and 25 days after planting respectively, while the velvetleaf were in the 2 to 4 leaf stage and 2.5 to 5 cm in height. Data from treatments made at these two locations is given in table 4. Bentazon at 0.84 kg/ha plus crop oil concentrate (COC) at 2.34 L/ha provided 90% velvetleaf control in 1985. By maintaining the bentazon rate at 0.84 kg/ha and adding acifluorfen (0.28 kg/ha) plus COC (1.17 L/Ha) or chloramben (3.02 kg/ha) plus COC (2.34 L/ha) velvetleaf control increased to 98% and 100%. In 1986, 95% or greater control was achieved with all three of the above treatments. Chloramben at 3.02 kg/ha plus COC at 2.34 L/ha gave only 78% velvetleaf control in 1985. In 1986 under different environmental conditions and combined with a cultivation, 98% control was achieved. Table 4 also shows velvetleaf control obtained with postemergence treatments of bentazon and acifluorfen as affected by different additives for mid and late season rating dates in 1986. At the midseason rating bentazon (0.84 kg/ha) plus COC (2.34 L/ha) or 28% nitrogen solution (9.36 L/ha) provided 95% or greater control. By the late season rating velvetleaf control obtained with the bentazon plus

Table 3: Velvetleaf control as affected by the addition of chlorimuron-ethyl to metribuzin or linuron applied preemergence.^a

Herbicide	Rate	Evaluation date ^b
		7/10/86
	(kg/ha)	----(% control)--
Metribuzin	0.42	88 b
Metribuzin + chlorimuron-ethyl (6:1)	0.42	100 a
Metribuzin + chlorimuron-ethyl (10:1)	0.42	100 a
Linuron	0.84	83 b
Linuron + chlorimuron-ethyl (12:1)	0.84	100 a
Linuron + chlorimuron-ethyl (16:1)	0.84	98 a

^aalachlor (3.36 kg/ha) applied with all treatments.

^bMeans followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test. Data taken from Eaton County, MI.

Table 4: Mid and late season evaluations of velvetleaf control in soybeans with postemergence herbicide treatments.^a

Herbicide	Rate	Evaluation date ^b			
		7/1/85	8/1/85	7/21/86	8/13/85
	(kg/ha)	-----(% control)-----			
Bentazon + COC	0.84 + 2.34 L/ha	90 ab	77 a	95 a	78 b
Bentazon + acifluorfen + COC	0.84 + 0.28 + 1.17 L/ha	98 a	88 a	96 a	90 a
Bentazon + chloramben + COC	0.84 + 3.02 + 2.34 L/ha	100 a	93 a	100 a	100 a
Chloramben + COC	3.02 + 2.34 L/ha	78 b	98 a	99 a	97 a
Bentazon + 28%	0.84 + 9.36 L/ha	-	-	97 a	88 ab
Acifluorfen + X-77	0.56 + .125%	-	-	96 a	91 a
Acifluorfen + 10-34-0	0.56 + 2.34 L/ha	-	-	98 a	98 a

^aalachlor (2.24 kg/ha) PRE applied to all treatments.

^bMeans within a column followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test. 1985 data is from Ingham County, MI; 1986 data is from Clinton County, MI. Velvetleaf plants were in the 2 to 4 leaf stage 2.5-5 cm in height at the time of herbicide application.

COC treatment declined to 78% as compared to 88% control for the bentazon plus 28% N solution treatment. On these small (2.5 to 5 cm tall) velvetleaf acifluorfen (0.56 kg/ha) plus X-77 (0.12% v/v) or 10-34-0 fertilizer solution (2.34 L/ha) provided excellent velvetleaf control.

The velvetleaf at the Eaton County location were 7 to 8 cm tall when the postemergence applications were made. Bentazon at 0.56 kg/ha or 1.12 kg/ha was used in combination with COC, 28% nitrogen solution, ammonium sulfate (AMS), and combinations of COC plus either of the fertilizer additives. The differences between treatment means was not significantly different at the 0.05 level of probability (Table 5). However, the trend was for greater velvetleaf control for the herbicide combinations with the high rate of bentazon. At the low rate of bentazon (0.56 kg/ha), combinations with COC (2.34 L/ha) plus 28% N (9.36 L/ha) or COC (2.34 L/ha) plus AMS (2.8 kg/ha) provided 92% velvetleaf control. This compares to 77, 83, and 70% velvetleaf control for COC, 28% N, or AMS respectively for each of the additives used alone with the 0.56 kg/ha rate of bentazon. Bentazon (1.12 kg/ha) applied alone provided 92% velvetleaf control compared to 93 to 95% control with either of the additives. With this high (1.12 kg/ha) rate of bentazon, efficacy appeared to be solely dependent on the bentazon as the affect of the additives was negligible.

Acifluorfen (0.56 kg/ha) plus X-77 (0.12% v/v) provided only 50% velvetleaf control on these taller (7 to 8 cm tall) velvetleaf (Table 5). Bentazon at 1.12 kg/ha plus COC (2.34 L/ha) provided 95% control. By reducing the rate of bentazon to 0.56 kg/ha and adding acifluorfen at 0.28 or 0.14 kg/ha plus COC at 1.17 L/ha, velvetleaf control

Table 5: Velvetleaf control in soybeans with postemergence herbicide treatments.^a

Herbicide	Rate	Evaluation date ^b
		7/10/86
	(kg/ha)	---(% control)---
Bentazon	1.12	92 a
Bentazon + COC	0.56 + 2.34 L/ha	77 ab
Bentazon + COC	1.12 + 2.34 L/ha	95 a
Bentazon + 28%	0.56 + 9.36 L/ha	83 a
Bentazon + 28%	1.12 + 9.36 L/ha	93 a
Bentazon + AMS	0.56 + 2.8	70 ab
Bentazon + AMS	1.12 + 2.8	93 a
Bentazon + 28% + COC	0.56 + 9.36 L/ha + 2.34 L/ha	92 a
Bentazon + 28% + COC	1.12 + 9.36 L/ha + 2.34 L/ha	95 a
Bentazon + AMS + COC	0.56 + 2.8 + 2.34 L/ha	92 a
Acifluorfen + Ag-98	0.56 + .125%	50 b
Bentazon + acifluorfen + COC	0.56 + 2.8 + 1.17 L/ha	73 ab
Bentazon + acifluorfen + COC	0.56 + 0.14 + 1.17 L/ha	77 ab

^aalachlor (3.36 kg/ha) PRE applied to all treatments.

^bMeans followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test. Data taken from Eaton County, MI. Velvetleaf were in the 4-5 leaf stage, 7-8 cm in height at the time of application.

declined to 70 and 73%. Bentazon (0.56 kg/ha) plus COC (2.34 kg/ha) without the addition of acifluorfen provided 77% velvetleaf control. This data suggests that velvetleaf control at this growth stage with bentazon-acifluorfen herbicide combinations is dependent on the rate of bentazon used.

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CHAPTER 3

OFF-TARGET INJURY FROM CLOMAZONE

ABSTRACT

Field trials were conducted in 1985 and 1986 to evaluate the volatilization of clomazone [2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone] as affected by application method. A bioassay using potted velvetleaf (Abutilon theophrasti Medik.) indicator plants placed over treated plots was used to detect volatilization. Chlorophyll content was determined by visual observation, and also by laboratory extraction in 1986. Volatilization was detected up to 2 weeks after both surface and incorporated treatments of clomazone at 1.12 kg/ha. The amount of detectable volatilization was dependent on climatic conditions and varied between years, although there was consistently greater volatilization detected on the surface treated plots than on the incorporated plots, regardless of the climatic conditions present. The rate of volatilization from surface applications was dependent on the amount of crop residue left on the soil surface. The extent of volatilization detected was in the order of no-till > minimum-till > conventional-till. Wheat (Triticum aestivum L.) injury from clomazone carryover was found to be rate dependent and was greater following

incorporated treatments. This supports the conclusion that surface applications of clomazone result in greater volatilization losses. Physical spray particle drift following clomazone application was detected in the downwind direction by velvetleaf indicator plants at a distance of 15 m from the point of application.

INTRODUCTION

Clomazone is a recently introduced herbicide that controls grass and broadleaf weeds in soybeans [Glycine max (L.) Merr.] (10). The compound has a relatively high vapor pressure of 1.44×10^{-4} mm Hg at 25°C and exerts its herbicidal activity by inhibiting the biosynthesis of chlorophyll and carotenoids (27). As a result, off-site movement and subsequent chlorosis to non-target plant species has been observed (9). Also of concern is the potential for carryover and injury to rotationally planted crops including corn [Zea mays L.] and wheat (7, 26).

Volatilization of herbicides from the soil surface is a mechanism facilitating off-target movement and has been reported to be the major mechanism of herbicide loss for butralin [4-(1,1-dimethylethyl)-N-(1-methylpropyl)-2,6-dinitrobenzenamine] and trifluralin [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine] (13).

When herbicide vapors remain contained in the soil matrix, volatilization can enhance herbicide efficacy (11, 18). However, once volatilized from the soil, herbicide vapors have the potential of adversely affecting the environment and public health (3, 24, 28). Injury to non-target plant species and loss of weed control (16) are other examples of adverse consequences resulting from excessive volatilization losses.

Environmental conditions which we have little or no control over such as temperature, precipitation, wind speed, and soil moisture are known to affect volatilization (1, 4, 17, 19). Cultural practices, which can be managed, also affect herbicide volatilization. Factors such as spray droplet size, application method and tillage system used, can be managed to reduce the potential for herbicide volatilization (1, 20, 22). Soil incorporation of trifluralin (1) and clomazone (8) has been shown to result in decreased volatilization as compared to surface applications. Application to plant or crop residue surfaces also affects volatilization. Atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] volatilization loss from plant material has been shown to be greater than losses from soil (2), and application of clomazone resulted in greater volatilization loss when applied to a straw mulch as compared to soil applications (9).

Perhaps the most important parameter governing the vapor behavior of herbicides is vapor pressure (6). The relationship between vapor pressure and volatilization is linear (5). However, most herbicides including clomazone have vapor pressures well below 10mm Hg at 20° C, but their mode of application frequently presents a high potential for loss by evaporation (21). This suggests that herbicide volatilization loss can be minimized if the application is managed correctly.

Spray drift at the time of herbicide application can also be an important component of off-target movement. Simulated spray drift of dicamba (3,6-dichloro-2-methoxybenzoic acid) and 2,4-D [(2,4-dichlorophenoxy)acetic acid] has been shown to reduce the extractable sucrose content of sugarbeets [*Beta vulgaris* L.] (25). Simulated spray drift of dicamba has also reduced tuber yield in potatoes [*Solanum*

tuberosum L.] (14).

Carryover of herbicides to rotationally grown crops is also an aspect of non-target injury. Wheat has been reported to be susceptible to injury from clomazone applied to rotationally grown soybeans (23, 26). High rates of clomazone (2.8 kg/ha) applied to soybeans have been reported to produce injury symptoms on rotationally planted corn (7).

The objectives of this study were to: a) examine the duration of clomazone volatilization; b) examine clomazone volatilization as affected by tillage systems; c) examine spray particle drift from clomazone application; and d) examine clomazone carryover to corn, sugarbeets, and winter wheat.

MATERIALS AND METHODS

General experimental procedure. Experiments were conducted in 1985 and 1986 to evaluate clomazone volatilization in the field. Vapor loss was detected by velvetleaf indicator plants placed in treated plots for all the experiments addressed except the rotational crop response study. The velvetleaf indicator plants were grown from seed in the greenhouse. Velvetleaf seeds were planted in 10.5-cm diameter plastic pots using greenhouse potting soil.¹ After ten days plants were thinned to three plants per pot and fertilized with 1.5 g of a 22.5 22.5 22.5 stock fertilizer in 25 ml of solution. Planting dates were timed such that indicator plants were 3 weeks old when placed into the field. In the

¹Baccto professional planting mix - sphagnum peat moss, horticultural vermiculite, perlite. Michigan Peat Co. P.O. Box 66388 Houston TX 77266.

field, switching stations, designed to secure the potted indicator plants, were placed into the test plots. The switching stations were constructed by taping a 30 cm long garden stake to a 10.5 cm plastic pot which was the same size as the pots containing the indicator plants. The pots had three 2 ml diameter holes drilled in the bottom to facilitate drainage. A Whatman #4 filter paper was then placed on the bottom of the pot followed by a 5 mm layer of activated charcoal which was then covered by another #4 filter paper. The pots containing the velvetleaf indicator plants were placed into these switching stations. After remaining in the field for the prescribed time period, the indicator plants were taken back to the greenhouse. After ten days in the greenhouse the plants were evaluated for chlorotic symptoms indicative of exposure to clomazone vapors. Chlorosis was determined by visual observation in 1985 and 1986, and by laboratory quantitation of the chlorophyll present in the leaves of the indicator plants in 1986. The chlorophyll extraction procedure used was derived from a procedure published by Moran and Porath (15). Three 1 cm leaf discs were removed from the second most recent, fully expanded leaf from two of the velvetleaf indicator plants present in each pot. The leaf discs were then immersed in 10 ml of N-N-dimethylformamide for 48 hours. The absorbance of the solution at 647 and 664.5 nm was recorded and the total chlorophyll content was calculated using the molar extinction coefficients (12) for this extraction procedure (Figure 1).

The herbicide treatments were applied with a compressed air, tractor mounted sprayer using 730308² flat fan nozzles. Treatments were applied at 207 kPa of pressure with a total spray volume of 215

Figure 1. Chlorophyll extraction procedure used to determine chlorosis of velvetleaf indicator plants. Chlorosis was reported as the reduction in chlorophyll ($\mu\text{g}/\text{cm}^2$) as a % of untreated plants.

10 DAYS IN GREENHOUSE



LEAF DISCS



N,N-DIMETHYLFORMAMIDE

48 HOUR EXTRACTION



ABSORBANCE AT 647 AND 664.5 NM

U.V.-VIS. SPECTROPHOTOMETER



TOTAL CHLOROPHYLL

$17.90 A_{647} + 8.08 A_{664.5}$

L/ha. All studies except the Spray Particle Drift study were designed as a randomized complete block containing three or four replications. Data were subjected to analysis of variance, and treatment mean comparisons were made using Duncan's multiple range test at the 0.05 level of significance.

Duration of volatilization. Field trials were conducted in 1985 and 1986 to examine the duration of clomazone volatilization. The 1985 study was located in Ingham County, Michigan, on a Colwood-Brookston loam soil with 3.0% organic matter and a pH of 6.5. The site was moldboard plowed the fall of 1984. On May 22, 1985, the site was tilled twice with a disk and once with a danish-tine harrow equipped with rolling baskets³. The clomazone applications were made following tillage. In 1986 the study was conducted on a Capac loam soil with a pH of 6.2 and an organic matter content of 2.7%. The site was moldboard plowed and disked in the spring of 1986. On July 3, 1987 the clomazone treatments were applied after the site was tilled with a danish tine harrow, equipped with rolling baskets. Treatments consisted of 1.12 kg/ha of clomazone applied preplant incorporated (PPI), and preemergence (PRE), and an untreated check. The PPI treatments were incorporated with one pass of a danish-tine harrow adjusted to a depth of 8 cm. Plots were 3 by 9 m in size. Volatilization was detected by velvetleaf indicator plants placed in the plots at the following time intervals subsequent to application:

²Spraying Systems Co., Wheaton, IL.

³Kongskilde Mfg. Co. Canada

0 to 24 hr., day 2 to 3, day 4 to 6, day 7 to 12, and day 13 to 24. Replacing the indicator plants at these time intervals allowed volatilization loss to be evaluated with respect to time after application. Environmental conditions during each study are presented in Table 1.

Influence of tillage. Field experiments were conducted in 1986 to evaluate the effect of tillage on volatilization loss of clomazone. Treatments consisted of 1.12 kg/ha of clomazone, applied PPI using conventional tillage and applied PRE using conventional tillage, reduced tillage and no-till tillage systems. The study was conducted on July 3, 1986 and again on September 5, 1986. The soil was a Capac loam and the previous crop was corn. The conventional tillage treatment consisted of moldboard plowing followed by one pass with a disk and one pass with a danish-tine harrow. Herbicide incorporation was done with one additional pass of the danish-tine harrow. Minimum tillage consisted of one pass with a heavy, 22-inch disk. The no-till treatments were applied directly to the previous corn crop residue. Total surface area covered by the previous corn crop residue was visually estimated at 0, 15, and 62% for the conventional-till, minimum-till, and no-till tillage systems. Volatilization was detected using the velvetleaf indicator plant procedure and chlorosis was determined using the chlorophyll extraction procedure. The total length of the study was 3 days with one set of bioassay plants exposed to the plots for the first 24 hours following application and a second set exposed to the plots for the remainder of the study.

Spray particle drift. Field studies were conducted in 1985 to evaluate spray particle drift occurring during application of clomazone. The study was done on June 28, 1985 and repeated on September 3, 1985. Windspeed was 6 to 10 km/h for both studies. During the June study the wind direction was from the Northeast, and in the September study the wind direction was from the Southwest. The experimental design consisted of a 9 by 9 m plot treated with 1.12 kg/ha of clomazone applied to the surface. Surrounding the treated plot, three concentric rings of 15, 30, and 60 meters in radius were drawn. Twelve sites for velvetleaf indicator plants were placed equidistantly on each of the three rings. At each of these sites, two pots of velvetleaf indicator plants were placed prior to herbicide application. Five minutes after application one of the pots from each of these twelve sites was removed and replaced with a second pot of indicator plants. After 24 hours, the remaining two pots at each of the 12 sites per ring were removed. The velvetleaf indicator plants were taken to a greenhouse following removal from the field. Ten days later they were evaluated visually for chlorosis.

Rotational crop response. Winter wheat, corn, and sugarbeets were planted into plots which had received treatments consisting of different rates and application methods of clomazone. The herbicide treatments were made on May 23, 1985 to a soybean crop on Capac and Colwood clay loam soils with a pH of 6.5 and an organic matter content of 2.5%. The winter wheat (Frankenmuth) was planted on October 23, 1985 following harvest of the soybeans. Two varieties of corn (Pioneer 3732 and Dekalb XL-8) were planted in 76 cm row on May 5,

1986. On May 30, 1986 two varieties of sugarbeets (HH33 and E-4) were planted in 71 cm rows. Throughout the 1986 growing season the three rotational crops were examined for visual injury symptoms. Parameters measured included plant height, population, chlorosis and yield. The wheat was evaluated as a randomized block and the two varieties of corn and sugarbeets were evaluated as a split plot with varieties comprising the main plots and clomazone treatments the subplots.

RESULTS AND DISCUSSION

Duration of volatilization. In 1985 velvetleaf indicator plants placed in the treated plots for the first 24 hours after clomazone application averaged 50% chlorosis from surface applications (PRE) and 3% from incorporated treatments (PPI) (Table 2). Indicator plants placed in the plots for the second and third days after treatment (DAT) averaged 0% and 4% for the surface and incorporated clomazone treatments. However detectable volatilization increased on the fourth through sixth DAT. A possible basis for this increase in volatilization is the occurrence of 1.4 cm of precipitation during this time period (Table 1). Volatilization was detected during both the 7 to 12 DAT period and the 13 to 24 DAT period. Indicator plants placed in plots receiving the PRE clomazone treatments consistently exhibited more chlorosis than the indicator plants placed in plots receiving the PPI treatments.

In 1986 the results were comparable to 1985. Volatilization was again detected for both PPI and PRE treatments as late as 13 to 24 DAT. The PRE clomazone treatments again caused significantly greater

Table 1: Environmental conditions present during volatilization studies.

	May, 1985			July, 1986			September, 1986		
Time after	Temperature			Temperature			Temperature		
application	High	Low	PPT	High	Low	PPT	High	Low	PPT
(days)	---(°C)--- (cm)			---(°C)--- (cm)			---(°C)--- (cm)		
1	19	4	0	22	8	0	23	10	0
2	23	8	0	29	13	0	19	5	0
3	27	4	0	32	22	0	17	2	0
4	28	8	0	33	22	0	-	-	-
5	31	13	0	28	20	0	-	-	-
6	19	12	1.4	27	18	1.1	-	-	-
7	19	7	0.5	26	17	0.2	-	-	-
8	22	1	0	26	13	0	-	-	-
9	25	11	0	21	14	0.4	-	-	-
10	26	18	0	27	17	0.5	-	-	-
11	25	9	0	28	18	0	-	-	-
12	24	13	0	24	14	0	-	-	-
13	21	8	0	29	13	1.5	-	-	-
14	21	7	0	31	19	0.1	-	-	-
15	23	12	0	33	23	0	-	-	-
16	23	3	0	33	23	0	-	-	-
17	26	9	0	33	23	0	-	-	-
18	31	13	0	30	20	0	-	-	-
19	28	17	2.3	26	15	0	-	-	-
20	23	11	0	28	15	0	-	-	-
21	16	8	0	30	16	0	-	-	-
22	13	7	1.6	31	19	0	-	-	-
23	21	5	0.1	27	19	0.5	-	-	-
24	24	7	0	28	16	0	-	-	-

Table 2: Effect of time on vapor injury to velvetleaf indicator plants placed in plots at the noted time interval subsequent to clomazone application.^{a,b}

Time After Application (days)	May, 1985		June, 1986			
	PPI ^c	PRE ^c	PPI ^c	PRE ^c	PPI ^d	PRE ^d
	-----(% chlorosis)-----					
1	3 A	50 B	8 A	56 B	27 A	57 B
2 to 3	0 A	4 B	5 A	50 B	7 A	52 B
4 to 6	28 A	51 B	9 A	77 B	19 A	79 B
7 to 12	2 A	30 B	31 A	54 B	33 A	55 B
13 to 24	1 A	17 B	4 A	17 B	0 A	22 B

^aMean comparisons can be made between PPI and PRE treatments within a given year, exposure time, and evaluation procedure. Means with a common letter are not significantly different at the 5% level using Duncan's multiple range test.

^bClomazone applied at 1.12 kg/ha.

^cEvaluated visually 10 days after exposure.

^dCalculated based on chlorophyll extraction 10 days after exposure.

chlorosis compared to the PPI clomazone treatments for a given time period (Table 2).

A comparison between the visual observation and chlorophyll extraction procedures for determining chlorosis showed agreement as the PPI clomazone treatments resulted in less chlorosis than PRE treatments at the 0.05 level of significance (Table 2).

Influence of tillage. Chlorosis on velvetleaf indicator plants placed in plots receiving conventional tillage in the July study for the first DAT period averaged 27% when the clomazone was applied PPI and 57% when it was applied PRE (Table 3). Minimum-till plots resulted in 94% chlorosis on indicator plants as compared to 97% for no-till plots. On the 2 to 3rd DAT period detectable volatilization increased with decreasing levels of tillage.

The September study produced similar results (Table 3). Thirty-eight percent chlorosis was reported on the indicator plants placed in plots receiving conventional tillage with the clomazone applied PPI, and 78% chlorosis where the herbicide was applied PRE. Indicator plants present in the minimum and no-till plots for the first DAT period had 75 and 88% chlorosis. On the 2 to 3 DAT period, during the September study, no volatilization was detected on both the PRE and PPI clomazone treated conventionally tilled plots. Cool weather present during this time period contributed to this decreased level of volatilization. However, 21 and 61% chlorosis was reported for the indicator plants present in the minimum and no-till plots during this same time period. This again clearly demonstrates that increased volatilization occurred with the increased levels of surface residue

Table 3: Effect of tillage systems on vapor injury to velvetleaf indicator plants placed in plots at the noted time period subsequent to clomazone application.^{a,b}

Tillage System	July, 1986		September, 1986	
	Day 1	Day 2-3	Day 1	Day 2-3
	-----(% chlorosis) ^c -----			
Conventional PPI	27 A	7 A	38 A	0 A
Conventional PRE	57 B	52 B	78 B	0 A
Minimum-Till	94 C	79 C	75 B	21 B
No-Till	97 C	93 D	88 B	61 C

^aMeans within a column followed by a common letter are not significantly different at the 5% level using Duncan's multiple range test.

^bClomazone applied at 1.12 kg/ha

^cCalculated based on chlorophyll extraction 10 days after exposure.

characteristic of minimum and no-till systems.

Spray particle drift. Clomazone spray particle drift occurring at the time of application was detected in the downwind direction at the 15 m distance from the point of application for both the June and September studies (Figure 2). No injury was observed on indicator plants placed in the switching stations subsequent to herbicide application.

Rotational crop response. The rate (0.07 to 1.4 kg/ha) or application method (PPI vs PRE) of clomazone used in soybeans planted in 1985 did not affect the population of the two varieties of sugarbeets planted in 1986 (data not shown). There were differences in height, stand count and fresh weight between the two varieties of corn used in the experiment but the analysis of variance indicates the response was not due to the clomazone application method or rate, at the .05 level of probability (Table 4). Visual chlorosis of corn on June 12, 1986, was not dependent on variety but was affected by the rate and application method of clomazone used (Table 4). Evaluation of the treatment means showed that the response to application rate was inconsistent (Table 5). Chlorosis was detected at the 0.84 and 1.4 kg/ha rate of clomazone applied PPI but not at the 1.12 kg/ha rate. Chlorosis was not observed on the corn grown in plots receiving the PRE treatments.

Of the three crop species used in the bioassay, the wheat proved to be the most sensitive to the residual clomazone and thus provided the best comparison between treatments. The height of the wheat was monitored throughout the 1986 growing season. At the May 12 evaluation the height of the wheat in the plots receiving the PPI treatment of clomazone (1.12 kg/ha) was significantly less than the

Figure 2. Experimental design used to evaluate clomazone spray particle drift. ^aEvidence of drift in June Study. ^bEvidence of drift September study. Windspeed was 6 to 10 km/h at application time for both studies. Wind direction was from the Northeast during the June study and from the Southwest during the September study.

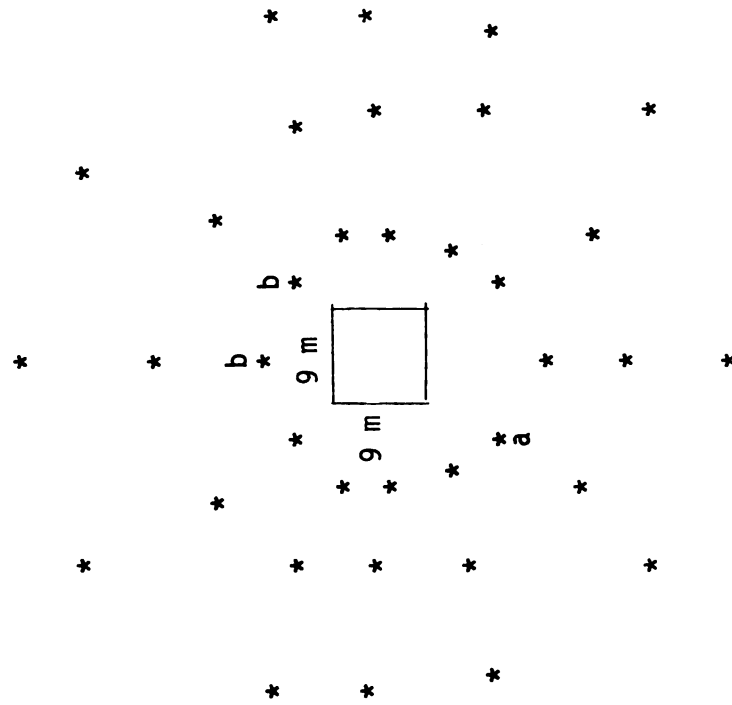
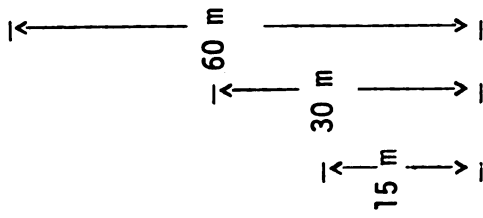


Figure 3. Height of wheat in 1986 as affected by application method of clomazone (1.12 kg/ha) applied to soybeans in 1985.

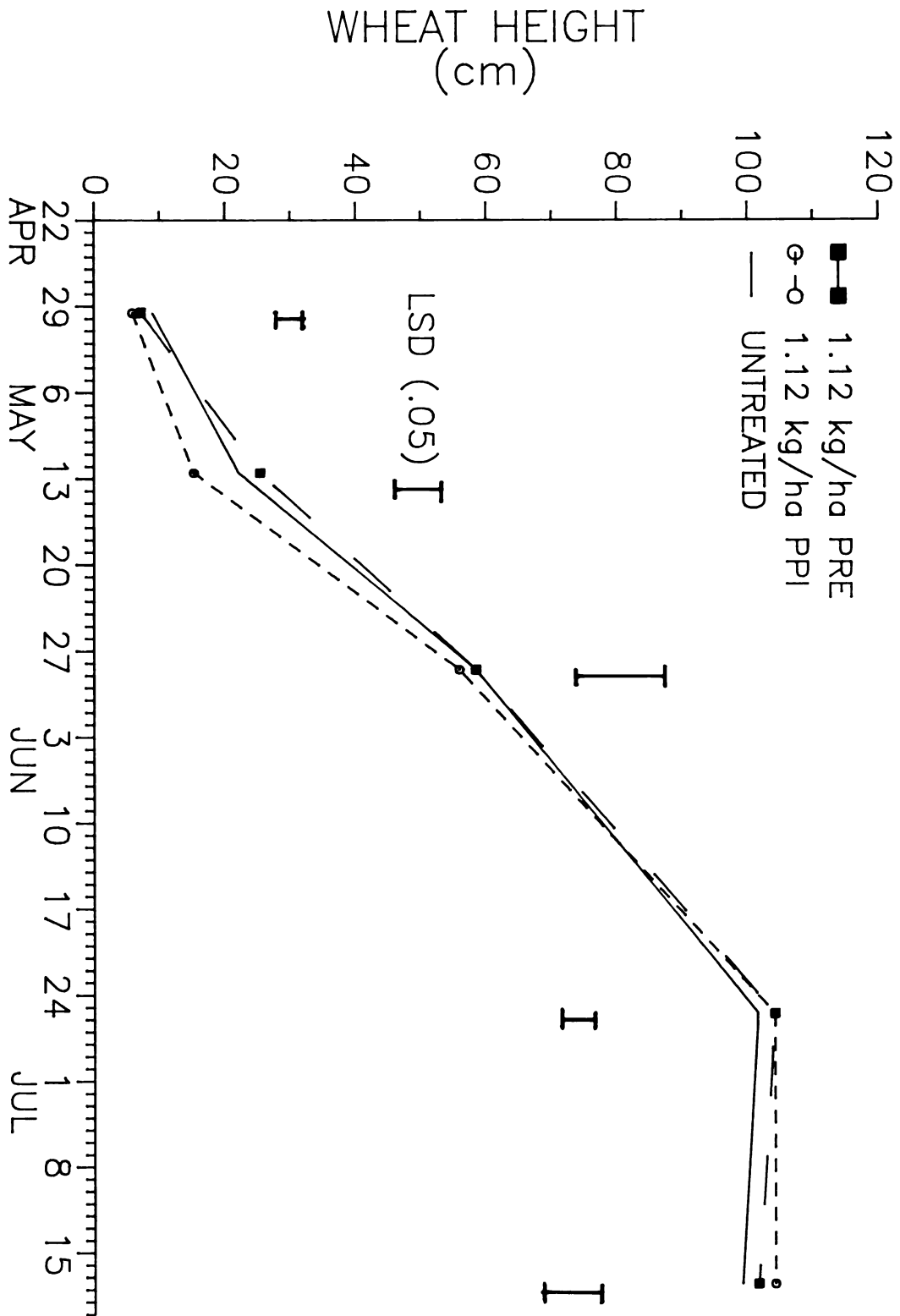


Table 4: F values from analysis of variance for stand count, height, % chlorosis^a, and fresh weight^b of varieties of corn as affected by clomazone treatments made to previous soybean crop.^a

Source	Plant Population	Height	Chlorosis	Fresh Weight
-----F value-----				
Rep	2.5	7.7* ^b	1.8	1.1
Variety	33.6*	48.7*	2.8	153.1*
Clomazone treatment	1.0	1.3	2.4*	1.4
Interaction	.9	1.0	2.4*	.8

^aEvaluations for stand count, height, and chlorosis were taken on June 12, 1986. Fresh weight was taken on June 27, 1986.

^b*Denotes an F value is significant at the 0.05 level.

Table 5: Chlorosis observed June 12, 1987, on rotationally grown corn as affected by clomazone treatments made to previous soybean crop.^a

Clomazone	Application	
rate	method	Chlorosis
(kg/ha)		---(%)---
0.84	PPI	5
1.12	PPI	0
1.4	PPI	10
.84	PRE	0
1.12	PRE	0
LSD 0.05		3.5

^aEvaluated visually.

height of the wheat grown in the plots receiving the PRE treatments (Figure 3). However, as the growing season progressed the wheat in the PPI plots overcame the initial stunting and the height difference between the PPI and PRE treatments was not significant at the 5% level for the later evaluations. On the April 29 visual evaluation the wheat grown in the plots receiving 1.12 kg/ha of clomazone applied PPI the previous spring averaged 48% chlorosis as compared to 27% for the PRE treatment (Figure 4). By the May 12 rating, visual chlorosis declined to 17 and 4% for the PPI and PRE treatments and by June 29 all the wheat had outgrown the visible chlorosis. The rate effect of PPI and PRE clomazone treatments on chlorosis and yield of rotationally grown wheat was evaluated (Figure 5). Chlorosis was visible for both PPI and PRE treatments with 0.5 kg/ha of clomazone applied the previous spring. However, yield reduction was not evident until the rate of clomazone was 1.12 kg/ha. The incidence of greater crop injury occurring on plots treated the previous spring with incorporated treatments supports the findings that appreciably greater volatilization loss occurred with surface applications of clomazone.

SUMMARY

Volatilization was detected from plots treated with PPI or PRE applications of clomazone (1.12 kg/ha) up to 2 weeks after herbicide application. However, significantly greater volatilization was detected from PRE treatments than from PPI treatments. Volatilization from PRE treatments of clomazone increased with increasing levels of crop residue present on the soil surface. Spray particle drift from

clomazone applications was detected at a distance of 15 m, in the downwind direction, from the point of application. Visual injury to rotationally grown corn and wheat following soybeans treated with PPI applications of clomazone tended to be more severe than injury from PRE treatments.

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Figure 4. Visible chlorosis of wheat in 1986 as affected by time and application method of clomazone applied to soybeans in 1985.

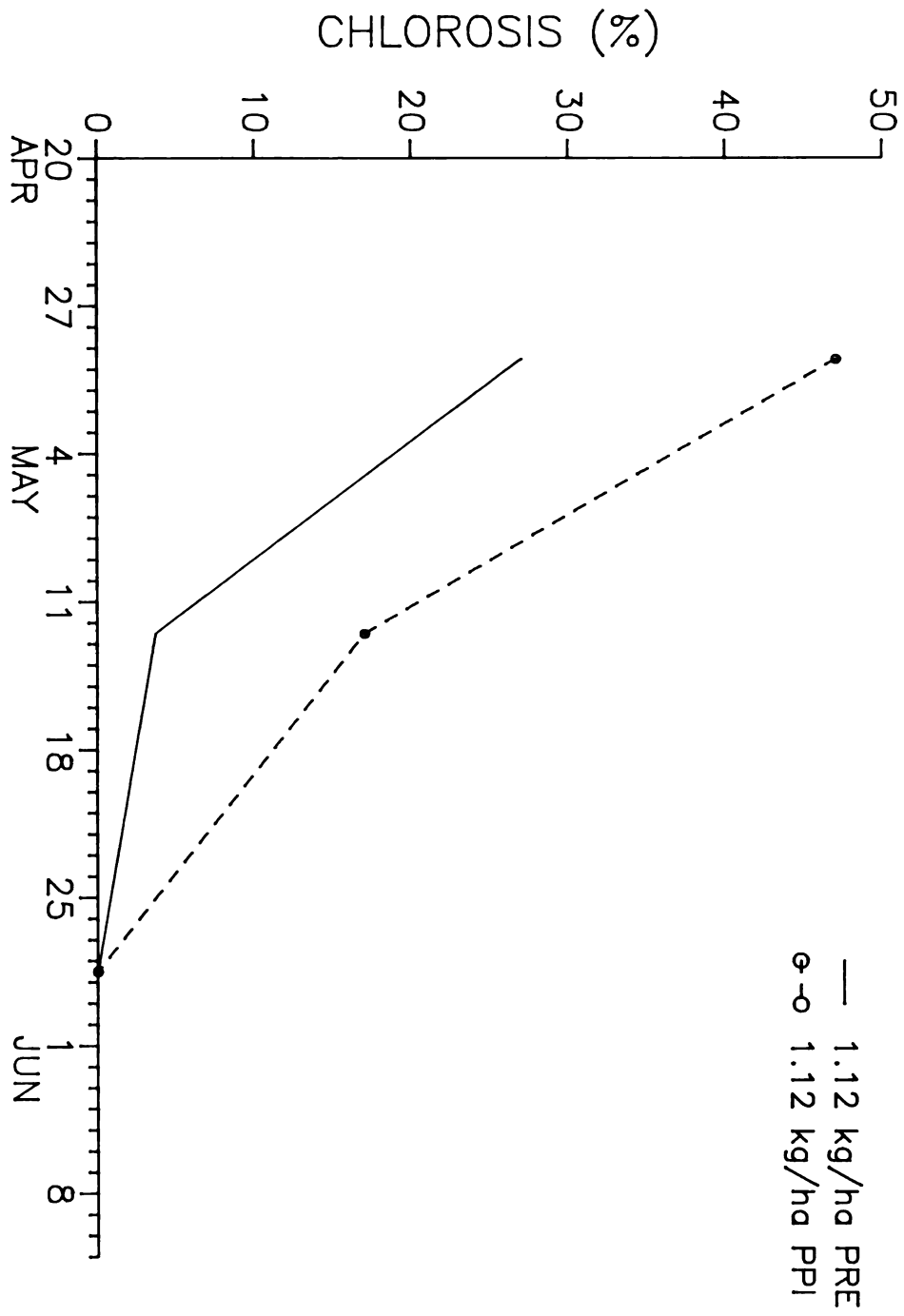
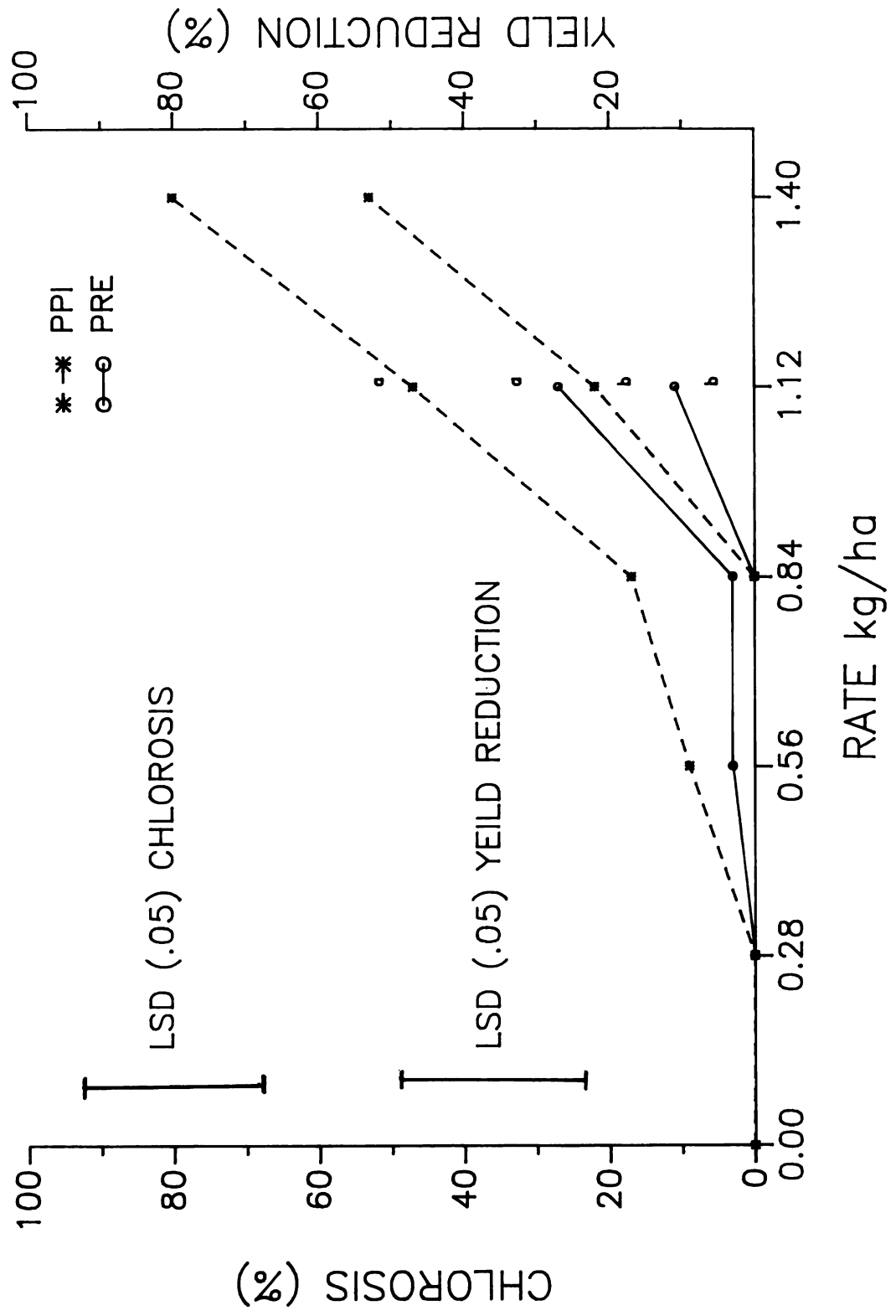


Figure 5. Visible chlorosis and yield of wheat in 1986 as affected by rate and application method of clomazone applied to soybeans in 1985.



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