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SHATTERCANE [SORGHUM BICOLOR (L.) MOENCH] CONTROL WITH THIOCARBAMATE HERBICIDES APPLIED ALONE OR IN COMBINATION WITH FONOFOS (O-ETHYL-S-PHENYLETHYL PHOSPHORODITHIOATE) OR R-33865 (O,O-DIETHYL-O-PHENYLPHOSPHOROTHIOATE) ON SOILS WITH AND WITHOUT PREVIOUS EPTC (S-ETHYL DIPROPYLTHIOCARBAMATE) HISTORY

by

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TO MY FAMILY

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INTRODUCTION

Shattercane [Sorghum bicolor (L.) Moench] has developed into a severe weed problem in the major grain sorghum [Sorghum bicolor (L.) Moench] producing areas stretching from Nebraska to northern Texas. It has also gained stronghold in Kentucky and is beginning to make headway in Maryland, Pennsylvania, Tennessee and Virginia (1).

EPTC (S-ethyl dipropylthiocarbamate) is commonly used to control shattercane in corn in Kansas. However several complaints were received from Kansas farmers in 1980 concerning poor shattercane control when EPTC was used continuously in corn fields. The authors first became aware of EPTC failures in Kansas in a corn field owned by Robert and Ken DuBois near Scranton, Kansas and later learned that EPTC failed in corn fields owned by Norman Anderson and William Devlin of Jamestown and Bellaire, Kansas respectively. Early in 1981 the authors became aware that EPTC also failed to control shattercane when used continuously on the Eric Miller and Clem Bauck farms located near Ulysses and Selkirk, Kansas respectively.

Recently, Stauffer Chemical Company has discovered that fonofos (O-ethyl-S-phenylethyl-phosphorodithioate) and R-33865 (O,O-diethyl-O-phenyl-phosphorothioate) prolong activity of thiocarbamate herbicides in soil when applied in combination. Initial reports by Stauffer Chemical Company researchers (47) indicate that these compounds directly or indirectly inhibit degradation of EPTC by soil microorganisms. Fonofos appears to act as a general biocide in the soil whereas R-33865 specifically inhibits enzymes present in microorganisms that are involved in EPTC degradation.

To gain further information and/or possible explanation of the current problem, greenhouse studies were undertaken with the following objectives:

1) to determine if applications of EPTC, butylate (S-ethyl-diisobutylthiocarbamate), or vernolate (S-propyldipropylthiocarbamate) alone or in combination with R-33865 effectively controlled shattercane grown in the greenhouse in soils sampled from fields treated continuously with EPTC and severe shattercane infestations; 2) to determine effect of delay between application and shattercane planting on activity of EPTC and EPTC plus R-33865 in soils with and without previous history of EPTC applications. Since no field studies have been conducted yet under Kansas conditions where EPTC failures were known to occur, we also deemed it necessary to initiate field studies in the State of Kansas to determine 1) if EPTC is dissipating rapidly in soils with history of repeated EPTC applications; 2) if additives (fonofos and R-33865) added to EPTC prolonged its activity and 3) if experimental herbicides or other thiocarbamate herbicides applied alone or in combination with fonofos or R-33865 can provide acceptable shattercane control in these soils.

CHAPTER 1

LITERATURE REVIEW

SHATTERCANE BIOLOGY AND ECOLOGY AND THIOCARBAMATE HERBICIDE ACTIONS WITH FONOFOS OR R-33865 IN SOIL

Introduction

EPTC, the active ingredient in the commercial herbicide product sold as Eradicane, has been used extensively to control shattercane in corn for several years. Studies (8,38) have shown that EPTC is more effective in controlling shattercane than butylate, the active ingredient in Sutan+. Recent reports revealed EPTC is degrading rapidly on some soils where it has been used continuously and, consequently it is not providing acceptable shattercane control. This review may provide information on the existing problem of EPTC failure in controlling shattercane.

Shattercane biology and ecology

Shattercane which is also known as wild cane is a serious annual weed problem in grain sorghum grown continuously in corn and other row crops grown in rotation with forage or grain sorghum. It closely resembles forage sorghum throughout all stages of development up to maturity when shattercane seed begins to shatter. It is similar to grain sorghum in early stages of development but is distinguishable at the later stages of growth due to differences in height, seed color and also shattering characteristics. Research results indicated that shattercane evolved from natural cross-pollination between grain sorghum varieties (1). The plant can grow up to a height of 3.7 meters, depending on heredity, growing conditions, fertility and soil type (1); and it can tiller extensively (18).

Seed heads (panicles) tend to droop to one side and vary from compact to diffusely branced (1,18). A typical seed head may consit of up to 1,000 viable seeds. Each shattercane seed is usually enclosed by a glume which vary in color from shiny black to reddish to dull yellow colored and shatters upon seed maturity (1). Seed falls to the ground when the plant is shaken by wind or combines.

Seeds start germinating as soils warm above 16 C and plants are known to emerge from as deep as 20 cm in the soil (41). Data on shattercane seed viability in soil show that this weed will be difficult to eradicate once it becomes established. A 14-year Nebraska study (9) revealed that greater than 30 percent of shattercane seed remained viable after 8 years of burial at a depth of 22 cm. It was also noted that the seed can remain viable as long as 12 to 13 years in the soil although most seeds either germinate or lose viability before then (9,18). Another seed burial study (28) conducted in Kansas for 3 years indicated that some shattercane seed, but no grain sorghum seed survived this burial period.

Shattercane is a tough and serious competitor of row crops for light, water, and essential soil nutrients and can reduce crop yields on both dryland and irrigated fields (1).

Thiocarbamate herbicide behavior in soil

The present extensive use of soil-applied herbicides has resulted in interest concerning dissipation of these chemicals in soil (10). Several processes that influence the behavior, activity and longevity of thiocarbamate herbicides have been studied extensively by many investigators. These include transfer from soil colloidal surfaces via volatilization and degradation by chemical processes, by light and by soil microorganisms (16,22,36).

Volatilization

Volatilization results in loss of thiocarbamate herbicides from soil (16). Studies (17,20) revealed that EPTC loss is greater in moist soils than in dry soils. Twenty percent of the applied EPTC was observed to disappear from dry soil, 27 percent from moist soil, and 44 percent from wet soil during the first 15 minutes after spraying on the soil surface (21). The loss was 23, 49, and 69 percent after 1 day and 44, 68, and 90 percent after 6 days on dry, moist, and wet soils, respectively.

A laboratory study (22) on behavior of five thiocarbamate herbicides in soil revealed that cycloate (S-ethyl N-ethylthiocyclohexane) was the least volatile compound followed by molinate (S-ethylhexahydro-1H-azepine-1-carbothioate), pebulate (S-propyl butylethyl-thiocarbamate), vernolate, and EPTC in order of increasing volatility. This study also showed that cycloate loss from the surface of moist soil was almost 30 percent of that originally applied within two hours after application.

A study (17) showed that EPTC is strongly adsorbed by soil particles in dry soil. This study revealed that as organic matter and clay content of soil increased EPTC loss decreased. It was further noted that EPTC remained longer and was less active primarily due to greater adsorption energy in soils high in organic matter and clay content.

Photodegradation and chemical degradation

Research indicates that the loss of thiocarbamate herbicides by photodegradation under field conditions is negligible. Data from a photolysis study (15) indicated that cycloate, butylate, molinate, and vernolate were not degraded when placed on thin layer chromotography plates and exposed to sunlight for 16 hours. It was also reported in this study that EPTC, PEBC (S-propyl-N,N-butylethyl-thiolcarbamate) and cycloate were degraded at an initial rate of 0.02 moles per minute when present in hexane and exposed to ultraviolet light. Another study (5) revealed that triallate (S-2,3,3-trichloroallyl-N,N-diisopropylthiocarbamate) did not absorb electromagnetic radiation (light) above 2800 nm. Photodegradation of triallate would not be expected since absorption is essential in the degradative process and the wavelength of solar radiation at the earth surface is above 2900 nm.

Studies (22,49) have shown that chemical degradation of thiocarbamate herbicides in soil may also occur. Gray and Weierich (22) observed that cycloate in glass containers disappeared from autoclaved soil. They theorized that chemical degradation occurred by hydrolysis.

Microbial degradation

Soil microorganisms contribute significantly to the disappearance of thiocarbamate herbicides applied and incorporated in soil (10,13,32, 50,57). Longevity of these herbicides in soil under conditions where volatility is a minor factor is therefore determined predominantly by microbial degradation (10,57). Sheets (49) reported that autoclaving soil prior to treatment reduced inactivation rate of EPTC by two-thirds. Gray and Weierich (22) observed that autoclaving soil greatly increased the longevity of cycloate, butylate, molinate and vernolate. Another study (36) revealed that soil sterilization resulted in much slower inactivation of EPTC, pebulate, and diallate (S-2,3-dichloroallyl N,N-diisopropylthiolcarbamate).

Microbial degradation rates of thiocarbamate herbicides are directly related to percent organic matter and clay in soil (17,36,49,57). Temperature and moisture also influence microbial degradation of thiocarbamate herbicides in soil. Decomposition of the herbicides is always observed in soil under temperatures conducive to microbial growth (33). Usually, degradation is most rapid in warm (20-30 C) moist soil (46). Weak adsorption of the chemical is proposed to occur under these conditions thus allowing the chemical to be more available to microorganisms (46). The half-lives of EPTC, butylate and vernolate in moist loam soil at 21-27 C are 1, 3, and 1.5 weeks respectively (57). Fang et al. (17) observed that EPTC persisted much longer at a soil temperature of 0-3 C than at a soil temperature of 25-35 C. Another study (13) revealed that as soil temperature increased, rate of EPTC dissipation also increased. EPTC and other thiocarbamate herbicides therefore, appear to persist longer when conditions for microbial growth are less than optimal (49).

EPTC failure and possible causes

Several theories are proposed herein concerning failure of EPTC to control shattercane in some fields. EPTC failures may be explained by a single theory or combination of theories.

Hypothesis A- Improper application

Proper application of EPTC is necessary for effective shattercane control. EPTC should be applied at 6.7 kg active ingredient/ha for shattercane control (18). Applying EPTC too early in the spring might lead to poor shattercane control due to herbicide breakdown before shattercane germination (18). EPTC applied to soil too wet is subject to rapid loss by volatilization processes.

EPTC and other thiocarbamate herbicides must be incorporated into the soil to a depth of 5 to 7 cm immediately after application for optimum weed control (22,57). Tillage most often is utilized to incorporate thiocarbamate herbicides. Insufficient and non-uniform incorporation of these herbicides may result in localized accumulations or uneven distribution (11,55). Improper incorporation can occur when soil is too wet due to insufficient mixing. Implements which can be used for incorporation vary with different herbicides and chemical manufacturers usually specify which equipment should be employed with particular products (55). In addition, speed, number of incorporation passes and orientation of the second pass in relation to first pass can influence incorporation uniformity. Deviation from recommended incorporation procedures can result in EPTC failure to control shattercane. Thorough soil incorporation is necessary to prevent loss by volatilization of herbicides such as EPTC.

Hypothesis B-Shattercane susceptibility to thiocarbamate herbicides

Differences in herbicide susceptibility have been found in some naturally occuring biotypes of weeds (38,45). However, this does not appear to be the case in regard to shattercane (19). EPTC failure to control shattercane is apparently not due to shattercane resistance to the herbicide since shattercane from problem fields can easily be controlled when grown in EPTC-treated soil in the greenhouse (18).

Several researchers (18,38) however, have noted that high shattercane population may in part be responsible for poor control in the field. A study (38) in Nebraska revealed that extremely high populations of shattercane can occur in some fields. The data from this study showed that numbers of shattercane seed in the top 10 cm of soil in certain fields range from 500,000 to 210 million per hectare. EPTC in these fields may control 90 percent or more of the germinating shattercane but the live shattercane plants that escape the herbicide treatment allow these fields to appear weedy.

Hypothesis C- Rapid degradation of EPTC after continuous use

The extensive use of soil-applied herbicides has made it essential to study their effects on soil microorganisms (12). In considering the interactions between herbicides and the microflora, many investigators have examined only the decomposition of the herbicide and/or the inhibition of microorganism growth. However, many investigators have also been interested in determining the effects of initial and subsequent applications of herbicides on proliferation of microorganisms capable of degrading these herbicides.

Herbicide stimulation of microorganism growth can be determined indirectly by measuring accelerated degradation of the herbicide applied to a medium containing microorganisms or directly by isolating and counting microorganisms. These type of studies (7,25,26,27,29,37,40,45,52,53) have shown that the degradation rate of some herbicides increases when repeat applications are made. A greenhouse study (37) revealed that dalapon (2,2-dichloropropionic acid) applied at a rate of 56 kg/ha at weekly intervals for 7 weeks to the same soil only slightly reduced growth of several dalapon-sensitive plant species planted after the last treatment. However, dalapon substantially reduced growth of all plant species when planted immediately after initial treatment. A second study (29) revealed that dalapon undergoes more rapid decomposition in the soil after repeat applications are made. A laboratory study (7) confirmed that incubation of soil with dalapon results in large increases of dalapon-decomposing microorganisms.

Results from a TCA (trichloroacetic acid) persistence study (39) indicated that TCA degradation is mainly by microorganisms. This study also revealed that persistence of TCA was shortened appreciably in the field when repeat applications were made annually. A bioassay study under greenhouse conditions (26) revealed that TCA activity in a field soil was previously treated with TCA at the same rate. Trials (52) in Sweden indicated that the half-life of TCA was 30 days in a previously untreated soil whereas half-life of TCA was less than 10 days in a soil previously treated with the compound. It was suggested that soil microorganisms are mainly responsible for TCA degradation and that the time delay for degradation to begin in previously untreated soil is the time required for induced enzymes to be synthesized by the cells of certain responsive strains or species of bacteria or fungi. Once these enzymes are synthesized, degradation of subsequent TCA treatments is no longer subject to this delay (52).

Investigations (53) on the degradation of different herbicides after repeat applications have also been conducted under field conditions. Second and third applications of 2,4-D [(2,4-dichlorophenoxy)acetic acid], MCPA [(4-chloro-o-tolyl)Oxy)acetic acid] were degraded more rapidly after second or third applications than first or single applications. It was noted that the initial application apparently caused an increase in the number of degrading organisms which resulted in more rapid degradation when repeat applications were made. Linuron [3-(3,4-dichlorophenyl)-1 methoxy-1-methylurea], however, did not appear to be more rapidly degraded when repeat applications were made (53).

Recent studies (25,27,45) have revealed that EPTC effectiveness is reduced when EPTC is applied continuously in the field on some soils. Investigators in New Zealand (45) indicated that EPTC failed to provide satisfactory control of rough bristlegrass (Setaria verticillata L.) in field plots where EPTC had been applied in previous years, but it provided excellent weed control on adjacent plots where alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide] was previously applied. Results from this study indicated that EPTC applied at 8 kg/ha provided sufficient weed control for 10 to 12 weeks in the soil which had not previously been treated with EPTC but provided sufficient weed control for only 4 to 6 weeks in a soil previously treated with the herbicide for three years in succession. Other studies (40,56) later revealed that EPTC provided inadequate control of wild proso millet (Panicum miliaceum L.) in soils with history of continuous EPTC use but provided effective wild proso millet control in soils without previous history of EPTC use. Laboratory study (27) initiated after these field observations revealed that half lives were 1.9 and 4.3 days in two different soils previously treated with EPTC and maintained at 25 C in the laboratory and 7.7 and 14 days respectively in these same soils that were not previously treated with EPTC. Other studies (25,27,38,43,45,48) also revealed rapid degradation of EPTC after continuous use. Recently, various investigators have referred to these soils as conditioned or predisposed soils (27,43). Longevity of EPTC in these problem soils increased to the same level as in other soils if a microbial enzyme inhibitor (R-33865) is applied in combination with EPTC. Sterilizing the soil by steaming or by other chemical treatments have also been observed to substantially prolonged activity of EPTC (45). These observations are strong evidence that population of EPTC-degrading microorganisms have increased in certain soils.

Effect of additives on herbicide longevity

Herbicide longevity studies usually have been conducted with single herbicides. The effects of a second or even third pesticide on the breakdown of a particular herbicide has been studied in only a few instances. One study (30) showed that microbial degradation of dalapon was inhibited by the presence of amitrole (3-amino-1,2,4-triazole). A greenhouse study (31) showed that carbaryl (1-naphthyl N-methylcarbamate), a carbamate insecticide inhibited microbial degradation of chlorpropham (isopropyl m-chlorocarbanilate), a carbamate herbicide, and thus extended its activity in a silty clay loam soil. Another study (35) indicated that diazinon [O,O,-diethyl O-2-isopropyl-4-methylpyrimidyl-(6)], an organophosphate insecticide, increased the longevity of chlorpropham.

Kaufman et al. (34) demonstrated that applications of PPG-124 (p-chlorophenyl-N-methyl carbamate) retarded the degradation of propanil [N-(3,4-dichlorophenyl)propionamide] in soil. PPG-124 has been reported to reduce the rate of chlorpropham hydrolysis (6). PPG-124 is a compound being developed by agrichemical industry to prolong activity of carbamate herbicides in the soil.

A laboratory study (27) revealed that the organophosphate insecticide fonofos inhibited EPTC degradation. Rahman et al. (45) observed that the organophosphate insecticide fensulfothion [O,O-diethyl-O-(methylsulfnyl) phenyl)phosphorothioate] increased the activity of EPTC. It was suggested that the fensulfothion caused a reduction in the degradation of EPTC in the soil.

R-33865 is another compound being developed by agrichemical industry and is currently being investigated for its potential in increasing the longevity of thiocarbamate herbicides. R-33865 itself like PPG-124 has no herbicidal activity (51,57). Current studies in progress indicate that R-33865 is an efficient inhibitor of soil microbial enzyme(s) (54). At the concentration levels used in soil, R-33865 does not inhibit the growth and development of soil microorganisms. Results revealed that inhibitory action of R-33865 appears to be specific for the thiocarbamate herbicides and the enzymes involved. R-33865 prevents the sulfoxidation and subsequent metabolism of the thiocarbamate herbicides thus resulting in an improvement of their performance in the field (51). Numerous university studies (25,27,40,43,48,56) confirm that R-33865 is effective in prolonging EPTC activity especially in problem soils.

CHAPTER 2

MATERIALS AND METHODS

<u>Greenhouse investigations</u>. A study was initiated to examine activity of thiocarbamate herbicides applied alone or in combination with R-33865 in soil sampled from two fields in Kansas with previous history of EPTC applications and with severe shattercane infestations. Soil samples were taken in August, 1980 in a field located near Scranton (east central Kansas) which had been treated annually with EPTC from 1972 to 1977, butylate in 1978 and EPTC in 1979 and 1980 and in September, 1980 in a field near Jamestown (north central Kansas) which had been treated annually with EPTC from 1976 to 1980. Soils were passed through a 2 mm screen to remove large aggregates, crop residue and shattercane seed soon after sampling. Soils were stored in plastic-lined, galvanized containers in the greenhouse until time of study initiation to prevent excessive drying. Twenty-five hundred grams of soil (air-dry basis) were added to four-liter plastic pots. Five cm of soil was removed from each pot and sprayed with EPTC, butylate or vernolate at 4.5 kg/ha alone or in combination with R-33865 at 0.8 kg/ha with a moving boom sprayer equipped with an even flat-fan nozzle delivering 234 liter/ha at 1.4 kg/cm^2 pressure. The soil was mixed immediately to uniformly distribute the herbicide.

Twenty-five seeds of 'Kansas Orange' forage sorghum were placed in each pot to simulate a shattercane infestation and covered with 5 cm of treated soil.

Vesecky et al. (54) reported that the influences of shattercane and 'Kansas Orange' forage sorghum on total grain sorghum grain production were similar. These investigators also noted that 'Kansas Orange' forage sorghum can be a suitable substitute for shattercane in experimental work.

Studies (2,3,14,23,42,44) have shown that with EPTC and other thiocarbamate herbicides, uptake was mainly through the underground shoots (coleoptiles) and are also considered as the principal site of action of these herbicides.

Pots were than placed in the greenhouse without supplemental lighting with a temperature regime of 20-30 C and sub-irrigated daily with sufficient water to bring the soil moisture content to a pre-determined field capacity level. Emergence counts were taken 10 days after planting and plants then thinned to 10 per pot. Heights were recorded 21 days after planting and plants then harvested, oven dried, and weighed. Pots were reseeded immediately with forage sorghum at a 5 cm depth and data collected using the same procedures as discussed.

A second greenhouse study was conducted to examine effect of delay between applications and planting on EPTC activity. The same procedures were utilized as in the previous study except planting of forage sorghum was delayed 3, 5, 7, and 14 days and also planted immediately after EPTC or EPTC plus R-33865 were applied. Soil used in this study was taken in October, 1980 from the same field with previous history of EPTC applications near Scranton.

EPTC activity in soils with and without EPTC history was also examined under greenhouse conditions. The same procedures were utilized as mentioned in the first greenhouse study except EPTC or EPTC plus R-33865 were applied every four weeks up to sixteen weeks.

Forage sorghum was planted 5 days after herbicide was applied and was harvested 21 days after planting. Soils used in this study were collected from fields near Hiawatha (northeast KS), Bellaire (northcentral KS) Ulysses (southwest KS), Selkirk (westcentral KS) and also from fields near Scranton and Jamestown, Kansas as previously described. EPTC had been applied to the field near Hiawatha in both 1979 and 1980 and to the field near Bellaire continuously since 1972. EPTC was applied on the field near Ulysses in 1978 to 1980. EPTC and butylate were applied on the field near Selkirk in 1976 to 1979 and 1980 respectively. Treatments were replicated four times in a completely randomized design.

Field studies were conducted in 1981 on two separate fields located near Scranton and Bellaire, Kansas. Fields were selected with previous history of EPTC applications and with severe shattercane infestations. Actual history of EPTC applications was previously described in greenhouse study procedures.

Treatments consisted of EPTC at 4.5 or 6.7 kg/ha and butylate, vernolate, or cycloate at 6.7 kg/ha in combination with antidotes (R-25788 or R-29148) at appropriate rates to provide protection to corn. R-33865 was combined with EPTC, butylate or vernolate in a 6:1 ratio (w/w basis). Fonofos was also applied with EPTC or butylate at 4.5 kg/ha. SC-7829 or SC-8149, two experimental herbicides being developed by Stauffer Chemical Company, were also applied at 2.2 and 4.5 kg/ha. Commercial or experimental emulsifiable concentrate formulations were used for all treatments except SC-7829 which was a wettable powder formulation.

Treatments were applied on April 13, 1981 and May 15, 1981 onto plots measuring 5 by 18 meters and 7 by 18 meters at Scranton and Bellaire, respectively. A truck-mounted sprayer equipped with flood jet nozzles delivering 234 liters/ha at a pressure of 2.1 kg/cm^2 was used to apply the herbicides. Herbicides were immediately incorporated at a depth of approximately 10 cm by two disc operations at Scranton and by a disc operation followed by a field cultivator operation at Bellaire. The second incorporation operation was perpendicular to the first one.

Soil and climatic conditions at each location were recorded. At Scranton, soil type was a silt loam with a pH of 6.5 and 3.0% organic matter. Soil particle separation procedures revealed 19% sand, 65% silt and 16% clay for the soil at this location. Fertilizer was applied at the rate of 168 kg/ha N, 79 kg/ha P and 67 kg/ha K. The upper 1 cm of soil was dry and the lower 7.5 cm was moist. Soil temperature was 29 C at the surface, 24 C 7.5 cm below the surface and air temperature was 29 C with hazy skies. At Bellaire, the soil type was also a silt loam with a pH of 5.9 and 1.6% organic matter. Soil particle separation procedures revealed 19% sand, 65% silt and 17% clay for the soil at this location. Fertilizer was applied at the rate of 225 kg/ha N and 67 kg/ha P. The upper 1 cm of soil was slightly moist and the lower 7.5 cm was at approximately field capacity. Soil temperature was 17 C at the surface, 16 C 7.5 cm below soil surface and air temperature was 17 C with cloudy skies.

'Funks 4503' corn was planted on April 14, 1981 5 cm deep in 76 cm rows at a seeding rate of 59,000 plants/ha at Scranton. 'Dekalb XL 372' corn was planted on May 15, 1981 5 cm deep in rows 96 cm wide at a seeding rate of 54,000 plants/ha at Bellaire.

Control was rated visually at two, four, and eight weeks and four and eight weeks at Scranton and Bellaire, respectively, by utilizing a scale where 0 = no control and 100 = complete control. Number of shattercane plants per square meter was determined four and eight weeks after planting by counting plants in four different 0.25 m^2 areas in each plot. Shattercane biomass was determined at eight weeks by clipping plants greater than 5 cm in height in each of four different 0.25 m^2 areas per plot, combining plants into one composite sample then ovendrying samples at 55 C followed by weighing.

Treatments were replicated three times in a randomized complete block design at both locations.

CHAPTER 3

RESULTS AND DISCUSSION

Greenhouse study: thiocarbamate herbicide - R-33865 combinations.

Emergence of forage sorghum was reduced significantly when planted immediately after applications of EPTC alone or EPTC in combination with R-33865, butylate alone, and vernolate alone in a soil sampled near Scranton, KS (Table 1). Emergence was not reduced when butylate plus R-33865 or vernolate plus R-33865 was applied or when forage sorghum was planted 21 days after treatment. Height was severely reduced when forage sorghum was planted immediately after butylate plus R-33865 treatment while sorghum planted in soils treated with butylate alone or with other compounds did not continue to grow after emergence (Table 2). Height of sorghum planted 21 days after treatment was reduced only when EPTC plus R-33865 was applied. Top growth of forage sorghum planted immediately after treatments did not occur for any of the treatments except butylate plus R-33865 applications; however, this treatment severely reduced top growth when compared to growth of plants grown in nontreated soils (Table 3). Top growth of sorghum planted 21 days after treatment was less when soil was treated with EPTC plus R-33865 as compared to EPTC alone. This reduction in top growth was not observed when R-33865 was combined with either butylate or vernolate.

Dry weight of forage sorghum was reduced when planted immediately after treatment for all treatments in a soil sampled near Jamestown, KS.

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Table 1. Emergence of 'Kansas Orange' forage sorghum in silt loam soil[a] with a history of EPTC applications and treated with thiocarbamate herbicides alone or in combination with R-33865.

Herbicide	Rate	R-33865	Incubation time[b] 0 days	Incubation time[b] 21 days
	(kg/ha)	(kg/ha)	(%)[c]	
EPTC	4.5	0.0	67 bc	50 ab
		0.8	58 c	43 ab
Butylate	4.5	0.0	77 bc	51 ab
		0.8	84 a	55 a
Vernolate	4.5	0.0	66 bc	50 ab
		0.8	80 ab	44 ab
None	---	0.0	84 a	38 b

[a] Soil sampled near Scranton, KS in August, 1980.

[b] Incubation time = time of forage sorghum planting after application of herbicide with and without R-33865.

[c] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 2. Height of 'Kansas Orange' forage sorghum in silt loam soil[a] with a history of EPTC applications and treated with thiocarbamate herbicides alone or in combination with R-33865.

Herbicide	Rate	R-33865	Incubation time[b] 0 days	Incubation time[b] 21 days
	(kg/ha)	(kg/ha)	(cm)[c]	
EPTC	4.5	0.0	0.0 c	33.5 a
		0.8	0.0 c	7.5 d
Butylate	4.5	0.0	0.0 c	19.0 ab
		0.8	5.1 b	27.8 ab
Vernolate	4.5	0.0	0.0 c	22.4 bc
		0.8	0.0 c	25.8 bc
None	---	0.0	48.4 a	23.4 bc

[a] Soil sampled near Scranton, KS in August, 1980.

[b] Incubation time = time of forage sorghum planting after application of herbicide with and without R-33865.

[c] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 3. Dry weight of 'Kansas Orange' forage sorghum in silt loam soil[a] with a history of EPTC applications and treated with thiocarbamate herbicides alone or in combination with R-33865.

Herbicide	Rate	R-33865	Incubation time[b] 0 days	21 days
			——(g/10 plants)[c]——	
EPTC	4.5	0.0	0.00 b	1.02 a
		0.8	0.00 b	0.10 d
Butylate	4.5	0.0	0.00 b	0.38 c
		0.8	0.12 b	0.78 b
Vernolate	4.5	0.0	0.00 b	0.55 b
		0.8	0.00 b	0.67 b
None	---	0.0	3.83 a	0.44 c

[a] Soil sampled near Scranton, Kansas in August, 1980.

[b] Incubation time = time of forage sorghum planting after application of herbicide with and without R-33865.

[c] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 4. Dry weight of 'Kansas Orange' forage sorghum in silt loam soil[a] with a history of EPTC applications and treated with thiocarbamate herbicides alone or in combination with R-33865.

Herbicide	Rate	R-33865	Incubation time[b] 0 days	Incubation time[b] 21 days
	(kg/ha)	(kg/ha)	(g/10 plants)[c]	
EPTC	4.5	0.0	.01 b	0.38 ab
		0.8	.00 b	0.04 d
Butylate	4.5	0.0	.04 b	0.35 ab
		0.8	.06 b	0.11 cd
Vernolate	4.5	0.0	.03 b	0.36 ab
		0.8	.01 b	0.23 bc
None	---	0.0	.47 a	0.39 a

[a] Soil sampled near Jamestown, KS. in August, 1980.

[b] Incubation time = time of forage sorghum planting after application of herbicide with and without R-33865.

[c] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Only EPTC plus R-33865 severely reduced top growth of sorghum planted 21 days after application (Table 4).

Greenhouse study: delay between herbicide application and planting.

Forage sorghum growth was severely reduced by EPTC when sorghum was planted immediately after application, slightly reduced when planted 3 days after application and was not reduced when planted 5, 7, or 14 days later (Table 5). EPTC plus R-33865 prevented growth when sorghum was planted 0, 3, 5, or 7 days after application and severely inhibited growth when sorghum was planted 14 days after application.

Greenhouse study: comparison of thiocarbamate herbicide activity in soils with and without EPTC history.

EPTC applied to soil sampled near Scranton and with previous EPTC history prevented forage sorghum growth after the first application but not after later applications (Table 6). EPTC also did not prevent growth after the second and later applications in soil without previous history of EPTC applications. However, forage sorghum growth was severely inhibited after the fourth application on both soils. EPTC plus R-33865 did prevent forage sorghum growth in either soil after the first and later applications.

EPTC did not inhibit forage sorghum growth in the soil sampled near Jamestown, KS with previous EPTC history after the first, second and third application but did reduce sorghum growth after the fourth application (Table 7). EPTC plus R-33865 did prevent sorghum growth after the first and later applications. EPTC activity was observed in the soil without previous history of EPTC applications after the first but not after later applications.

Table 5. Effect of EPTC applications with and without R-33865 and time of planting on dry weight of forage sorghum in silt loam[a] with a history of EPTC applications.

EPTC	R-33865	Incubation Time[b] 0 days	3 days	5 days	7 days	14 days
(kg/ha)	(kg/ha)	(g/10 plants)[c]				
4.5	0.0	0.03 d	0.23 c	0.32 bc	0.35 bc	0.56 a
4.5	0.8	0.00 d	0.00 d	0.00 d	0.00 d	0.01 d
0.0	0.0	0.38 bc	0.40 b	0.41 b	0.32 bc	0.37 bc

[a] Soil sampled near Scranton, Kansas on October, 1980.

[b] Incubation time = time of forage sorghum planting after application of EPTC with and without R-33865.

[c] Means followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 6. Effect of EPTC with and without R-33865 on dry weight of forage sorghum in silt loam soil[a] with and without a history of EPTC applications.

EPTC	R-33865	EPTC history	EPTC application number[b]			
			1	2	3	4
(kg/ha)	(kg/ha)		(g/10 plants)[c]			
4.5	0.0	yes	0.00 b	1.20 a	2.53 a	0.02 b
4.5	0.8	yes	0.00 b	0.00 c	0.00 c	0.00 b
0.0	0.0	yes	0.86 a	0.78 b	2.40 a	1.35 a
4.5	0.0	no	0.00 b	1.13 a	2.03 b	0.12 b
4.5	0.8	no	0.00 b	0.00 c	0.00 c	0.00 b
0.0	0.0	no	0.84 a	0.72 b	2.44 a	1.42 a

[a] Soil sampled near Scranton, Kansas in August, 1980.

[b] Applications made at four-week intervals. Sorghum planting 5 days after herbicide application.

[c] Means within columns are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 7. Effect of EPTC with and without R-33865 on dry weight of forage sorghum in silt loam soil[a] with and without a history of EPTC applications.

EPTC	R-33865	EPTC history	EPTC application number[b] 1	2	3	4
(kg/ha)	(kg/ha)		(g/10 plants)[c]			
4.5	0.0	yes	0.53 a	0.48 a	2.03 a	0.44 b
4.5	0.8	yes	0.00 b	0.00 b	0.00 b	0.00 c
0.0	0.0	yes	0.46 a	0.58 a	2.04 a	0.68 a
4.5	0.0	no	0.00 b	0.53 a	2.10 a	0.33 b
4.5	0.8	no	0.00 b	0.00 b	0.00 b	0.00 c
0.0	0.0	no	0.52 a	0.63 a	2.06 a	0.46 b

[a] Soil sampled near Jamestown, Kansas in August, 1980.

[b] Applications made at four-week intervals. Sorghum planting 5 days after herbicide application.

[c] Means within columns are *not significantly different at the* 5% level according to Duncan's Multiple Range Test.

The initial application of EPTC prevented growth of forage sorghum in a soil without EPTC history but not in a soil with EPTC history sampled near Bellaire, KS (Table 8). EPTC did not inhibit growth of forage sorghum after the second application but essentially prevented growth after third and fourth applications in a soil with a previous EPTC history. EPTC essentially prevented growth of forage sorghum in the soil without previous EPTC history after applications as did EPTC plus R-33865 after all applications.

EPTC prevented growth of forage sorghum after all applications in soil sampled near Hiawatha with previous EPTC history (Table 9). The first application of EPTC prevented forage sorghum growth in a soil without EPTC history. Growth was not reduced after the second and fourth applications but was reduced after the third application in this soil. EPTC plus R-33865 again prevented sorghum growth in both soils after all applications.

EPTC severely inhibited but did not prevent forage sorghum growth in the soil sampled near Ulysses, KS with previous EPTC history (Table 10). EPTC prevented forage sorghum growth in soil without EPTC history. EPTC plus R-33865 did prevent sorghum growth in both soils. Forage sorghum growth was severely reduced but not prevented by butylate treatments on both soils.

Significant inhibition of forage sorghum growth was observed when EPTC was applied on soil sampled near Selkirk and with EPTC history (Table 11). EPTC prevented sorghum growth in soil without EPTC history. EPTC plus R-33865 did prevent growth of sorghum on both soils. Forage sorghum growth was severely reduced when butylate was applied in soils with and without EPTC history.

Table 8. Effect of EPTC with and without R-33865 on dry weight of forage sorghum in silt loam soil[a] with and without a history of EPTC application.

EPTC	R-33865	EPTC history	EPTC application number[b]			
			1	2	3	4
(kg/ha)	(kg/ha)					
4.5	0.0	yes	0.51 c	4.52 a	0.01 c	0.00 b
4.5	0.8	yes	0.00 d	0.00 b	0.00 c	0.00 b
0.0	0.0	yes	1.15 b	4.12 a	1.58 b	4.32 a
4.5	0.0	no	0.00 d	0.01 b	0.00 c	0.00 b
4.5	0.8	no	0.00 d	0.00 b	0.00 c	0.00 b
0.0	0.0	no	1.49 a	4.10 a	1.66 a	4.42 a

[a] Soil sampled near Bellaire, Kansas in January, 1981.

[b] Application made at four-week intervals. *Sorghum planting 5 days after herbicide application.*

[c] Means within columns are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 9. Effect of EPTC with and without R-33865 on dry weight of forage sorghum in silt loam soil[a] with and without a history of EPTC application.

EPTC	R-33865	EPTC history	EPTC application number			
			1	2	3	4
(kg/ha)	(kg/ha)					
4.5	0.0	yes	0.00 c	0.01 c	0.02 c	0.00 b
4.5	0.8	yes	0.00 c	0.00 c	0.00 c	0.00 b
0.0	0.0	yes	1.68 a	4.40 a	2.10 a	5.72 a
4.5	0.0	no	0.00 c	4.51 a	0.20 c	5.78 a
4.5	0.8	no	0.00 d	0.00 c	0.00 c	0.00 b
0.0	0.0	no	1.49 b	3.42 b	1.82 b	5.68 a

[a] Soil sampled near Hiawatha, Kansas in December, 1980.

[b] Application made at four-week intervals. Sorghum planting 5 days after herbicide application.

[c] Means within columns are not significantly different at the 5% level according to Duncan's Multipel Range Test.

Table 10. Dry weight of 'Kansas Orange' forage sorghum in silt loam soil[a] with and without history of EPTC plus R-25788 applications and treated with thiocarbamate herbicides alone or in combination with R-33865.

Herbicide	Rate	R-33865	EPTC history	Dry weight
	(kg/ha)	(kg/ha)		—(g/10 plants)[b]—
EPTC	4.5	0.0	yes	0.03 d
		0.0	no	0.00 d
EPTC	4.5	0.8	yes	0.00 d
		0.8	no	0.00 d
Butylate	6.7	1.1	yes	0.13 c
		1.1	no	0.11 c
None	---	0.0	yes	0.61 b
		0.0	no	0.80 a

[a] Soil sampled near Ulysses, Kansas in April, 1981.

[b] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 11. Dry weight of 'Kansas Orange' forage sorghum in silt loam soil[a] with and without history of EPTC plus R-25788 applications and treated with thiocarbamate herbicides alone or in combination with R-33865.

Herbicide	Rate	R-33865	EPTC history	Dry Weight
	(kg/ha)	(kg/ha)		(g/10 plants)[b]
EPTC	4.5	0.0	yes	0.02 d
		0.0	no	0.00 d
EPTC	4.5	0.8	yes	0.00 d
		0.8	no	0.00 d
Butylate	6.7	1.1	yes	0.07 d
		1.1	no	0.18 c
None	---	0.0	yes	0.58 b
		0.0	no	1.22 a

a Soil sampled near Selkirk, Kansas in April, 1981.

b Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Field study near Scranton, Kansas.

EPTC applied alone at 6.7 kg/ha did not provide acceptable shattercane control (Table 12). Lack of control became more evident as the season progressed. Poor control of shattercane was also observed when butylate or cycloate was applied at 6.7 kg/ha. These herbicides were less effective than EPTC after two weeks but more effective later. Vernolate when applied alone controlled shattercane to the greatest extent among thiocarbamate herbicides examined.

Fonofos at 4.5 kg/ha significantly increased EPTC activity. However this combination still failed to provide acceptable control of shattercane. Fonofos did not increase SC-7829 and SC-8149, EPTC activity.

Excellent control was observed when EPTC was applied at 4.5 or 6.7 kg/ha in combination with R-33865. R-33865 did not increase butylate activity but did increase vernolate activity. Vernolate plus R-33865 treatment effectively reduced shattercane biomass at eight weeks.

Experimental herbicides being developed for broad spectrum control of annual weeds in corn did not provide excellent shattercane control at this location.

Significant reduction in corn height at eight weeks was observed only when EPTC was applied in combination with R-33865.

None of the treatments significantly reduced corn stand at four weeks except EPTC at 4.5 kg/ha (Table 13). The reduction observed when EPTC was applied at the low rate appears to be inconsistent with other stand observations and cannot be explained.

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Table 12. Effect of thiocarbamate herbicides applied alone or in combination with fonofos or R-33865 and other experimental herbicides on shattercane growth in corn near Scranton, Kansas.

Treatment	Rate	2 weeks	4 weeks		8 weeks		
		visual rating	visual rating	density[b]	visual rating	density[b]	biomass[c]
	(kg/ha)	(%)[d]					
EPTC	4.5	77 d-g	54 hi	64 e-h	30 i	45 e	51 h
EPTC	6.7	75 d-g	47 i	52 f-h	37 i	32 fg	47 h
Butylate	6.7	63 f-h	73 e-g	70 d-h	62 f-h	62 d-f	70 e-h
Vernolate	6.7	92 a-c	86 c-e	87 b-e	79 c-f	62 d-f	87 b-e
Cycloate	6.7	70 e-h	62 g-i	57 e-h	53 hi	61 d-f	86 c-g
EPTC + Fonofos	6.7 + 4.5	86 b-d	82 d-f	82 b-f	77 c-g	61 d-f	86 c-g
EPTC + R-33865	4.5 + 0.8	95 ab	94 bc	97 a-c	91 bc	94 ab	99 ab
EPTC + R-33865	6.7 + 1.1	97 a	98 ab	99 ab	97 ab	97 ab	99 a-c
Butylate + Fonofos	6.7 + 4.5	57 h	62 g-i	38 h	63 e-h	60 d-f	61 gh
Butylate + R-33865	6.7 + 1.1	60 gh	64 g-i	50 gh	62 gh	59 d-f	64 f-h
Vernolate + R-33865	6.7 + 1.1	83 c-e	83 c-e	87 a-e	85 cd	94 ab	95 a-d
EPTC[a]	6.7	82 c-e	67 f-h	71 d-h	35 i	51 d-f	55 h
EPTC[a] + R-33865	6.7 + 1.1	87 b-d	90 cd	94 a-d	89 bc	88 b	94 a-d
SC - 7829	2.2	63 gh	63 g-i	66 e-h	66 e-h	66 c-e	67 e-h
SC - 7829	4.5	77 d-g	82 d-f	85 b-f	82 c-e	88 bc	89 b-f
SC - 8149	2.2	70 e-h	68 f-h	78 c-h	69 d-h	80 b-d	83 d-g
SC - 8149	4.5	78 d-f	76 e-g	77 c-h	79 c-g	79 b-d	83 d-g
No treatment	---	0 i	0 j	0 i	0 j	0 g	0 i
Weed free	---	----	100 a	100 a	100 a	100 a	100 a

[a] These treatments also included R-29148 as protectant at 0.3 kg/ha. Other thiocarbamate herbicide treatments included R-25788 as protectant at 0.3, 0.4, or 0.6 kg/ha.

[b] Actual shattercane density in no treatment plots averaged 604 and 437 plants/m^2 at 4 and 8 weeks respectively.

[c] Actual shattercane biomass in no treatment plots averaged 376 g/m^2 (oven dry weight basis).

[d] Percent values represent reduction in density and/or biomass from that observed in no treatment plots. Means within columns followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 13. Effect of thiocarbamate herbicides applied alone or in combination with fonofos or R-33865 and other experimental herbicides on corn growth near Scranton, Kansas.

Treatment	Rate	Corn stand 4 weeks	Corn height 8 weeks
	(kg/ha)	(plants/8m)	——(cm)——
EPTC	4.5	18 d	105 ab
EPTC	6.7	24 a-c	106 ab
Butylate	6.7	25 a-c	102 a-d
Vernolate	6.7	26 ab	99 a-e
Cycloate	6.7	24 a-c	94 c-f
EPTC + Fonofos	6.7 + 4.5	25 a-c	104 ab
EPTC + R-33865	4.5 + 0.8	23 a-d	94 c-f
EPTC + R-33865	6.7 + 1.1	23 a-d	88 gf
Butylate + Fonofos	6.7 + 4.5	26 ab	106 ab
Butylate + R-33865	6.7 + 1.1	27 a	103 a-c
Vernolate + R-33865	6.7 + 1.1	26 ab	91 ef
EPTC[a]	6.7	21 b-d	93 d-f
EPTC[a] + R-33865	6.7 + 1.1	20 cd	82 g
SC - 7829	2.2	27 a	97 b-d
SC - 7829	4.5	22 a-d	102 a-d
SC - 8149	2.2	25 a-c	105 ab
SC - 8149	4.5	23 a-d	102 a-d
No treatment	---	25 a-c	108 a
Weed free	---	------	101 a-e

[a] These treatments also included R-29148 as protectant at 0.3 kg/ha. Other thiocargamate herbicide treatments included R-25788 at 0.3, 0.4 or 0.6 kg/ha.

[b] Means within columns followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Field study near Bellaire, Kansas.

EPTC at 4.5 and 6.7 kg/ha also did not control shattercane at this location (Table 14). Poor EPTC activity was especially evident at eight weeks. Butylate or cycloate applied alone provided excellent control whereas vernolate applied alone provided only fair shattercane control.

Fonofos at the rate of 4.5 kg/ha increased EPTC activity to a greater extent than R-33865 at this location. A similar result was observed when fonofos was combined with butylate.

The addition of R-33865 to EPTC was observed to increase EPTC activity when shattercane growth was evaluated at four weeks. R-33865 effect on EPTC was more evident when biomass measurements were made than when visual ratings or stand counts were taken. Numerous shattercane plants were present in plots treated with EPTC plus R-33865 but had recently emerged and/or were stunted. R-33865 did not increase butylate activity but did increase vernolate activity when shattercane growth was evaluated at four or eight weeks.

Experimental herbicides provided excellent shattercane control at this location.

Herbicide treatments did not significantly affect corn stand and height at this location (Table 15).

Table 14. Effect of thiocarbamate herbicides applied alone or in combination with fonofos or R-33865 and other experimental herbicides on shattercane growth in corn near Bellaire, Kansas.

Treatment	Rate	4 weeks visual rating	4 weeks density[b]	8 weeks visual rating	8 weeks density[b]	8 weeks biomass[c]
	(kg/ha)	(%)[b]				
EPTC	4.5	81 d	72 c-e	39 g	59 f	70 d
EPTC	6.7	79 d	77 b-e	39 g	74 b-f	60 e
Butylate	6.7	96 ab	94 a-c	89 ab	92 a-c	99 ab
Vernolate	6.7	86 cd	80 b-e	45 fg	69 c-f	83 ab
Cycloate	6.7	98 ab	91 a-c	84 b-e	89 b-e	98 ab
EPTC + Fonofos	6.7 + 4.5	97 ab	90 b-e	83 b-e	84 b-f	99 ab
EPTC + R-33865	4.5 + 0.8	94 a-c	85 b-e	64 e-g	68 d-f	92 bc
EPTC + R-33865	6.7 + 1.1	93 a-d	84 b-e	67 d-g	65 d-f	93 a-c
Butylate + Fonofos	6.7 + 4.5	91 b-d	70 de	92 a-d	73 b-f	98 ab
Butylate + R-33865	6.7 + 1.1	91 b-d	59 e	88 b-e	66 b-f	87 bc
Vernolate + R-33865	6.7 + 1.1	95 a-c	87 b-e	69 d-g	86 a-d	92 b-c
EPTC[a]	6.7	80 d	84 b-e	39 g	64 ef	62 d
EPTC[a] + R-33865	6.7 + 1.1	96 ab	89 b-e	73 c-f	78 b-f	96 a-c
SC - 7829	2.2	98 ab	94 a-c	95 a-c	89 b-f	99 ab
SC - 7829	4.5	98 ab	87 b-e	93 a-c	85 b-e	99 ab
SC - 8149	2.2	98 ab	91 b-d	97 a-c	92 a-d	99 ab
SC - 8149	4.5	98 ab	94 ab	97 a-c	92 a-d	99 ab
No treatment	---	0 e	0 f	0 h	0 g	0 f
Weed free	---		100 a	100 a	100 a	100 a

[a] These treatments also included R-29148 as protectant at 0.3 kg/ha. Other thiocarbamate herbicide treatments include R-25788 as protectant at 0.3, 0.4, or 0.6 kg/ha.

[b] Actual shattercane density in no treatment plots averaged 186 and 140 plants/m^2 at 4 and 8 weeks respectively.

[c] Actual shattercane biomass in no treatment plots averaged 647 g/m^2 (oven dry weight basis).

[d] Percent values represent reduction in density and/or biomass. Means within columns followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 15. Effect of thiocarbamate herbicides applied alone or in combination with fonofos or R-33865 and other experimental herbicides on corn growth near Bellaire, Kansas.

Treatment	Rate	Corn stand 4 weeks	Corn height 8 weeks
	(kg/ha)	(plants/cm)	(cm)
EPTC	4.5	30 a-c	103 ab
EPTC	6.7	25 bc	92 a-c
Butylate	6.7	27 a-c	101 a-c
Vernolate	6.7	28 a-c	103 ab
Cycloate	6.7	28 a-c	101 a-c
EPTC + Fonofos	6.7 + 4.5	33 ab	110 a
EPTC + R-33865	4.5 + 0.8	28 a-c	94 a-c
EPTC + R-33865	6.7 + 1.1	28 a-c	97 a-c
Butylate + Fonofos	6.7 + 4.5	35 a	109 a
Butylate + R-33865	6.7 + 1.1	29 a-c	95 a-c
Vernolate + R-33865	6.7 + 1.1	27 a-c	100 a-c
EPTC[a]	6.7	25 bc	102 a-c
EPTC[a] + R-33865	6.7 + 1.1	24 c	92 c
SC - 7829	2.2	29 a-c	101 a-c
SC - 7829	4.5	25 bc	101 a-c
SC - 8149	2.2	30 a-c	102 a-c
SC - 8149	4.5	23 c	97 a-c
No treatment	---	----	86 b-c
Weed free	---	28 a-c	99 a-c

[a]These treatments also included R-29148 as protectant at 0.3 kg/ha. Other thiocarbamate herbicide treatments included R-25788 at 0.3, 0.4, or 0.6 kg/ha.

[b]Means within columns followed by common letters are not significantly different at 5% level according to Duncan's multiple range test.

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A P P E N D I X

Table 1. Effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on shattercane growth in corn near Scranton, Kansas.

Treatment	Rate	Density 4 weeks	Density 8 weeks	Biomass 8 weeks
	(kg/ha)	(plants/m^2)[b]		(g/m^2)[b]
EPTC	4.5	222 b-e	241 bc	186.06 b
EPTC	6.7	278 bc	295 b	197.96 b
Butylate	6.7	182 b-e	167 c-f	111.75 b-d
Vernolate	6.7	77 c-e	167 c-f	49.96 c-e
Cycloate	6.7	246 b-d	170 c-f	139.44 bc
EPTC + Fonofos	6.7 + 4.5	114 c-e	169 c-f	52.72 c-e
EPTC + R-33865	4.5 + 0.8	16 e	24 g	3.06 e
EPTC + R-33865	6.7 + 1.1	6 e	15 g	3.76 e
Butylate + Fonofos	6.7 + 1.1	383 b	177 b-f	147.52 bc
Butylate + R-33865	6.7 + 1.1	293 bc	179 b-e	135.78 bc
Vernolate + R-33865	6.7 + 1.1	83 c-e	25 g	19.21 de
EPTC[a]	6.7	175 b-e	213 b-d	169.80 b
EPTC[a] + R-33865	6.7 + 1.1	10 de	52 fg	21.67 de
SC-7829	2.2	204 c-e	147 c-f	123.06 b-d
SC-7829	4.5	80 c-e	52 fg	43.04 c-e
SC-8149	2.2	132 c-e	87 e-g	63.36 c-e
SC-8149	4.5	143 c-e	93 d-g	63.89 c-e
No treatment	---	604 a	437 a	376.23 a
Weed free	---	0 e	0 g	0.00 e

[a] These treatments also included R-29148 as protectant at 0.3 kg/ha. Other thiocarbamate herbicide treatments included R-25788 as protectant at 0.3, 0.4, or 0.6 kg/ha.

[b] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 2. Effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on shattercane growth in corn near Bellaire, Kansas.

Treatment	Rate	Density 4 weeks	Density 8 weeks	Biomass 8 weeks
	(kg/ha)	plants/m^2		(gm^2)
EPTC	4.5	52 bc	58 b	193.81 cd
EPTC	6.7	42 b-d	37 b-d	402.31 b
Butylate	6.7	12 cd	10 cd	7.67 e
Vernolate	6.7	37 b-d	44 bc	108.31 de
Cycloate	6.7	16 cd	16 b-d	14.86 e
EPTC + Fonofos	6.7 + 4.5	19 cd	23 b-d	7.57 e
EPTC + R-33865	4.5 + 0.8	28 cd	44 bc	54.59 e
EPTC + R-33865	6.7 + 1.1	30 b-d	49 bc	44.19 e
Butylate + Fonofos	6.7 + 4.5	56 bc	38 b-d	10.58 e
Butylate + R-33865	6.7 + 1.1	77 b	46 bc	85.45 de
Butylate + R-33865	6.7 + 1.1	25 cd	13 cd	53.93 e
EPTC[a]	6.7	30 b-d	52 bc	246.96 c
EPTC[a] + R-33865	6.7 + 1.1	21 cd	31 b-d	28.49 e
SC-7829	2.2	12 cd	19 b-d	2.37 e
SC-7829	4.5	25 cd	15 cd	5.81 e
SC-8149	2.2	16 cd	11 cd	3.08 e
SC-8149	4.5	11 cd	11 cd	3.33 e
No treatment	---	186 a	140 a	646.66 a
Weed free	---	0 d	0 d	0.00 e

[a] These treatments also included R-29148 as protectant at 0.3 kg/ha. Other thiocarbamate herbicide treatments included R-25788 at 0.3, 0.4, or 0.6 kg/ha.

[b] Means within columns followed by common letters are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 3. Analysis of variance of the effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on visual evaluations of shattercane control in corn near Scranton, Kansas.

		Mean Square		
		Visual Rating		
Source	d.f.	2 weeks	4 weeks	8 weeks
Rep.	2	0.1748	0.1932	0.1881
Treat.	18	0.2682	0.3633	0.4376
Error	36	0.0157	0.0166	0.0222

Table 4. Analysis of variance of the effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on shattercane density and growth in corn near Scranton, Kansas.

		Mean Square					
		Density				Biomass	
		4 weeks		8 weeks		8 weeks	
Source	d.f.	Actual	% control	Actual	% control	Actual	% control
Rep.	2	17899.07	0.0510	5984.33	0.0046	4891.81	0.0095
Treat.	18	65820.09	0.4414	36046.11	0.4421	25981.91	0.4842
Error	36	13263.35	0.0624	4245.09	0.0412	3109.56	0.0457

Table 5. Analysis of variance of the effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on corn grown near Scranton, Kansas.

		Mean square	
Source	d.f.	Corn stand 4 weeks (plants/8m)	Corn height 8 weeks (cm)
Rep.	2	1.1053	14.8948
Treat.	18	107.3665	22.4444
Error	36	7.5682	4.0059

Table 6. Analysis of variance of the effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on visual evaluations of shattercane control in corn near Bellaire, Kansas.

		Mean square Visual Rating	
Source	d.f.	4 weeks	8 weeks
Rep.	2	0.0542	0.1731
Treat	18	0.5487	0.6378
Error	36	0.0225	0.0534

Table 7. Analysis of variance of the effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on shattercane density and growth in corn near Bellaire, Kansas.

Source	d.f.	Means Square					
		Density				Biomass	
		4 weeks		8 weeks		8 weeks	
		Actual	% control	Actual	% control	Actual	% control
Rep.	2	870.39	0.0203	631.07	0.1160	1417.17	0.1385
Treat	18	49.67	0.2983	2822.23	0.3264	85459.15	0.5460
Error	36	658.99	0.0454	458.70	0.0562	4814.12	0.0367

Table 8. Analysis of variance of the effect of thiocarbamate herbicides applied alone or in combination with microbial enzyme inhibitors or experimental compounds on corn grown near Bellaire, Kansas.

Source	d.f.	Mean square	
		Corn stand 4 weeks (plants/8m)	Corn height 8 weeks (cm)
Rep.	2	20.33	16.8596
Treat	18	150.71	20.0448
Error	36	19.57	13.3782

SHATTERCANE [SORGHUM BICOLOR (L.) MOENCH] CONTROL WITH THIOCARBAMATE HERBICIDES APPLIED ALONE OR IN COMBINATION WITH FONOFOS (O-ETHYL-S-PHENYLETHYL PHOSPHORODITHIOATE) OR R-33865 (O,O-DIETHYL-O-PHENYLPHOSPHOROTHIOATE) ON SOILS WITH AND WITHOUT PREVIOUS EPTC (S-ETHYL DIPROPYLTHIOCARBAMATE) HISTORY

by

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Activity of thiocarbamate herbicides applied alone or in combination with fonofos (O-ethyl-S-phenylethyl-phosphorodithioate) or R-33865 (O,O-diethyl-O-phenylphosphorothioate) was evaluated under greenhouse conditions in late 1980 or early 1981 and in the field in 1981. Soils used in the greenhouse study were sampled from six different locations in Kansas where EPTC (S-ethyl dipropylthiocarbamate) was applied in 1980 and/or 1979, planted to corn and where severe shattercane [Sorghum bicolor (L.) Moench] infestations were present. Two locations, namely Scranton and Bellaire, were used in the field study.

EPTC, butylate (S-ethyl diisobutylthiocarbamate) and vernolate (S-propyl dipropylthiocarbamate) significantly reduced emergence and prevented top growth of 'Kansas Orange' forage sorghum planted immediately after application in one soil with EPTC history and severely reduced top growth in a second soil with EPTC history. R-33865 effectively prevented loss in activity of EPTC, but not butylate, or vernolate in these two soils 21 days after application. EPTC caused a slight reduction in dry matter production of sorghum planted 3 days but not 5, 7, or 14 days after application. EPTC activity in three different soils as indicated by growth of forage sorghum planted 5 days after treatment was less in a soil subsample with EPTC history than in a soil subsample without EPTC history.

Previous applications in three other fields did not affect activity of EPTC applied to soils from these fields. Loss of EPTC activity was observed in all six soils when repeat applications were made at four week intervals. Usually loss of EPTC activity was evident after the second application both in soils with and without

EPTC history. R-33865 prevented loss in activity of EPTC even when EPTC plus R-33865 applications were repeated four times.

EPTC did not provide adequate shattercane control in corn at either Scranton or Bellaire. Butylate and cycloate effectively controlled shattercane at Bellaire but not at Scranton. Vernolate did provide adequate control at both locations. Fonofos (O-ethyl-S-phenylethyl-phosphorodithioate) and R-33865 appeared to prolong EPTC activity at these locations since EPTC combined with these compounds effectively controlled shattercane after eight weeks. Fonofos and R-33865 did not significantly affect butylate activity and R-33865 did not affect vernolate activity at either location. None of the treatments affected corn stand at either location. EPTC plus R-33865 applied at 6.7 plus 1.1 kg/ha did significantly reduce corn height at eight weeks at Scranton but not at Bellaire even though a crop protectant was present.