This is to certify that the

thesis entitled

Influence of Adjuvants and Desmedipham Plus Phenmedipham on Velvetleaf and Sugarbeet Response to Triflusulfuron Methyl

presented by

Robert Joseph Starke

has been accepted towards fulfillment of the requirements for

M. S. degree in Crop & Soil Science

Karen A Renner
Major professor

Date March 21, 1995

INFLUENCE OF ADJUVANTS AND DESMEDIPHAM PLUS PHENMEDIPHAM ON VELVETLEAF AND SUGARBEET RESPONSE TO TRIFLUSULFURON METHYL

By

Robert Joseph Starke

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crop & Soil Sciences

1995

ABSTRACT

INFLUENCE OF ADJUVANTS AND DESMEDIPHAM PLUS PHENMEDIPHAM ON VELVETLEAF AND SUGARBEET RESPONSE TO TRIFLUSULFURON METHYL

By

Robert Joseph Starke

Velvetleaf currently cannot consistently be controlled with herbicides in sugarbeet. Sugarbeet response and velvetleaf control from postemergence applications of triflusulfuron alone and in combination with desmedipham plus phenmedipham, and adjuvants were evaluated in field and greenhouse experiments. Studies also determined if various adjuvants or desmedipham plus phenmedipham influenced triflusulfuron absorption by velvetleaf.

Sugarbeet injury was temperature dependent with greater and more persistent visual injury when triflusulfuron was applied at temperatures below 15 C. Triflusulfuron alone and in combination with desmedipham plus phenmedipham did not affect sugarbeet yield in the absence of weeds more than standard postemergence treatments.

Triflusulfuron controlled velvetleaf with negligible sugarbeet injury when an adjuvant was added to the spray solution. Adjuvants increased velvetleaf control from 10 to 84% depending on the adjuvant. With one exception, adding an adjuvant increased ^{14}C-triflusulfuron absorption by 16 to 75%. Adding desmedipham plus phenmedipham to triflusulfuron plus an adjuvant may decrease velvetleaf control and/or increase sugarbeet injury.

ACKNOWLEDGEMENTS

I would like to thank Dr. Karen Renner for her advice and guidance during my stay at Michigan State University. I would also like to acknowledge Doc. Penner and Dr. Bernie Zandstra for their helpful advice and for serving on my guidance committee. Special thanks also goes to Dr. Jim Kells for his wise instruction on my professional development (golf and otherwise).

G. Powell deserves a sincere thanks for his field expertise and for teaching me which party stores in Michigan have the coldest diet coke and the best ice cream cones. Special thanks goes out to Frank Roggenbuck for saving me many hours with all of his helpful greenhouse and laboratory advice.

My sincere appreciation is extended to Melody Davies for all of her assistance in this research. Special thanks also goes to Julie Lich for being the fastest and most dependable herbicide mixer the PRC has ever seen. Special thanks also goes to C. J. Palmer for his assistance.

I would also like to thank all of the other Michigan State "weed" people, (Boyd Carey, Rick Schmenk, Andy Chomas, Karen Geiger, Corey Guza, Jason Fausey, James Mickelson, Karen Novosel, Corey Ransom, Jeff Stachler, and Brent Tharp), who have all helped out at one time or another with this research.

Gratitude is also extended to those who started my career in weed science including Dr. Mike DeFelice, Dr. W.B. Brown, Cheryl Holman and Dr. L.G. Thompson.

TABLE OF CONTENTS

LIST OF TABLES

List of Figures

Chapter 1

Review of Literature

Velvetleaf was introduced to the Eastern United States around 1700 as a potential fiber source (70). Velvetleaf is now a widespread weed problem between 32° and 45° N in North America (77). Velvetleaf is also becoming an increasing problem in southern Europe (61).

Velvetleaf is a serious weed problem in sugarbeet and reduced sugarbeet yields 14, 17, 25, and 30% at densities of 6, 12, 18, and 24 weeds per 30 m of row (67). Currently velvetleaf is controlled in sugarbeet by preplant followed by postemergence herbicide applications (59). Triflusulfuron methyl is a sulfonylurea herbicide which controls velvetleaf postemergence in sugarbeet (3,71). An adjuvant is essential for velvetleaf control (71).

Desmedipham and phenmedipham are the most widely used postemergence herbicides in sugarbeet production in the United States and Canada (68). Triflusulfuron and desmedipham plus phenmedipham provide a broadspectrum postemergence weed control program in sugarbeet when applied as a tank mixture or sequentially (3,21,58).

<u>Name</u> (*Abutilon theophrasti* Medicus.)

Avicenna, an Arabic philosopher, coined the word "abutilon" for plants resembling a mallow or mulberry around 900 B.C. (49). In 1787, Fredrich Casimir Medicus, director of the garden at Mannheim, published a volume in which he placed the genus *abutilon* with the epithet *theophrasti*. *Theophrasti* honors the

Greek philosopher Theophrastus, who is regarded as the father of modern botany. The "Medicus" citation refers to Fredrich Casimir Medicus (49). *Abutilon theophrasti* has also been referred to as *Sida abutilon* and *Abutilon avicennae* (36,49). Common names of velvetleaf include abutilon hemp, American jute, butterprint, buttonweed, China jute, cottonweed, elephant ears, Indian mallow, Manchurian jute, and Tientsin jute (49,70).

History and Distribution.

Velvetleaf has been grown in China as a fiber crop since 200 B.C. The fiber of the velvetleaf plant is processed for rope, course cloth paper, fishing nets, and caulk for boats (49,70,77). Spencer (70) suggested that velvetleaf seeds are also eaten, mainly by children in China and Kashmir.

Velvetleaf was probably introduced into the United States as a prospective fiber source in Virginia or Pennsylvania early in the 18th century (70). Fiber was very important in the 17th and 18th century for the marine industry. A single ship might require 3 1/2 miles of rope which had to be replaced every 2 to 4 years (70).

A report at the 1871 Illinois State Fair indicated mixed feelings about a potential fiber plant that was becoming a persistent weed in the corn fields of Illinois (70). The concern expressed was well founded.

Velvetleaf is a persistent weed in waste areas, fence rows, and cultivated fields. Velvetleaf seeds germinate more rapidly under conventional tillage than with a reduced or no-till tillage system (12,45). The continuous soil disturbance by conventional tillage may move the velvetleaf seeds to a depth in the soil which is more favorable for germination. Dekker and Meggitt (19) found the mean depth of velvetleaf seedling emergence was 9 to 39 mm below the soil surface and velvetleaf emerged from shallower depths as the growing season progressed. Mester and Buhler (46) reported a higher survival rate of velvetleaf seeds that germinated at a 2 to 6 cm depth as compared to velvetleaf seeds which germinated on the soil surface.

Lueschen and Anderson (45) reported that after 4 years in a conventional tillage rotation with no additional velvetleaf seed produced, 21% of the original seeds in the seedbank remained viable in the soil. After 17 years with no velvetleaf seed produced under a no tillage system, 25% of the original velvetleaf seeds remained and nearly 100% of the seeds were still viable. This experiment illustrates the extreme difficulty of eradicating velvetleaf seeds from the soil (44).

General Morphology

Velvetleaf is an annual species which reproduces only by seed (49). The taproot of velvetleaf is slender and has many branches (77). The root growth rate of velvetleaf exceeds redroot pigweed, green foxtail, and several other weeds (60). Stems are 1 to 4 m tall with short velvety hairs and many branches in the upper portion of the plant (77). Leaves are alternate, long-petiolated, broadly heart-shaped, 7 to 20 cm wide, shallowly round-toothed, and velvety with a dense covering of stellate hairs (77). Velvetleaf has both simple and complex trichomes on the leaf surface which may reduce the effectiveness of herbicides (32,52).

Velvetleaf flowering is triggered by day length. The flowers are single or in small clusters from the leaf axils, with five sepals and five yellow to yellow-orange

petals which are slightly notched, apically. The fruit or capsule is a cup-shaped, circular cluster of 12 to 15 seed pods which contain one to three seeds and is generally black at maturity (77). Average capsules produce 35 to 45 seeds, with 70 to 199 mature capsules per plant resulting in 700 to 1700 seeds produced per plant (1,77). The seeds are kidney shaped, purplish brown, 1 mm thick and 2 to 3 mm long. Velvetleaf is a hexaploid species with 2n=6x=42 chromosomes (77).

The majority of velvetleaf seeds exhibit a type of primary dormancy known as "hardseededness", because the seed coat is impermeable to water (35,45,77). The hard seed coat not only extends germination, but also protects the seed against damage from ingestion by animals and from storage in manure (77). Alternate freezing and thawing temperatures under field conditions produce fractures in the seed coat and terminate seed dormancy (42,77). Velvetleaf seeds also exhibit embryo dormancy in which the seeds germinate sporadically after the seed coat is broken (45,77).

Primary dormancy of velvetleaf seeds can be broken by various chemical and physical treatments. An effective way is to immerse the seed in 60 to 70 C water for 5 to 10 minutes (37,77). Mechanical scarification and immersion in sulfuric acid (H_2SO_4) are other possible alternatives to overcome primary dormancy of velvetleaf seeds (72). Khedir and Roeth (37) found that immersion of velvetleaf seed in water at 70 C for 5 minutes improved seed germination from 11% to 84% compared to 52% for sulfuric acid, 48% for scarification, and 62% for seed coat puncture. Egley (25) indicated 92% of velvetleaf seeds were viable after being heated to 60 C for seven days in dry soil, but only 4% were viable after seven days if the temperature was 70 C. In moist soil, temperatures above 60 C resulted in the germination of velvetleaf seedlings which were subsequently killed by the heat (25). Leuschen and Anderson (45) suggested seeds which have broken primary dormancy may reverse and become water impermeable (dormant).

Velvetleaf seeds are resistant to degradation by microbial organisms. Kremer (41) reported velvetleaf seeds inhibited the growth of 117 of 202 bacteria isolates and all 39 fungal isolates examined. Gressel (29) found aqueous extracts from velvetleaf seeds contained free amino acids which inhibited the germination of radish (*Raphanus sativus* L.) and tomato (*Lycopersicum esculentum* Mill.) seedlings. Paszkowski and Kremer (54) isolated six flavonoids from velvetleaf seed coats which reduced the germination and radicle growth of cress (*Lepidium sativum* L.), radish (*Raphanus sativus* L.), and soybean (*Glycine max* L.). Kremer (41) also reported naturally occurring seedborne microorganisms which hindered the establishment of soil microorganisms on velvetleaf seeds. A dense layer of palisade cells within the seedcoat also provides a physical barrier to the establishment of microorganisms capable of degrading velvetleaf seeds (38).

Dormancy mechanisms of velvetleaf seeds allow the seeds to remain viable for many years. Estimates of viability range from 70% after 3 years, 37% after 4 years, to 43% after 39 years (45,75,76). Differences in these estimates may vary because of the different methods used by researchers to break the primary dormancy of velvetleaf seeds. Burnside (13) reported 43% of seeds viable after 7 years of burial, however 100% of the seeds were still viable according to a tetrazolium test.

Biological Control

Many attempts have been made to discover an economically feasible method of biologically controlling velvetleaf. Benzyl isothiocyanate, isolated from papaya seeds, (*Carica papaya* L.) inhibited velvetleaf germination and killed velvetleaf seedlings (84). Mortenson (50) found the fungus *Colletotrichum gloeosporioides* provided 60 to 70% control of velvetleaf after 72 hours in a mist chamber, however, very low infection rates were obtained under field conditions. Boyette and Walker (9) reported the fungus *Fusarium lateritium* controlled velvetleaf preemergence and postemergence, but the control was not as affective as bentazon [3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] applied postemergence. In greenhouse studies, Boyette (10) determined a dew period of 16 h was required to achieve 80% control of velvetleaf with *Fusarium lateritium* postemergence.

Wymore and Porier (85) reported *Colletotrichum coccodes,* a fungal pathogen gave 100% control of velvetleaf placed in a mist chamber for 18 to 24 h, however only 46% of velvetleaf were controlled under field conditions. *Colletotrichum coccodes* and thidiazuron [N-phenyl-N′-1,2,3-thiadiazol-5-yl-urea], a plant growth regulator, interacted synergistically to control velvetleaf when the plants were placed in a dew chamber for 18 hours (87). Hodgson and Snyder (34) found the combination of thidiazuron and *Colletotrichum coccodes* increased ethylene production by velvetleaf plants. Wymore and Watson (86) concluded *Colletotrichum coccodes* required strain improvement, discovery of methods to enhance spore survival under adverse environmental conditions and/or combinations with chemical herbicides or growth regulators to be an effective commercial velvetleaf herbicide.

Insects have also been evaluated for biological velvetleaf control. The scentless plant bug *(Niesthrea louisianica* Sailer) reduced viable seed production by 98% in controlled environmental chambers (55). Kremer and Spencer (39) reported field infestations of the scentless plant bug reduced viability of velvetleaf seed by 15.5 and 17.5% at two locations in central Missouri. Feeding by the scentless plant bug vectored infestation by seedborne microorganisms resulting in decreased velvetleaf seed viability (40).

Economic Importance

Velvetleaf was ranked the most troublesome weed in soybeans by 9 of 14 North Central states (60). Soybean growers spent $229 million to control velvetleaf in 1982 . If left uncontrolled, velvetleaf would cause an estimated $1 billion loss in soybeans (70). Corn growers spent $114 million to control velvetleaf in 1982 (70).

Many researchers have attempted to quantify interference by velvetleaf. Sterling and Putman (73) found in field experiments sweet corn (*Zea mays* L.) dry weight was reduced 51 to 91% by one velvetleaf plant growing 5 cm away. The extent of the dry weight reduction was dependent on the time of velvetleaf planting. Schmenk (62) reported 9 velvetleaf plants per meter of row reduced corn yield by 17%.

DeFelice et al. (18) measured velvetleaf growth in conventional and no-till corn. Velvetleaf grown in monoculture had a greater dry weight and growth rate than velvetleaf grown in conjunction with conventional or no-tillage corn. Weaver and Hamill (80) found velvetleaf produced more dry matter above ground at a soil pH of 6.0 or 7.3 than at 4.8, however, corn grain yield was reduced equally regardless of pH.

Researchers have reported velvetleaf reduces soybean yield 25 to 31% at a density of 2.5 plants/m^2 (74,20,30). Eaton et al. (24) reported a soybean yield decrease of 66% when velvetleaf were seeded 1.3 to 2.8 plants/m^2 at planting. Munger et al. (51) indicated that velvetleaf populations of 5 plants/m^2 resulted in an average soybean yield loss of 44%. Oliver (53) reported velvetleaf at a density of one plant per 30 cm of row reduced soybean yields 27% if the soybeans were planted in mid-May and 14% if the soybeans were planted in late June. Other researchers have also reported velvetleaf competition decreases if velvetleaf emerges later in the growing season (24,30).

Many researchers have attempted to determine if velvetleaf plants are allelopathic to other plants. Colton and Einhellig (14) found that aqueous extracts of exudates from velvetleaf leaves decreased germination of radish seeds and inhibited the growth of soybean seedlings in the greenhouse. Bhowmik and Doll (7) suggested velvetleaf residues inhibited corn and soybean growth in the greenhouse. In the field, velvetleaf residues did not affect corn yields, however, soybean yields were decreased 17% (7). Sterling and Putnam (73) reported that liquid globules exuded by velvetleaf trichomes are phytotoxic to certain species in controlled environments, however, they do not appear to play a role in the interference by velvetleaf in the field. They theorized ultraviolet degradation, leaching and/or microbial degradation might be responsible for decreased allelopathic activity in the field (73).

Competitiveness of Sugarbeet with weeds.

Sugarbeet has a prostrate growth habit and is not an effective competitor with weeds for light. Broadleaf weeds are generally more effective competitors with sugarbeets than annual grasses, because broadleaf weeds are more competitive for light (68). In Colorado, kochia (*Kochia scoparia* L.) at a density of 40 plants per m of row reduced root yield 95% (78). Common lambsquarters (*Chenopodium album* L.) at a density of 27 plants/m^2 reduced yields by 94% in Washington (17). In Wyoming, rough pigweed (*Amaranthus hybridus* L.) at 7 per m of row reduced yields 81% (11).

Low densities of broadleaf weeds or herbicide "escapes" also decrease sugarbeet yields. Six common sunflower (*Helianthus annuus* L.) plants per 30 m of row reduced sugarbeet root yield by 40% (67). Kochia, redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters or velvetleaf at a density of 6 plants per 30 m of row reduced sugarbeet root yield by 13 to 16% depending on the species (14,65,67,79). Mixed populations of weeds have also been found to decrease yields. Equal populations of common lambsquarters, kochia, and redroot pigweed decreased sugarbeet yields 11% at a density of 6 plants per 30 m of row (64). Wicks and Wilson (81) reported weeds which germinated at or before sugarbeets reached the two leaf stage were the most detrimental to yield.

Researchers have attempted to find alternative methods to handweeding for the control of weeds which are not controlled by initial herbicide treatment and cultivation. Schweizer and Bridge (66) evaluated applying the non-selective herbicide glyphosate [N-(phosphonomethyl)glycine] with a recirculating sprayer or a vertical roller for the control of common sunflower, kochia, common lambsquarters, and velvetleaf. They concluded glyphosate could be safely applied with a rope-wick applicator, however, great care must be taken to avoid glyphosate contact with the sugarbeet, because sugarbeet is very susceptible to glyphosate. Postemergence applications of triflusulfuron methyl may be an effective future method of control for "escaped" kochia, sunflower, and velvetleaf.

Triflusulfuron methyl

Triflusulfuron methyl is a sulfonylurea herbicide which controls velvetleaf with negligible sugarbeet response at rates of 9 to 32 g ai ha^{-1} (21,57,58,71). Sulfonylurea herbicides inhibit the production of the acetolactate synthase (ALS) enzyme in the chloroplast of susceptible plants (3,6,47). Inhibition of the enzyme stops the production of the essential branched-chain amino acids, isoleucine, leucine and valine, halting cell division and growth (3,6,47). Sugarbeet inactivates triflusulfuron by metabolizing it into compounds which are inactive on the ALS enzyme (3).

Triflusulfuron is believed to degrade equally by microbial degradation and chemical hydrolysis (3). Triflusulfuron has a half-life of 3 days at 25 C in a sandy loam soil. Degradation is temperature dependent with 40% of triflusulfuron remaining in a silt loam soil after 28 days at 4 C compared to less than 1% remaining at 25 C (3).

A surfactant is needed for optimum velvetleaf control with triflusulfuron (57,71). Velvetleaf control has been increased by adding surfactant and/or UAN to other postemergence herbicides (27,28,33,88). The addition of surfactant and/or UAN increased chlorimuron {2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid}, thifensulfuron {3-[[[[(4-methoxy-6-methyl,-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} and bentazon absorption by velvetleaf (4,27,28,43). Surfactants are known to change the surface tension of spray droplets, alter the morphology of epicuticular waxes, and cause cell necrosis (26). Research indicates additives react differently to various epicuticular waxes and epicuticular waxes vary in composition by plant species (26).

Researchers have attempted to obtain broad spectrum postemergence weed control in sugarbeet by tankmixing triflusulfuron with other herbicides. Control of kochia, common lambsquarters, redroot pigweed, and eastern black nightshade (*Solanum ptycanthum* Dun.) increased by adding desmedipham plus phenmedipham to triflusulfuron (21,22,57,58).

Desmedipham and Phenmedipham

Desmedipham and phenmedipham are the most commonly used postemergence herbicides in sugarbeets in the United States and Canada (68). Phenmedipham is a postemergence herbicide which controls common lambsquarters, hairy nightshade, and other broadleaf weeds (16,63,69,). Desmedipham is an analogue of phenmedipham and controls redroot pigweed which is not controlled by phenmedipham (19). Desmedipham and phenmedipham are formulated equally together and sold as one herbicide (2).

Desmedipham and phenmedipham are *bis*-carbamate herbicides which inhibit the Hill reactions of Photosystem II in the electron transport chain of photosynthesis (8,56). Monocotyledonous crops are able to tolerate applications of phenmedipham because of limited herbicide translocation to the apical meristem (8). Sugarbeet is believed to be tolerant to desmedipham and phenmedipham by increased metabolism of desmedipham and phenmedipham (15,31). Desmedipham and phenmedipham decreased sugarbeet photosynthesis by 60% 1 day after treatment; however, 10 days after treatment, photosynthetic rates were similar to the untreated control (56). Inhibition of sugarbeet photosynthesis increases as temperature and light intensity increase (5).

Mixtures of desmedipham and phenmedipham are often applied in split applications 5 to 10 days apart (68). Applying the herbicides at reduced application rates in split applications injures sugarbeet less than one application at a higher rate and improves control of broadleaf weeds (68). Researchers have also suggested at temperatures above 22 C applications of desmedipham plus phenmedipham should be delayed until the late afternoon to avoid sugarbeet injury (83).

Desmedipham plus phenmedipham is more effective than triflusulfuron in controlling common lambsquarters and redroot pigweed, however, it is less effective in suppressing kochia (82). Miller and Nalewaja (48) reported increased weed control and sugarbeet injury when additives were added to phenmedipham. Researchers have also noted increased sugarbeet injury when applying

desmedipham or phenmedipham to sugarbeet treated preemergence with cycloate {S-ethyl cyclohexylethylcarbamothioate or ethofumesate {(±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate (16,23). Ethofumesate decreased deposition of alkanes and *sec*-ketones in the surface of sugarbeet leaves allowing greater foliar absorption of desmedipham (23). This process is believed to be responsible for increased sugarbeet injury and weed control when ethofumesate or cycloate is applied preemergence and a postemergence herbicide is applied (16,23).

Greater than 99% of sugarbeets harvested receive a herbicide application, however, in many cases weed control is still inadequate (68). Triflusulfuron will be an effective tool for sugarbeet growers to control velvetleaf, a problem weed species. Researchers need to determine the optimal way for sugarbeet growers to use this new tool.

Literature Cited

1. Andersen, R. N., R. M. Menges, and J. S. Conn. 1985. Variability in velvetleaf *(Abutilon theophrasti)* and reproduction beyond its current range in North America. Weed Sci. 33:507-512.

2. Anonymous 1994. Betamix® Label. NOR-AM, 3509 Silverside Road, Wilmington DE. p. 1.

3. Anonymous. 1994. UpBeet herbicide technical bulletin. E.I. Dupont de Nemours and Company, Agricultural Products, Wilmington, Delaware p. 1-5.

4. Beckett, T. H., and E. W. Stoller. 1991. Effects of methylammonium and urea ammonium nitrate on foliar uptake of thifensulfuron in velvetleaf *(Abutilon theophrasti)*. Weed Sci. 39:333-338.

5. Bethlenfalvay, G., and R. R. Norris. 1975. Phytotoxic action of desmedipham: influence of temperature and light intensity. Weed Sci. 23:499-503.

6. Beyer, E. M. Jr., M. J. Duffy, J. V. Hay and D. Schleuter. 1988. Sulfonylureas. p. 117-189 *in* P. C. Kearney and D. D. Kaufman eds. Herbicides: Chemistry, Degradation and Mode of Action. 3rd ed., Marcel-Dekker, New York.

7. Bhowmik, P. C., and J. D. Doll. 1982. Corn and soybean response to allelopathic effects of weed and crop residues. Agron. J. 74:601-606.

8. Börner, H. 1979. Causes of the selective action of the photosynthetic inhibitors phenmedipham and bentazon. Z. Naturforsch. 34:926-93.

9. Boyette, C. D., and H. L. Walker. 1986. Evaluation of *Fusarium lateritium* as a biological herbicide for controlling velvetleaf *(Abutilon theophrasti)* and prickly sida *(Sida spinosa)*. Weed Sci. 34:106-109.

10. Boyette, C. D., and H. L. Walker. 1985. Factors influencing biocontrol of velvetleaf *(Abutilon theophrasti)* and prickly sida *(Sida spinosa)* with *Fusarium lateritium*. Weed Sci. 33:209-211.

11. Brimhall, P.B., E. W. Chamberlain, and H. P. Alley. 1965 Competition of annual weeds and sugarbeets. Weeds 13:33-35.

12. Buhler, D. D., and T. C. Daniel. 1988. Influence of tillage systems on giant foxtail, *Setaria faberi*, and velvetleaf, *Abutilon theophrasti*, density and control in corn, *Zea mays*. Weed Sci. 36:642-647.

13. Burnside, O. C., C. R. Fenster, L. L Evetts, and R. F. Mumm. 1981. Germination of exhumed weed seed in Nebraska. Weed Sci. 29:577-586.

14. Colton, C. E., and F. A. Einhellig. 1980. Allelopathic mechanisms of velvetleaf *(Abutilon theophrasti Medic., Malvaceae)* on soybean. American J. Bot. 67:1407-1413.

15. Davies, H. M., A. Merydith, L. Mende-Mueller, and A. Aapola. 1990. Metabolic detoxification of phenmedipham in leaf tissue of tolerant and susceptible species. Weed Sci. 38:206-214.

16. Dawson, J. H.. 1975. Cycloate and phenmedipham as complementary treatments in sugarbeets. Weed Sci. 23:478-485.

17. Dawson J. H. 1965. Competition between irrigated sugar beets and annual weeds. Weeds 13:245-249.

18. Defelice, M. S., W. W. Witt, and M. Barrett. 1988. Velvetleaf *(Abutilon theophrasti)* growth and development in conventional and no-tillage corn *(Zea mays)*. Weed Sci. 36:609-615.

19. Dekker, J., and W. F. Meggit. 1986. Field emergence of velvetleaf *(Abutilon theophrasti)* in relation to time and burial depth. Iowa State Journal of Research 61:65-80.

20. Dekker, J., and W. F. Meggit. 1983. Interference between velvetleaf (*Abutilon theophrasti* Medic.) and soybean (*Glycine max* (L.) Merr.) II. population dynamics. Weed Res. 23:103-107.

21. Dexter, A. G., J. L. Luecke, and M. W. Bredehoeft. 1992. Postemergence control of broadleaf weeds in sugarbeet. Proc. North Cent. Weed Sci. 47:125.

22. Dexter, A. G., J. L. Luecke, and M. W. Bredehoeft. 1993. Postemergence herbicide combinations in sugarbeet. Proc. North Cent. Weed Sci. 48:90.

23. Duncan, D. N., W. F. Meggitt, and D. Penner. 1982. Basis for increased activity from herbicide combinations with ethofumesate applied on sugarbeet *(Beta vulgaris)*. Weed Sci. 30:195-200.

24. Eaton, B. J., O. G. Russ, and K. C. Feltner. 1976. Competition of velvetleaf, prickly sida, and venice mallow in soybeans. Weed Sci. 24:224-228.

25. Egley, G. H.. 1990. High-temperature effects on germination and survival of weed seeds in soil. Weed Sci. 38:429-435.

26. Falk, R. H., R. Guggenheim, and G. Schulke. 1994. Surfactant-induced phytotoxicity. Weed Technol. 8:519-525.

27. Fielding, R. J., and E. W. Stoller. 1990. Effects of additives on the efficacy, uptake, and translocation of the methyl ester of thifensulfuron. Weed Sci. 38:172-178.

28. Fielding, R. J., and E. W. Stoller. 1990. Effects of additives on efficacy, uptake, and translocation of chlorimuron ethyl ester. Weed Tech. 4:264-271.

29. Gressel, J. B., and L. G. Holm. 1964. Chemical inhibition of crop germination by weed seeds and the nature of inhibition by *Abutilon theophrasti.* Weed Res. 4:44-53.

30. Hagood, E. S. JR., T. T. Bauman, J. L. Williams, JR., and M. M. Schreiber. 1980. Growth analysis of soybeans *(Glycine max)* in competition with velvetleaf *(Abutilon theophrasti)*. Weed Sci. 28:729-734.

31. Hendrick L. W., W. F. Meggitt and D. Penner. 1974. Basis for selectivity of phenmedipham and desmedipham on wild mustard, redroot pigweed, and sugarbeet. Weed Sci. 22:179-184.

32. Hess, F. D., and R. H. Falk. 1990. Herbicide deposition on leaf surfaces. Weed Sci. 38:280-288.

33. Hinz, J. R., and M. D. K. Owen. 1994. Effect of drought stress on velvetleaf *(Abutilon theophrasti)* and bentazon efficacy. Weed Sci. 42:76-81.

34. Hodgson, R. H., and R. H. Snyder. 1989. Thidiazuron and *Colletotrichum coccodes* effects on ethylene production by velvetleaf (*Abutilon theophrasti*) and prickly sida (*Sida spinosa*). Weed Sci. 37:484-489.

35. Horowitz, M., and T. B. Taylorson. 1984. Hardseededness and germinability of velvetleaf *(Abutilon theophrasti)* as affected by temperature and moisture. Weed Sci. 32:111-115.

36. Li, Hui-Lin. 1970. The origin of cultivated plants in southeast Asia. Econ. Bot. 24:3-19.

37. Khedir, K. D., and F. W. Roeth. 1981. Velvetleaf *(Abutilon theophrasti)* seed populations in six continuous-corn *(Zea mays)* fields. Weed Sci. 29:485-490.

38. Kremer, R. J., L. B. Hughes Jr. and R. J. Aldrich. 1984. Examination of microorganisms and deterioration mechanisms associated with velvetleaf seed. Agron. J. 76:745-749.

39. Kremer, R. J., and N. R. Spencer. 1989. Impact of a seed-feeding insect and microorganisms on velvetleaf *(Abutilon theophrasti)* seed viability. Weed Sci. 37:211-216.

40. Kremer, R. J., and N. R. Spencer. 1989. Interaction of insects, fungi, and burial on velvetleaf *(Abutilon theophrasti)* seed viability. Weed Tech. 3:322-328.

41. Kremer, R. J. 1986. Antimicrobial activity of velvetleaf *(Abutilon theophrasti)* seeds. Weed Sci. 34:617-622.

42. LaCroix, L. J., and D. W. Staniforth. 1964. Seed dormancy in velvetleaf. Weeds 12:171-174.

43. Levene, B. C., and M. D. K. Owen. 1994. Movement of ^{14}C-bentazon with adjuvants into common cocklebur *(Xanthium strumarium)* and velvetleaf *(Abutilon theophrasti)*. Weed Tech. 8:93-98.

44. Lueschen, W. E., R. N. Andersen, T. R. Hoverstad, and B. K. Kanne. 1993. Seventeen years of cropping systems and tillage affect velvetleaf *(Abutilon theophrasti)* seed longevity. Weed Sci. 41:82-86.

45. Lueschen, W. E., and R. N. Andersen. 1980. Longevity of velvetleaf *(Abutilon theophrasti)* seeds in soil under agricultural practices. Weed Sci. 28:341-346.

46. Mester, T. C., and D. D. Buhler. 1991. Effects of soil temperature, seed depth, and cyanazine on giant foxtail *(Setaria faberi)* and velvetleaf *(Abutilon theophrasti)* seedling development. Weed Sci. 39:204-209.

47. Miflin, B., 1974. The localization of nitrate reductase and other enzymes related to amino acid biosynthesis in the plastids of roots and leaves. Plant Physiol. 54:550.

48. Miller, S. D., and J. D. Nalewaja. 1973. Effect of additives upon phenmedipham for weed control in sugarbeets. Weed Sci. 21:67-70.

49. Mitich, L. W.. 1991. Intriguing world of weeds. velvetleaf. Weed Tech. 5:253-255.

50. Mortensen, K.. 1988. The potential of an endemic fungus, *Colletotrichum gloeosporioides*, for biological control of round-leaved mallow *(Malva pusilla)* and velvetleaf *(Abutilon theophrasti)*. Weed Sci. 36:473-478.

51. Munger, P. H., J. M. Chandler, J. T. Cothren, and F. M. Hons. 1987. Soybean *(Glycine max)* - velvetleaf *(Abutilon theophrasti)* interspecific competition. Weed Sci. 35:647-653.

52. Navasero, R. C., and S. B. Ramaswamy. 1991. Morphology of leaf surface trichomes and its influence on egglaying by *Heliothis virescens*. Crop Sci. 31:342-353.

53. Oliver, L. R.. 1979. Influence of soybean *(Glycine max)* planting date on velvetleaf *(Abutilon theophrasti)* competition. Weed Sci. 27:183-188.

54. Paszkowski, W. L., and R. J. Kremer. 1988. Biological activity and tentative identification of flavonoid components in velvetleaf (*Abutilon theophrasti* Medik.) seed coats. Journal of Chemical Ecology 14:1573-1582.

55. Patterson, D. T., R. D. Coffin, and N. R. Spencer. 1987. Effects of temperature on damage to velvetleaf *(Abutilon theophrasti)* by the scentless plant bug (*Niesthrea louisianica)*. Weed Sci. 35:324-327.

56. Prodoehl, K. A., L. G. Campbell, and A. G. Dexter. 1992. Phenmedipham + desmedipham effects on sugarbeet. Agron. J. 84:1002-1005.

57. Reese, K. D., and M. M. Loux. 1992. Efficacy and timeliness of DPX-66037 for weed control in sugar beets. Proc. North Cent. Weed Sci. Soc. 47:124.

58. Renner, K.A., and T. M. Crook. 1992. Postemergence weed control in sugar beets with DPX-66037. Proc. North Cent. Weed Sci. Soc. 47:126.

59. Renner, K. A., and G. E. Powell. 1991. Velvetleaf *(Abutilon theophrasti)* control in sugarbeet. Weed Technol. 5:97-102.

60. Roeth, F. 1987. Velvetleaf. Coming on strong. Crops and Soils Mag. March:10-11.

61. Sattin, M., G. Zanin, and A. Berti. 1992. Case history for weed competition/population ecology: velvetleaf *(Abutilon theophrasti)* in corn (*Zea mays*). Weed Tech. 6:213-219.

62. Schmenk R. E. Jr. 1994. Velvetleaf (*Abutilon theophrasti* (Medik.)) competitiveness in corn as affected by preemergence herbicides. Masters Thesis, Michigan State University. pp. 64.

63. Schweizer, E. E. 1974. Weed control in sugarbeets with cycloate, phenmedipham and EP 475. Weed Res. 14:39-44.

64. Schweizer, E. E.. 1981. Broadleaf weed interference in sugarbeets *(Beta vulgaris)*. Weed Sci. 29:128-133.

65. Schweizer, E. E.. 1983. Common lambsquarters *(Chenopodium album)* interference in sugarbeets *(Beta vulgaris)*. Weed Sci. 31:5-8.

66. Schweizer, E. E., and L. D. Bridge. 1982. Control of five broadleaf weeds in sugarbeets *(Beta vulgaris)* with glyphosate. Weed Sci. 30:291-296.

67. Schweizer, E. E., and L. D. Bridge. 1982. Sunflower *(Helianthus annus)* and velvetleaf *(Abutilon theophrasti)* interference in sugarbeets *(Beta vulgaris)*. Weed Sci. 30:514-519.

68. Schweizer, E. E., and A. G. Dexter. 1987. Weed control in sugarbeets *(Beta vulgaris)* in North America. Rev. Weed Sci. 3:113-133.

69. Schweizer, E. E., and D. M. Weatherspoon. 1971. Response of sugarbeets and weeds to phenmedipham and two analogues. Weed Sci. 19:635-639.

70. Spencer, N. R., 1984. Velvetleaf, *Abutilon theophrasti* (Malvaceae), history and economic impact in the United States. Econ. Bot. 38:407-416.

71. Starke, R. J., and K. A. Renner. 1993. Velvetleaf *(Abutilon theophrasti)* response to triflusulfuron methyl. Proc. North Cent. Weed Sci. 48:88-89.

72. Steinbauer G. P., and B. Grigsby. Methods of obtaining field and laboratory germination of seeds of bindweeds, lady's thumb and velvetleaf. Weeds 7:41-46.

73. Sterling, T. M., and A. R. Putnam. 1987. Possible role of glandular trichome exudes in interference by velvetleaf *(Abutilon theophrasti)*. Weed Sci. 35:308-314.

74. Stoller, E. W., and J. T. Woolley. 1985. Competition for light by broadleaf weeds in soybeans *(Glycine max)*. Weed Sci. 33:199-202.

75. Stoller, E. W., and J. T. Woolley. 1974. Dormancy changes and the fate of some annual weed seeds in the soil. Weed Sci. 22:151-155.

76. Toole, E. H., and E. Brown. 1946. Final results of the buried seed experiments. J. Agric. Res. 72:201-210.

77. Warwick, S. I., and L. D. Black. 1988. The biology of Canadian weeds.90. *Abutilon theophrasti.* Canadian Journal of Plant Sci. 68:1069-1085.

78. Weatherspoon, D. M., and E. E. Schweizer, 1969. Competition between kochia and sugarbeets (*Beta vulgaris*). Weed Sci. 17:464-467.

79. Weatherspoon, D. M., and E. E. Schweizer. 1971. Competition between sugarbeets and five densities of kochia. Weed Sci. 19:125-128.

80. Weaver, S. E., and A. S. Hamill. 1985. Effects of soil pH on competitive ability and leaf nutrient content of corn *(Zea mays* L.) and three weed species. Weed Sci. 33:447-451.

81. Wicks, G. A. and R. G. Wilson. 1983. Control of sugarbeets (*Beta vulgaris*) with handhoeing and herbicides. Weed Sci. 31:493-499.

82. Wilson, R. G.. 1994. New herbicides for postemergence application in sugarbeet *(Beta vulgaris)*. Weed Technol. 8:807-811.

83. Winter, S. R., and A. F. Wiese. 1978. Phytotoxicity and yield response of sugarbeets *(Beta vulgaris)* to a mixture of phenmedipham and desmedipham. Weed Sci. 26:1-4.

84. Wolf, R. B., G. F. Spencer, and W. F. Kwolek. 1984. Inhibition of velvetleaf *(Abutilon theophrasti)* germination and growth by benzyl isothiocyanate, a natural toxicant. Weed Sci. 32:612-615.

85. Wymore, L. A., C. Poirier, A. K. Watson, and A. R. Gotlieb. 1988. *Colletotrichum coccodes,* a potential bioherbicide for control of velvetleaf *(Abutilon theophrasti).* Plant Disease 72:534-538.

86. Wymore, L. A., and A. K. Watson. 1989. Interaction between a velvetleaf isolate of *Colletotrichum coccodes* and thidiazuron for velvetleaf *(Abutilon theophrasti)* control in the field. Weed Sci. 37:478-483.

87. Wymore, L. A., A. K. Watson, and A. R. Gotleib. 1987. Interaction between *Colletotrichum coccodes* and thidiazuron for control of velvetleaf *(Abutilon theophrasti).* Weed Sci. 35:377-383.

88. Zhao, C. C., J. R. Teasdale, and C. B. Coffman. 1990. Factors affecting the activity of thifensulfuron. Weed Sci. 38:553-557.

Chapter 2

Sugarbeet and Velvetleaf Response to Triflusulfuron Methyl and Desmedipham plus Phenmedipham[1]

ROBERT J. STARKE and KAREN A. RENNER[2]

Abstract. Sugarbeet response and velvetleaf control from postemergence applications of triflusulfuron alone and in combination with desmedipham plus phenmedipham, non-ionic surfactant, and 28% liquid urea ammonium nitrate were evaluated in the field. Velvetleaf control was also evaluated in greenhouse experiments. Another field experiment determined if preemergence applications of cycloate, ethofumesate, pyrazon, or pyrazon plus ethofumesate followed by postemergence applications of triflusulfuron, desmedipham plus phenmedipham, ethofumesate, endothall or combinations thereof influenced sugarbeet yield or quality in the absence of weeds. Sugarbeet injury was temperature dependent with greater and more persistent visual injury when triflusulfuron was applied at temperatures below 15 C. Triflusulfuron controlled velvetleaf when non-ionic surfactant was added to the spray solution. Desmedipham plus phenmedipham increased velvetleaf control by triflusulfuron in the absence of non-ionic surfactant

---

[1]Received for publication _________ and in revised form __________ .

[2]Grad. Asst. and Assoc. Professor., Dep. Crop and Soil Sci. Michigan State Univ., East Lansing, MI 48824

in the field. However, adding desmedipham plus phenmedipham to triflusulfuron plus non-ionic surfactant decreased velvetleaf control in the greenhouse. In the absence of weeds, cycloate, pyrazon and pyrazon plus ethofumesate reduced sugarbeet yield. All postemergence herbicide combinations reduced sugarbeet root yield by 3.4 to 5.5 Mg/ha in the absence of weed competition. **Nomenclature:** Cycloate, *S*-ethyl bis(2-methylpropyl)carbamothioate; desmedipham, ethyl[3-[[(phenylamino)carbonyl]oxy]phenyl]carbamate; endothall, 7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid; ethofumesate, (±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate; phenmedipham, 3-[(methoxycarbonyl)amino]phenyl (3-methylphenyl)carbamate; pyrazon, 5-amino-4-chloro-2-phenyl-3(2*H*)-pryidazinone; triflusulfuron, 2-[[[[[4-(dimethylamino)-6-(2,2,2-trifluoroethoxy)-1,3,5-triazin-2-yl]amino]carbonyl]amino]sulfonyl]-3-methylbenzoic acid; velvetleaf, *Abutilon theophrasti* Medicus., #[3] ABUTH, sugarbeet, *Beta vulgaris* L. 'MonoHybrid E4'.

Additional index words: adjuvant, cycloate, endothall, ethofumesate, pyrazon.

INTRODUCTION

Velvetleaf is a serious weed problem in North America, because of its seedling vigor, rapid growth habit, tolerance to many herbicides, and ability to produce large amounts of seed (1, 12, 21, 24). Nine velvetleaf plants per meter of

---

[3]Letters following this symbol are WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

row reduced corn yield 17% (20). Soybean yield was reduced 42% by seven velvetleaf plants per meter of row (10). Sugarbeet are a less competitive crop with a yield reduction of 30% by one velvetleaf plant per meter of row (19).

Consistent velvetleaf control in sugarbeet currently requires preplant followed by postemergence herbicide applications (16). Triflusulfuron methyl is a sulfonylurea herbicide which controls velvetleaf with negligible sugarbeet response at rates of 9 to 32 g ai ha^{-1} (6, 14, 15, 22). A surfactant is needed for velvetleaf control with triflusulfuron (15, 22).

Desmedipham and phenmedipham are the most widely used postemergence herbicides for broadleaf weed control in sugarbeet in the United States and Canada (18). Desmedipham plus phenmedipham is more effective than triflusulfuron in controlling common lambsquarters (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.), but is less effective in suppressing kochia (*Kochia scoparia* L.) (26). Miller and Nalewaja (11) reported increased weed control and sugarbeet injury when adjuvants were added to phenmedipham. Researchers have also reported increased sugarbeet injury when desmedipham or phenmedipham were applied postemergence to sugarbeet treated preemergence with cycloate or ethofumesate (4,7). Ethofumesate decreased deposition of alkanes and *sec*-ketones on the leaf surface of sugarbeet allowing greater foliar absorption of desmedipham (7). This process is believed to be responsible for increased sugarbeet injury and weed control when ethofumesate or cycloate is applied preemergence and followed by postemergence herbicide applications (4, 7).

The objectives of this research were to 1) determine the rate of triflusulfuron required to control velvetleaf ; 2) determine if desmedipham plus phenmedipham or adjuvants influence velvetleaf control by or sugarbeet response to triflusulfuron; and 3) determine if preemergence or postemergence herbicides applied alone or in combination to sugarbeet influence visual injury, plant population, root yield, or root quality.

MATERIALS AND METHODS

Velvetleaf Control experiments. The first field study was a randomized complete block design with three replications conducted in 1993 and repeated in 1994. The soil type was a Capac sandy clay loam with 5.5% organic matter and a pH of 6.2. Plots were 3 m wide, (4 rows), and 9 m in length. All herbicide treatments were applied twice with seven days between applications. Herbicide treatments were in a factorial arrangement with the factors consisting of triflusulfuron (0.0 + 0.0, 8.8 + 8.8 or 17.5 + 17.5 g ai ha^{-1}), desmedipham plus phenmedipham (0.0 + 0.0 or 360 + 360 g ha^{-1}), urea ammonium nitrate, (UAN),[4] (0.0 + 0.0 or 4.0 + 4.0% v/v), and non-ionic surfactant (NIS)[4,5] (0.0 + 0.0 or 0.25 + 0.25% v/v). Before any herbicide application, three cotyledon stage velvetleaf plants were marked

---

[4]Abbreviations: UAN, 28% liquid urea ammonium nitrate; NIS, non-ionic surfactant; DALP, days after last postemergence application

[5]X-77 (alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol) from Valent U.S.A. Corp., 1333 N. California Blvd., Walnut Creek, CA 94596

with small potting stakes and the sugarbeet stand counted for 4.6 m of the center plot rows. The area was marked with flags and recounted 7 days after the last postemergence application (DALP)[4] to determine stand loss. The first application was made when sugarbeet were in the cotyledon stage and 70% of the velvetleaf emerged were at cotyledon and 30% at the first true leaf stage. All field herbicide treatments were applied with a compressed air tractor sprayer at 5 km h^{-1} in a spray volume of 206 L ha^{-1} and at a spray pressure of 207 kPa. All postemergence herbicides were applied after 5 p.m. because of earlier research completed by Winter et al. (27) which suggested morning application of desmedipham plus phenmedipham at temperatures above 22 C decreased sugarbeet stand. Sugarbeet injury and velvetleaf control were estimated visually where 0 = no injury and 100 = complete death at 7, 14, 21, and 35 DALP. The marked velvetleaf plants were harvested 21 DALP and dry weights measured.

The same herbicide treatment combinations were repeated in a greenhouse with conditions maintained at 25 ± 5 C and natural and supplemental metal halide lighting providing a midday photosynthetic flux of 700 $\mu E\ m^{-2}\ s^{-1}$. Velvetleaf seeds were planted one cm deep in 945-ml pots containing a commercial potting mix[6]. After emergence, velvetleaf were thinned to two plants per pot. Plants were watered as needed and fertilized 2 days before herbicide application with 50 ml of water soluble fertilizer solution (400 ppm N, 400 ppm

---

[6]Baccto Professional Planting Mix, Michigan Peat Co., P.O. Box 980129, Houston, TX 77098

P_2O5 , 400 ppm K_2O). Triflusulfuron rates were reduced to 2.2 + 2.2 and 4.4 + 4.4 g ha^{-1} to decrease velvetleaf growth by approximately 50% in the presence of NIS. The study was also modified to include four replications and repeated three times. The first application was made when velvetleaf were in the cotyledon growth stage and the identical treatment applied 7 days later. All greenhouse treatments were applied with a moving belt sprayer at 1.5 km h^{-1}, in a spray volume of 235 L ha^{-1} and at a spray pressure of 207 kpa. Velvetleaf plants were harvested 14 DALP and dry weights determined.

Sugarbeet Yield experiments. A second field experiment determined if sugarbeet stand, visual injury, root yield or sugar quality was influenced by preemergence followed by postemergence herbicide application. The experiment was a split plot with four replications repeated in 1993 and 1994. In both years, the site was a Misteguay clay soil with 3.2 % organic matter and a soil pH of 8.0. The main plots were preemergence herbicide treatments including: no preemergence treatment, cycloate at 3.4 kg ha^{-1}, pyrazon at 4.5 kg ha^{-1}, ethofumesate at 2.2 kg ha^{-1}, and pyrazon plus ethofumesate at 4.5 + 2.2 kg ha^{-1}. Cycloate was applied preplant incorporated. All other preemergence herbicides were applied to the soil surface after planting. The subplots were postemergence herbicide treatments and included no postemergence treatment, triflusulfuron at 18 + 18 g ha^{-1} plus NIS at 0.25% v/v, triflusulfuron at 35 + 35 g ha^{-1} plus NIS, desmedipham plus phenmedipham at 370 + 370 g ha^{-1} plus NIS, 18 + 18 g ha^{-1} triflusulfuron plus desmedipham plus phenmedipham plus NIS, 35 + 35 g ha^{-1} triflusulfuron plus desmedipham plus phenmedipham plus NIS, desmedipham plus phenmedipham plus ethofumesate at 170 + 170 g ha $^{-1}$, and desmedipham plus phenmedipham plus endothall at 280 + 280 g ha^{-1}. Plots were 3 m wide (4 rows), and 12 meters in length. The sugarbeet stand was counted for 4.6 m of both center plot rows to determine differences in sugarbeet emergence. The area was marked with flags and recounted 7 DALP to determine any change in sugarbeet populations following postemergence herbicide applications. Herbicide treatments were applied as previously described. At 7 DALP, all plots were manually thinned to a population of 125 plants 30 m^{-1} to negate any effect of stand reduction on root yield. Visual crop response was rated 7, 14, and 28 DALP. Weeds were manually removed in all plots throughout the growing season. The center two rows of all plots were harvested with a modified mechanical harvester. Samples from each plot were sent to a commercial laboratory[7] for sucrose analysis.

Data Analysis. Data was subjected to ANOVA and combined if significant run by treatment interactions did not occur. If significant run by treatment interactions occurred, the data is presented separately by run (year). Treatment means were separated using Fisher's (protected) LSD test ($P \leq 0.05$).

---

[7]Michigan Sugar Company, 320 Sugar Street, Carrollton, MI 48724

RESULTS AND DISCUSSION

Sugarbeet response to postemergence applications of triflusulfuron, desmedipham plus phenmedipham, UAN, and NIS. With one exception, treatments containing desmedipham plus phenmedipham plus NIS injured sugarbeet 7 DALP as compared to the untreated control (Table 1). In 1994, adding 17.5 + 17.5 g ha^{-1} triflusulfuron plus NIS to desmedipham plus phenmedipham increased sugarbeet injury as compared to desmedipham plus phenmedipham plus NIS alone (Table 1). The difference in herbicide injury between 1993 and 1994 may possibly be explained by the temperature at the time of second application. It was 6 C cooler in 1994 at the time of the second application compared to 1993 (Table 2). The injury in 1993 was mainly leaf tip necrosis, which is injury typical of desmedipham plus phenmedipham (3, 13). In 1994, the sugarbeet injury was a yellowing and inhibition of sugarbeet growth (personal observations). All injury was $\leq$ 8% by 14 DALP in 1993 (Table 1). In 1994 sugarbeet injury was greater 14 DALP as compared to 1993 (Table 1). With one exception, treatments containing triflusulfuron and desmedipham plus phenmedipham ± NIS and/or UAN resulted in greater sugarbeet injury than either herbicide applied alone with an identical adjuvant system (Table 1). Sugarbeet stand increased each year due to sugarbeet emergence after the first split application and was not affected by postemergence herbicide applications (Table 1).

Velvetleaf dry weight reduction and visual control by triflusulfuron in the field. Desmedipham plus phenmedipham alone or in combination with UAN or NIS did not control velvetleaf (Table 1). Adding UAN or NIS increased velvetleaf control by triflusulfuron (Table 1). Velvetleaf control by 8.7 + 8.7 g ha^{-1} triflusulfuron increased more with NIS than UAN. Fielding et al. (8, 9) observed the most ^{14}C-chlorimuron {2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid} and ^{14}C-thifensulfuron {3-[[[[(4-methoxy-6-methyl,-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} absorption by velvetleaf when NIS plus UAN were applied as the adjuvants and more absorption of the two sulfonylurea herbicides when NIS was the adjuvant as compared to UAN.

Velvetleaf was controlled by either application rate of triflusulfuron in the presence of NIS. Adding NIS to 8.7 + 8.7 g ha^{-1} of triflusulfuron increased visual control of velvetleaf more than adding desmedipham plus phenmedipham. Adding desmedipham plus phenmedipham to 8.7 + 8.7 g ha^{-1} triflusulfuron plus UAN increased velvetleaf control (Table 1). Adding desmedipham plus phenmedipham to triflusulfuron plus NIS did not affect velvetleaf control in the field.

Velvetleaf control by triflusulfuron in the greenhouse. Velvetleaf dry weight was not reduced by desmedipham plus phenmedipham alone or in combination with UAN or NIS (Table 1). Triflusulfuron reduced velvetleaf dry weight as compared to the untreated control when NIS was added (Table 1). Adding UAN to triflusulfuron did not reduce velvetleaf dry weight, however, adding UAN plus NIS to triflusulfuron decreased velvetleaf dry weight more than triflusulfuron plus NIS (Table 1). Adding desmedipham plus phenmedipham reduced velvetleaf control by triflusulfuron plus NIS in the greenhouse (Table 1). Adding desmedipham plus phenmedipham to 2.2 + 2.2 g ha^{-1} triflusulfuron plus NIS plus UAN decreased velvetleaf control, however, adding desmedipham plus phenmedipham to 4.4 + 4.4 g ha^{-1} triflusulfuron plus NIS plus UAN did not affect velvetleaf control.

Velvetleaf control was not affected by adding desmedipham plus phenmedipham to triflusulfuron plus NIS in the field (Table 1). Adding desmedipham plus phenmedipham decreased velvetleaf absorption of triflusulfuron plus NIS (23). This decrease in triflusulfuron absorption may affect velvetleaf control more in the greenhouse than in the field, because warm constant temperatures and adequate moisture in the greenhouse may allow velvetleaf to recover from triflusulfuron injury. Alternatively, the triflusulfuron rates applied in the field were four times greater than the triflusulfuron rates used in the greenhouse (Table 1). The greater concentration of triflusulfuron applied in the field may have resulted in sufficient triflusulfuron being absorbed into the plant for control even if absorption was reduced when desmedipham plus phenmedipham was applied with triflusulfuron. Adding desmedipham plus phenmedipham to triflusulfuron plus NIS may decrease velvetleaf control in the field if triflusulfuron rates are below 8.7 plus 8.7 g ha^{-1} or environmental conditions such as drought reduce herbicide uptake and efficacy.

Effect of preemergence herbicides on sugarbeet emergence and root yield. Sugarbeet response to preemergence herbicides was not affected by postemergence herbicide treatments, therefore the main effects are presented. Ethofumesate at 2.2 kg ha^{-1} reduced sugarbeet emergence (Table 3). Sugarbeet stand loss with mixtures of cycloate and ethofumesate is dependent on soil type with more stand loss reported on sandy loam than on clay loam soils (17). Wilson et al. (25) reported sugarbeet stand loss from cycloate, ethofumesate or cycloate plus ethofumesate on a sandy loam soil. The soil in this experiment had a 60% clay content. The large percentage of clay in this soil may have reduced cycloate availability and prevented the stand loss from cycloate that has been observed by other researchers. Applications of pyrazon or pyrazon plus ethofumesate reduced sugarbeet stand in 1994, but not 1993 (Table 3). In 1993, 2 cm of precipitation was reported during the 14 days after planting. In 1994, 6.5 cm of precipitation was reported in the 14 days after planting (Table 4). The saturated soil in 1994 may have resulted in more herbicide available for uptake by the emerging sugarbeet seedlings resulting in greater seedling mortality. Dawson (5) reported more stand loss in moist soil than dry soil from pyrazon surface applied and incorporated. Cycloate, pyrazon, and pyrazon + ethofumesate reduced sugarbeet yield in the weed free environment compared to the untreated control (Table 3). Preemergence herbicides did not affect sucrose content (Table 3).

Effect of postemergence herbicides on sugarbeet stand, injury and root yield. Sugarbeet response to postemergence herbicides was not affected by previous treatment with preemergence herbicide treatments, therefore the main effects are presented. All postemergence herbicides increased sugarbeet injury 7 DALP compared to the untreated control (Table 5). Desmedipham plus phenmedipham plus NIS was less injurious than desmedipham plus phenmedipham plus ethofumesate 7 DALP (Table 5). Injury by triflusulfuron was greater in 1994 than 1993 (Table 5). Lower temperature at the time of second application in 1994, (Table 6), resulted in a stunting and yellowing of sugarbeet plants while the injury in 1993 was mainly leaf desiccation (personal observation). Leaf desiccation is an injury symptom of desmedipham or phenmedipham, and is more prevalent at higher temperatures (3,4). Other research has indicated if triflusulfuron is applied at temperatures below 15 C sugarbeet injury may occur (2). Sugarbeet injury was less than 7% in 1993 14 DALP (Table 5). In 1994, herbicide injury varied from 13 to 22% 14 DALP (Table 5). Lower temperatures in 1994 probably did not allow the sugarbeet seedlings to recover from postemergence herbicide injury as quickly as in 1993 (Table 6). Adding triflusulfuron to desmedipham plus phenmedipham plus NIS increased sugarbeet injury as compared to desmedipham plus phenmedipham plus NIS at 14 DALP (Table 5). Wilson (25) observed increased sugarbeet injury when ethofumesate was added to desmedipham plus phenmedipham, however he did not observe increased injury when triflusulfuron without NIS was added to desmedipham plus phenmedipham. The NIS in our experiment probably contributed to the injury observed when triflusulfuron plus NIS was added to desmedipham plus phenmedipham.

In 1993, sugarbeet stand was reduced by postemergence applications of 35 g ha^{-1} triflusulfuron plus desmedipham plus phenmedipham plus NIS and by desmedipham plus phenmedipham plus ethofumesate (Table 5). All postemergence treatments reduced sugarbeet stand in 1994 (Table 5). The cooler temperatures in 1994 may have resulted in less root development by the sugarbeet seedlings allowing more seedlings to be uprooted by the wind (Table 6). The preemergence herbicides may have also contributed to the stand lost in 1994, because stand was reduced by 11 sugarbeet seedlings per 30 m of row in plots which did not receive a postemergence herbicide application (Table 5).

All postemergence herbicides reduced sugarbeet yield equally in the weed free environment as compared to the untreated control (Table 5). Postemergence applications did not affect sucrose concentrations of the sugarbeets (Table 5). Other researchers also have reported herbicide treatments do not affect sucrose content (13, 26, 25).

Triflusulfuron is an effective herbicide for velvetleaf control in sugarbeet. Temporary inhibition of sugarbeet growth and chlorosis may result if triflusulfuron is applied at temperatures less than 15 C. Triflusulfuron requires an adjuvant for velvetleaf control, however if desmedipham plus phenmedipham is applied with an adjuvant increased sugarbeet injury may occur. Therefore, desmedipham plus phenmedipham should not be applied with triflusulfuron and an adjuvant if environmental conditions are favorable for sugarbeet injury by desmedipham plus phenmedipham.

ACKNOWLEDGEMENTS

The authors wish to thank E. I. DuPont, Michigan Sugar Company, and Monitor Sugar Company for financial support of this research. The authors would also like to thank Michigan Agricultural Experiment Station, Saginaw Valley Bean and Beet Research Farm, and Stoneman Farms for their cooperation in this research.

LITERATURE CITED

1. Anderson, R. N., R. M. Menges, and J. S. Conn. 1985. Variability in velvetleaf *(Abutilon theophrasti)* and reproduction beyond its current range in North America. Weed Sci. 33:507-512.

2. Anonymous. 1994. UpBeet herbicide technical bulletin. E.I. DuPont de Nemours and Company, Agricultural Products, Wilmington, Delaware 19898.

3. Bethlenfalvay, G., and R. F. Norris. 1975. Phytotoxic action of desmedipham: influence of temperature and light intensity. Weed Sci. 23:499-503.

4. Dawson, J. H.. 1975. Cycloate and phenmedipham as complementary treatments in sugarbeets. Weed Sci. 23:478-485.

5. Dawson, J. H.. 1971. Response of sugarbeets and weeds to cycloate, propachlor, and pyrazon. Weed Sci. 19:162-165.

6. Dexter, A. G., J. L. Luecke, and M. W. Bredehoeft. 1992. Postemergence control of broadleaf weeds in sugarbeet. Proc. North Cent. Weed Control Conf.. 47:125.

7. Duncan, D. N., W. F. Meggitt, and D. Penner. 1982. Basis for increased activity from herbicide combinations with ethofumesate applied on sugarbeet *(Beta vulgaris)*. Weed Sci. 30:195-200.

8. Fielding, R. J., and E. W. Stoller. 1990. Effects of additives on the efficacy, uptake, and translocation of the methyl ester of thifensulfuron. Weed Sci. 38:172-271.

9. Fielding, R. J., and E. W. Stoller. 1990. Effects of additives on efficacy, uptake, and translocation of chlorimuron ethyl ester. Weed Technol. 4:264-271.

10. Hagood, E. S. JR., T. T. Bauman, J. L. Williams, Jr., and M. M. Schreiber. 1980. Growth analysis of soybeans *(Glycine max)* in competition with velvetleaf *(Abutilon theophrasti)*. Weed Sci. 28:729-734.

11. Miller, S. D., and J. D. Nalewaja. 1973. Effect of additives upon phenmedipham for weed control in sugarbeets. Weed Sci. 21:67-70.

12. Mitich, L. W.. 1991. Intriguing world of weeds. Velvetleaf. Weed Technol. 5:253-255.

13. Prodoehl, K. A., L. G. Campbell, and A. G. Dexter. 1992. Phenmedipham plus desmedipham effects on sugarbeet. Agron. J. 84:1002-1005.

14. Reese, K. D., and M. M. Loux. 1992. Efficacy and timeliness of DPX-66037 for weed control in sugar beets. Proc. North Cent. Weed Control Conf. 47:124.

15. Renner, K. A., and T. M. Crook. 1992. Postemergence weed control in sugar beets with DPX-66037. Proc. North Cent. Weed Control Conf. 47:126.

16. Renner, K. A., and G. E. Powell. 1991. Velvetleaf *(Abutilon theophrasti)* control in sugarbeet. Weed Technol. 5:97-102.

17. Schweizer, E. E.. 1979. Weed control in sugarbeets *(Beta vulgaris)* with mixtures of cycloate and ethofumesate. Weed Sci. 27:516-519.

18. Schweizer, E. E., and A. G. Dexter. 1987. Weed control in sugarbeets *(Beta vulgaris)* in North America. Rev. Weed Sci. 3:113-133.

19. Schweizer, E. E., and L. D. Bridge. 1982. Sunflower *(Helianthus annuus)* and velvetleaf *(Abutilon theophrasti)* interference in sugarbeets *(Beta vulgaris)*. Weed Sci. 30:514-519.

20. Schmenk, R. E., Jr. 1994. Velvetleaf *(Abutilon theophrasti* (Medik.)) competitiveness in corn as affected by preemergence herbicides. Master's Thesis, Michigan State University. pp. 64.

21. Spencer, N. R.. 1984. Velvetleaf, *Abutilon theophrasti* (Malvaceae), history and economic impact in the United States. Econ. Bot. 38:407-416.

22. Starke, R. J. and K. A. Renner. 1993. Velvetleaf *(Abutilon theophrasti)* response to triflusulfuron methyl. Proc. North Cent. Weed Control Conf. 48:88-89.

23. Starke, R. J., K. A. Renner, D. Penner, and F. C. Roggenbuck. Influence of adjuvants and desmedipham plus phenmedipham on velvetleaf (*Abutilon theophrasti*) control and sugarbeet response to triflusulfuron methyl. Weed Sci. (in review).

24. Warwick, S. I., and L. D. Black. 1988. The biology of Canadian weeds .90. *Abutilon theophrasti*. Can. J. Plant Sci. 68:1069-1085.

25. Wilson, R. G., J.A. Smith, and C. D. Yonts. 1990. Effect of seedling depth, herbicide, and variety on sugarbeet *(Beta vulgaris)* emergence, vigor and yield. Weed Technol. 4:739-742.

26. Wilson, R. G.. 1994. New herbicides for postemergence application in sugarbeet *(Beta vulgaris)*. Weed Technol. 8:807-811.

27. Winter, S. R., and A. F. Wiese. 1978. Phytotoxicity and yield response of sugarbeets *(Beta vulgaris)* to a mixture of phenmedipham and desmedipham. Weed Sci. 26:1-4.

Table 1. Sugarbeet injury and velvetleaf control by postemergence applications of triflusulfuron, desmedipham + phenmedipham, UAN, and NIS.

		Sugarbeet					Velvetleaf		
		7 DALP[b]		14 DALP[b]			Field		Greenhouse[d]
Treatment[a]	Rate	1993	1994	1993	1994	Gn/Loss[b]			
	g ha^{-1}	% injury				plants/30 m	% control	% dry weight reduction	
Triflusulfuron	8.7	0	8	0	3	21	35	4	10
Triflusulfuron + NIS[b]	8.7	5	10	0	7	27	71	83	16
Triflusulfuron + UAN[b]	8.7	4	5	0	3	25	39	49	0
Triflusulfuron + UAN + NIS	8.7	6	10	0	8	41	74	89	37
Triflusulfuron	17.5	0	5	0	0	19	35	52	0
Triflusulfuron + NIS	17.5	0	10	0	2	23	79	94	46
Triflusulfuron + UAN	17.5	3	8	0	3	22	67	71	4
Triflusulfuron + UAN + NIS	17.5	0	10	0	3	24	77	95	71
Des/phen	370	7	12	0	3	8	0	0	7
Des/phen + NIS	370	13	20	0	8	16	2	8	0
Des/phen + UAN	370	13	17	0	6	12	0	0	9
Des/phen + UAN + NIS	370	17	15	0	7	22	0	0	8
Triflusulfuron + des/phen	8.7 + 370	5	17	8	16	35	55	82	0
Triflusulfuron + des/phen + NIS	8.7 + 370	12	20	5	20	22	70	89	0
Triflusulfuron + des/phen + UAN	8.7 + 370	2	25	0	15	17	69	82	6
Triflusulfuron + des/phen + UAN + NIS	8.7 + 370	17	20	5	22	14	76	95	0
Triflusulfuron + des/phen	17.5 + 370	3	20	5	12	29	78	88	2
Triflusulfuron + des/phen + NIS	17.5 + 370	7	28	0	17	20	78	94	5
Triflusulfuron + des/phen + UAN	17.5 + 370	8	25	0	12	15	80	95	42
Triflusulfuron + des/phen + UAN + NIS	17.5 + 370	13	33	8	18	22	78	96	68
	LSD[e]	11	14	7	7	NS	8	29	11

[a]Herbicides were applied twice, seven days apart.
[b]Abbreviations: DALP, days after last postemergence application; Gn/Loss, stand gain or loss; NIS, non-ionic surfactant (X-77) (0.25% v/v); UAN, 28% urea ammonium nitrate (4.0% v/v).
[c]Calculated as 100 - ((plant dry weight) (untreated plant dry weight)$^{-1}$ * 100).
[d]Greenhouse triflusulfuron rates were 2.2 + 2.2 or 4.4 + 4.4 g ha^{-1}.
[e]Comparisons valid only within columns.

Table 2. Environmental conditions at application at the velvetleaf control study site.

Parameter	1993	1994
Application 1	6/5/93	5/12/94
Temperature (C)	17	16
Time	8:30 P.M.	8:00 P.M.
Relative Humidity	70%	47%
Crop Stage	Cotyledon to 1 leaf pair	Cotyledon
ABUTH Stage	Cotyledon	Cotyledon
Application 2	6/11/93	5/19/94
Temperature (C)	22	16
Time	8:30 P.M.	8:30 P.M.
Relative Humidity	58%	54%
Crop Stage	1-2 leaf pair	1-2 leaf pair
ABUTH Stage	Cotyledon to 3 leaf	Cotyledon to 2 leaf

Table 3. Sugarbeet emergence, injury, and root yield in response to preemergence herbicide treatments.[a]

Treatment	Rate	Population 1993	Population 1994	Root Yield	Sucrose
	kg/ha	plants/30 m row		Mg/ha	%
Cycloate	3.4	328	277	64.2	17.3
Pyrazon	4.5	311	269	64.1	17.4
Ethofumesate	2.2	277	266	65.6	17.3
Pyrazon + ethofumesate	4.5 + 2.2	303	251	63.1	17.2
No treatment	-	314	285	67.1	17.2
	LSD[b]=	24	13	1.6	NS

[a]Means presented are combined over all postemergence treatments.
[b]Mean comparisons valid only within columns.

Table 4. Differences in environmental conditions at the sugarbeet yield site.

Timing	1993 Ave. Daily Temp. Max.	1993 Ave. Daily Temp. Min.	1993 Rainfall	1994 Ave. Daily Temp. Max.	1994 Ave. Daily Temp. Min.	1994 Rainfall
	C		cm	C		cm
Pre-post 1	20	6	4.0	16	4	7.5
Post 1- Post 2	21	8	1.6	18	6	1.5
Post 2- 7 DALP	24	13	1.8	23	7	0
7 DALP- 14 DALP	27	15	3.2	21	8	1.9

Table 5. Sugarbeet injury, stand loss and root yield as affected by postemergence herbicide treatments.

Treatments[a]	Rate	Injury 7 DALP[b] 1993	Injury 7 DALP[b] 1994	Injury 14 DALP[b] 1993	Injury 14 DALP[b] 1994	Stand Gn/Loss[b] 1993	Stand Gn/Loss[b] 1994	Root Yield	Sucrose
	g ha^{-1}	---------- % injury ----------				plants/30 m row		Mg ha^{-1}	%
Triflusulfuron + NIS[b]	17.5 + 0.25%	6	17	1	22	-2	-26	64.3	17.2
Triflusulfuron + NIS	35 + 0.25%	12	20	3	21	0	-22	64.0	17.3
Des/phen + NIS	370 + 0.25%	14	14	2	13	-13	-26	65.1	17.3
Triflusulfuron + des/phen + NIS	17.5 + 370 + 0.25%	19	16	7	20	-6	-28	63.0	17.3
Triflusulfuron + des/phen + NIS	35 + 370 + 0.25%	22	18	7	25	-27	-35	64.3	17.2
Des/phen + ethofumesate	370 + 170	22	23	5	19	-26	-27	65.1	17.4
Des/phen + endothall	370 + 280	10	17	2	14	-6	-24	64.5	17.3
No treatment		1	2	0	5	0	-11	68.5	17.2
	LSD[c] =	4	4	3	6	19	11	2.0	NS

[a]Treatments applied twice seven days apart.
[b]Abbreviations: DALP, days after last postemergence application; Gn/Loss, stand gain or loss; NIS, non-ionic surfactant (X-77).
[c]Mean comparisons valid only within columns.

Table 6. Environmental conditions during postemergence applications.

Postemergence Application 1	6/1/93	5/10/94
Temperature (C)	14	18
Time	8:30 P.M.	8:30 P.M.
Relative Humidity	65%	56%
Crop Stage	Cotyledon	Cotyledon
Postemergence Application 2	6/10/93	5/17/94
Temperature (C)	23	12
Time	8:30 P.M.	9:00 P.M.
Relative Humidity	70%	70%
Crop Stage	1 leaf pair	1 leaf pair

Chapter 3

Influence of Adjuvants and Desmedipham plus Phenmedipham on Velvetleaf (*Abutilon theophrasti*) and Sugarbeet Response to Triflusulfuron Methyl[1]

ROBERT J. STARKE, KAREN A. RENNER, DONALD PENNER, and FRANK C. ROGGENBUCK[2]

Abstract. Greenhouse studies determined the influence of fourteen adjuvants and desmedipham plus phenmedipham on velvetleaf control and sugarbeet injury by triflusulfuron. Split applications of 4.4 + 4.4 g ai ha^{-1} triflusulfuron, alone or in combination with any adjuvant did not reduce sugarbeet dry weight. The addition of an adjuvant to 370 + 370 g ai ha^{-1} desmedipham plus phenmedipham decreased sugarbeet dry weight by 19% to 66%. The addition of an adjuvant increased velvetleaf control from triflusulfuron from 10 to 84%. Adding desmedipham plus phenmedipham to triflusulfuron plus an adjuvant increased, decreased or had no effect on velvetleaf control depending on the adjuvant. A second study determined if six adjuvants, or desmedipham plus phenmedipham influenced ^{14}C-triflusulfuron absorption by cotyledon or first true leaves of

---

[1]Received for publication on __________ and in revised form __________.

[2]Grad Asst., Assoc. Professor, Professor, and Res. Tech., respectively, Dep. Crop and Soil Sci., Michigan State Univ., East Lansing, MI 48824

velvetleaf. Cotyledonary leaves of velvetleaf absorbed 28% more ^{14}C-triflusulfuron than first true leaves. With one exception, adding an adjuvant increased ^{14}C-triflusulfuron absorption by 16 to 75%. Adding desmedipham plus phenmedipham to ^{14}C-triflusulfuron plus an adjuvant decreased or had no affect on absorption depending on the adjuvant used. Adjuvants increased triflusulfuron absorption by velvetleaf, but tank mixtures may reduce absorption depending on the adjuvant system. Velvetleaf was most easily controlled in the cotyledon stage of growth. Nomenclature: desmedipham, ethyl-[[(phenylamino)carbonyl]oxy]phenyl]carbamate; phenmedipham, 3-[(methoxycarbonyl)amino]phenyl (3-methylphenyl)carbamate; triflusulfuron, methyl 2-[-[-[[[4-dimethylamino)-6-(2,2,2,-trifluoroethoxy)-1,3,5-triazin-2-yl]amino]carbonyl]amino]sulfonyl]-3-methylbenzoate; velvetleaf, *Abutilon theophrasti* Medicus. #[3] ABUTH; sugarbeets *Beta vulgaris* (L.) 'Mono Hy E-4'. Additional index words. Absorption, sulfonylurea, surfactant, 28% liquid urea-ammonium nitrate, Chempro 6000, Dash, Dyne-amic, Hasten, Herbimax, Induce, K2000, Scoil, Sylgard 309, X-77.

INTRODUCTION

Velvetleaf is a serious weed problem in North America, because of its seedling vigor, rapid growth habit, tolerance to many herbicides, and ability to

---

[3] Letters following this symbol are WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Supple. 2. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

produce large amounts of seed (1, 11, 15, 20, 22). Nine velvetleaf plants per meter of row reduced corn yield 17% (19). Soybean yield was reduced 42% by seven velvetleaf plants per meter of row (8). Sugarbeet are a less competitive crop with a yield reduction of 30% by one velvetleaf plant per m of row (18).

Velvetleaf is currently controlled in sugarbeet by preplant followed by postemergence herbicide applications (14). Triflusulfuron methyl is a sulfonylurea herbicide which controls velvetleaf with negligible sugarbeet response at rates of 9 to 32 g ai ha^{-1} (3, 12, 13, 22). An adjuvant is needed for velvetleaf control with triflusulfuron (13, 21).

Velvetleaf control was increased by adding surfactants and/or UAN[4] to postemergence herbicides (6, 7, 9, 23). The addition of surfactants and/or UAN increased chlorimuron {2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid}, thifensulfuron {3-[[[[(4-methoxy-6-methyl-1,3,5,triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} and bentazon {3-(1-methylethyl)-(1H)-2,1,3-bensothiadiazin-4(3H)-one 2,2 dioxide} absorption by velvetleaf (6,7,10). The exact mechanism(s) by which these additives increase absorption is not known. Surfactants are known to change the surface tension of spray droplets, alter the morphology of epicuticular waxes, and cause cell necrosis (5). Research indicates additives react differently to various epicuticular waxes and epicuticular waxes vary

[4]Abbreviations: UAN, 28% urea ammonium nitrate; DAT, days after the first herbicide application; HAT, hours after treatment

in composition by plant species (5).

Researchers have attempted to obtain broad spectrum postemergence weed control in sugarbeet by tankmixing triflusulfuron with other herbicides. Control of kochia (*Kochia scoparia* L.), common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and eastern black nightshade (*Solanum ptycanthum* Dun.) increased by adding desmedipham plus phenmedipham to triflusulfuron (3, 4, 12, 13). However, in greenhouse studies adding desmedipham plus phenmedipham to triflusulfuron decreased velvetleaf control (21).

The objectives of this research were to 1) determine velvetleaf and sugarbeet response to triflusulfuron applied alone and with various adjuvants; 2) determine if the addition of desmedipham plus phenmedipham to triflusulfuron influences velvetleaf control or sugarbeet response; 3) determine if various adjuvants, including UAN, increase triflusulfuron absorption by velvetleaf; 4) determine if desmedipham plus phenmedipham in combination with various adjuvants influence absorption of triflusulfuron by velvetleaf and 5) evaluate velvetleaf control by triflusulfuron at three application timings.

MATERIALS AND METHODS

Sugarbeet and velvetleaf response to triflusulfuron, desmedipham plus phenmedipham and adjuvants. A greenhouse experiment was conducted to determine sugarbeet and velvetleaf response to triflusulfuron when applied alone and in combination with desmedipham plus phenmedipham and various adjuvants. Greenhouse conditions were maintained at 25 ± 5 C with natural and supplemental metal halide lighting providing a midday photosynthetic photon flux density of 700 μE $m^{-2}s^{-1}$. Velvetleaf and sugarbeet seeds were planted one cm deep in 945-ml plastic pots containing a commercial potting mix[5]. After emergence, plants were thinned to provide two plants per pot. Plants were watered as needed and fertilized 2 days before herbicide application with 50 ml of water soluble fertilizer solution (400 ppm N, 400 ppm P_2O_5, 400 ppm K_2O).

Herbicides were applied with a continuous link belt sprayer with a single 8001E[6] nozzle delivering 235 L ha^{-1} at a spray pressure of 207 kPA. The first herbicide application was made to cotyledon sugarbeet and velvetleaf and the identical treatment was applied 7 days later (split application). Treatments were in a factorial arrangement utilizing a randomized complete block design with four replications. Each replication consisted of two plants in the same pot. The first factor was triflusulfuron (0 + 0 or 4.4 + 4.4 g ai ha^{-1}). Preliminary experiments demonstrated 4.4 + 4.4 g ai ha^{-1} of triflusulfuron with non-ionic surfactant decreased velvetleaf dry weight by approximately 50%. The second factor of the experiment was adjuvant. Adjuvants evaluated were no adjuvant; UAN[4] (4% v/v);

---

[5]Baccto Professional Planting Mix, Michigan Peat Co., P.O. Box 980129, Houston TX 77098

[6]Teejet even flat fan tips. Spraying Systems Co., North Ave. and Schmale Road, Wheaton, IL 60188.

non-ionic surfactants, X-77[7] (0.25% v/v), Induce[8] (0.25% v/v), Chempro 6000[9] (1% v/v); seed oils, K2000[10] (1%), Hasten[11] (0.75% v/v), Scoil[12] (1% v/v); petroleum oil concentrate, Herbimax[13] (1% v/v); silicone surfactant, Sylgard 309[14] (0.25 % v/v); silicone surfactant plus methylated seed oils, Dyne-amic[15] (0.5% v/v); Dash[16] (1%

---

[7]X-77, a mixture of alkylarylpolyoxyethylene, glycols, free fatty acids, and isopropanol, Valent U.S.A. Corp., 1333 N California Blvd. Walnut, Creek, CA 94596.

[8]Induce, 90% alkyl aryl polyoxylkane ether, free fatty acids, isopropyl alcohol, and 10% inerts, Helena Chemical Company, 5100 Poplar, Suite 3200 Memphis, TN 38317.

[9]Chempro 6000, experimental adjuvant, Chemorse, Ltd. 4685 Merle Hay Road, Des Moines, IA 50322.

[10]K2000, saponified soybean oil, Central Soya, Box 1400, Ft. Wayne, IN 46801.

[11]Hasten, esterified corn, canola, soybean oil, and surfactant blend, Wilbur-Ellis, P.0. Box 16458, Fresno, CA 93755.

[12]Scoil, methylated seed oil, AGSCO, Inc. P.O. Box 458 Grand Forks, ND 58206.

[13]Herbimax, 83% petroleum hydrocarbons (light paraffinic distillate, odorless aliphatic petroleum solvent), 17% surfactant (mono and diesters of omega hydroxypoly oxyethylene), Loveland Industries, Inc., P.O. Box 1289, Greeley, CO 80632.

[14]Sylgard 309, an organosilicone adjuvant mixture containing the active ingredient 2-(3-hydroxypropyl)-heptamethyl-trisiloxane, ethoxylated acetate, Dow Corning Corp., Midland, Michigan 48686-0944.

[15]Dyne-amic, a blend of polyalkylene oxide, modified polydimethyl siloxane, nonionic emulsifiers, and methylated vegetable oils, Helena Chemical Company, 5100 Poplar, Suite 3200 Memphis, TN 38317.

[16]Dash, 99% functioning agents, (petroleum hydrocarbons, alkyl esters, alkyl acids, and anionic surfactants), and 1% ineffective constituents, BASF Wyandotte Corporation, 100 Cherry Hill Road, Parsippany, NJ 07054.

v/v); X-77 plus UAN (0.25 + 4.0% v/v); Sylgard 309 plus UAN (0.25 + 4.0% v/v); and Herbimax plus UAN (1.0 + 4.0% v/v). The third factor was the presence or absence of 370 + 370 g ai ha^{-1} desmedipham plus phenmedipham.

All plants were evaluated for visual injury 7, 14, and 21 days after the first herbicide treatment (DAT)[4]. Plants were harvested 21 DAT and fresh and dry weights were measured. Data presented are the means of three experiments with four replications in each.

Triflusulfuron absorption by velvetleaf. Velvetleaf seeds were planted one cm deep in commercial potting mix. Plants were grown outside to facilitate normal leaf surface development. The experiment was designed as a split plot with a factorial arrangement of treatments. The main factor consisted of leaf treated (cotyledon or first true leaf). The subfactors consisted of desmedipham plus phenmedipham (0 + 0 or 370 + 370 g ai ha^{-1}), UAN (0 or 4% v/v), and surfactant, (no surfactant, X-77 (0.25% v/v), Herbimax (1.0% v/v), Dash (1.0% v/v), Scoil (1.0% v/v), and Sylgard 309 (0.25% v/v)). Triflusulfuron, uniformly ^{14}C labeled on the triazine ring, was dissolved in acetone and 165 Bq ul^{-1} treatment solutions prepared. A triflusulfuron concentration corresponding to 17.5 g ai ha^{-1} was achieved by combining ^{14}C-triflusulfuron, triflusulfuron technical product (dissolved in acetone), and formulation blank (dissolved in water). The total acetone concentration in a treatment was less than 15% v/v. Velvetleaf plants were moved into a greenhouse immediately before treatment and remained in the greenhouse for the duration of the experiment. Greenhouse conditions were maintained at 25 ± 5 C with natural lighting only. A microsyringe was used to apply a 2-μl droplet on the cotyledon and first true leaf of each velvetleaf plant. The droplet was placed on the adaxial surface of the leaf centered between the leaf midvein and margin.

Leaves were excised at the appropriate harvest interval (0, 4, or 24 h after treatment (HAT)[4]) and rinsed for 45 seconds in 3 ml water:acetone (2:1) solution to remove unabsorbed ^{14}C-triflusulfuron. Fifteen mls of scintillation cocktail[17] was added to each ^{14}C-triflusulfuron residual and quantified by liquid scintillation spectrometry, corrected for quench. Treated leaves were frozen and later combusted in a biological oxidizer using a mixture of carbon dioxide absorbent[18] and scintillation cocktail (1:2) to trap $^{14}CO_2$. These samples were quantified by liquid scintillation spectrometry. Foliar absorption was calculated as the amount of ^{14}C-triflusulfuron not recovered by the washing of the treated leaf. Radioactivity remaining in the leaf was determined by combusting the treated leaf in a biological oxidizer. Data presented are the means of two experiments with four replications each.

Velvetleaf response to triflusulfuron at three application timings. A greenhouse experiment was designed to determine the effectiveness of triflusulfuron at three different application timings. The study was a two factor factorial with four

---

[17]Safety-Solve, Research Products International Corp. 410 N. Business Center Drive, Mount Prospect, IL 60056.

[18]Carbo-Sorb E, Packard Instrument Company Inc. One State Street, Meridan, CT 06450

replications, repeated in time. The first factor was the velvetleaf growth stage at the time of the first split application (cotyledon, first true leaf , or second true leaf) and the second factor was the rate of triflusulfuron applied. The six triflusulfuron rates applied ranged from 1.1 to 35.0 g ai ha^{-1}. Each ascending rate contained twice the concentration of triflusulfuron as the previous rate. All treatments contained X-77 at 0.25% v/v. Herbicide treatments were applied as described above and velvetleaf dry weights determined 21 DAT.

Data analysis. All data were subjected to analysis of variance and combined, because no significant experiment by treatment interactions occurred. Treatment means were separated using Fishers's (protected) LSD test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Sugarbeet response to desmedipham plus phenmedipham. Sugarbeet dry weight was not reduced by triflusulfuron, adjuvants or combinations thereof (data not presented). The addition of any adjuvant to desmedipham plus phenmedipham increased sugarbeet response compared to desmedipham plus phenmedipham alone (Table 1). Adding Dyne-amic, Chempro 6000, Induce, K2000, Sylgard 309, or Sylgard 309 plus UAN to desmedipham plus phenmedipham reduced sugarbeet dry weight by at least 43%.

Adding triflusulfuron to desmedipham plus phenmedipham plus UAN increased sugarbeet response compared to desmedipham plus phenmedipham plus UAN (Table 1). Conversely, adding triflusulfuron to desmedipham plus phenmedipham plus Dyne-amic or Induce decreased sugarbeet response as compared to desmedipham plus phenmedipham with the respective adjuvant. Adding triflusulfuron to all other desmedipham plus phenmedipham adjuvant combinations did not reduce sugarbeet dry weight more than desmedipham plus phenmedipham plus the respective adjuvant.

Velvetleaf response to triflusulfuron. Velvetleaf dry weight was not reduced by any adjuvant or any adjuvant plus desmedipham plus phenmedipham (data not presented). Triflusulfuron alone did not decrease velvetleaf dry weight compared to the untreated control. However, triflusulfuron plus all adjuvants except Herbimax reduced velvetleaf dry weight (Table 2). Triflusulfuron applied with Dash, Dyne-amic, Hasten, Scoil, Sylgard 309, Herbimax plus UAN, Sylgard 309 plus UAN and X-77 plus UAN reduced velvetleaf dry weight 50% or more (Table 2).

The addition of desmedipham plus phenmedipham increased velvetleaf control by triflusulfuron when applied with UAN, Hasten, or K2000. However, the addition of desmedipham plus phenmedipham to triflusulfuron plus X-77 or X-77 plus UAN decreased velvetleaf control. In field experiments, desmedipham plus phenmedipham increased velvetleaf control by triflusulfuron in the absence of an adjuvant (21). Adding desmedipham plus phenmedipham to triflusulfuron plus an adjuvant may increase, decrease or have no effect on velvetleaf control depending on the adjuvant.

Triflusulfuron absorption by velvetleaf. At 0 HAT[4], 100% of ^{14}C-triflusulfuron was recovered. Recovery of ^{14}C-triflusulfuron in the rinsate solution and in the oxidized leaf at 24 HAT averaged 92% of ^{14}C-triflusulfuron applied. Levene et al. (10) recovered 91% of ^{14}C-bentazon from velvetleaf leaves with harvest times of 1, 2, 4, and 24 hours after treatment.

Effect of leaf treated. At 24 HAT cotyledonary leaves of velvetleaf in the presence of an adjuvant, absorbed 28% more ^{14}C-triflusulfuron than first true leaves. Roggenbuck et al. (16) observed more ^{14}C-acifluorfen and ^{14}C-bentazon absorption by cotyledon leaves than the first true leaves of velvetleaf.

Rate of Absorption. Absorption of ^{14}C-triflusulfuron by cotyledonary leaves of velvetleaf in the presence of Scoil, X-77, and X-77 plus UAN was at least 24% greater at 24 HAT than at 4 HAT indicating slower absorption than treatment combinations with equal levels of absorption at 4 and 24 HAT (Tables 3 and 4). First true leaves of velvetleaf absorbed greater than 15% more ^{14}C-triflusulfuron at 24 HAT than at 4 HAT when Scoil, X-77, Dash, Herbimax plus UAN, X-77 plus UAN or Scoil plus UAN was the adjuvant (Tables 3 and 4). Roggenbuck et al. (16) determined $\leq$ 0.5% ^{14}C-acifluorfen was absorbed by the cotyledon or first true leaf of velvetleaf in 1 min if X-77 was used as the adjuvant. If Sylgard 309 was used as the adjuvant $\geq$ 80% of ^{14}C-acifluorfen was absorbed in 1 min by the cotyledon or first true leaf of velvetleaf (16). This difference in the rate of absorption is important to insure rainfastness.

Influence of adjuvants on ^{14}C-triflusulfuron absorption. The addition of any adjuvant increased ^{14}C-triflusulfuron absorption by the cotyledonary leaf of velvetleaf (Table 4). Velvetleaf absorbed the least amount of ^{14}C-triflusulfuron when X-77 or UAN was the adjuvant (Table 4). ^{14}C-triflusulfuron absorption was 67 to 71% in the presence of Dash, Herbimax, and Scoil. ^{14}C-triflusulfuron absorption was greatest by the cotyledonary leaf (90%) when Sylgard 309 was used as the adjuvant (Table 4).

The addition of any adjuvant except UAN increased ^{14}C-triflusulfuron absorption by the first true leaf of velvetleaf (Table 4). Sylgard 309 increased ^{14}C-triflusulfuron absorption by 52%, the most of any adjuvant.

Addition of UAN to ^{14}C-triflusulfuron plus an adjuvant. Adding UAN to Herbimax, Scoil, or X-77 increased absorption of ^{14}C-triflusulfuron by cotyledon and first true leaves of velvetleaf, suggesting the addition of UAN may increase velvetleaf control by triflusulfuron (Table 4). However, the addition of UAN to Sylgard 309 decreased ^{14}C-triflusulfuron absorption by cotyledon leaves of velvetleaf (Table 4). Velvetleaf control in the greenhouse was increased by the addition of UAN to triflusulfuron plus Herbimax, Sylgard 309, and X-77 (Table 2). The addition of UAN to triflusulfuron plus Sylgard 309 decreased ^{14}C-triflusulfuron absorption on the cotyledon leaves of velvetleaf (Table 4), yet cotyledon velvetleaf control was increased by adding UAN to triflusulfuron plus Sylgard 309. Hinz et al. (9) found dry weight reduction of drought stressed velvetleaf by bentazon plus UAN or crop oil concentrate could not be explained by differential bentazon absorption . UAN may increase triflusulfuron's velvetleaf control by mechanism(s) other than increasing absorption.

Effects of adding desmedipham plus phenmedipham to triflusulfuron. At 24 HAT, adding desmedipham plus phenmedipham to ^{14}C-triflusulfuron plus UAN, Dash, Dash plus UAN, Herbimax plus UAN, Sylgard 309 plus UAN, X-77 or X-77 plus UAN decreased absorption by 18 to 36% on the cotyledon leaves of velvetleaf (Table 4). The addition of desmedipham plus phenmedipham to triflusulfuron plus X-77 also decreased control of cotyledon stage velvetleaf by triflusulfuron (Table 2). However, the addition of desmedipham plus phenmedipham to triflusulfuron plus any other adjuvant did not influence control of cotyledon stage velvetleaf by triflusulfuron (Table 2). At 24 HAT, adding desmedipham plus phenmedipham to ^{14}C-triflusulfuron plus Dash, Dash plus UAN, Herbimax plus UAN, Sylgard 309, Sylgard 309 plus UAN, X-77, or X-77 plus UAN decreased absorption by first true leaves of velvetleaf (Table 4). The addition of desmedipham plus phenmedipham to ^{14}C-triflusulfuron plus Sylgard 309 $\pm$ UAN decreased the spread of the 2 μl droplet compared to triflusulfuron plus Sylgard 309 (data not presented). The change in the physical behavior of the applied droplet may explain the decreased ^{14}C-triflusulfuron absorption, because velvetleaf leaves are covered with trichomes which may prevent viscous droplets from contacting the leaf surface (22). Desmedipham plus phenmedipham may also only slow the rate of ^{14}C-triflusulfuron absorption. These results indicate desmedipham plus phenmedipham may increase, decrease, or have no effect on velvetleaf control by triflusulfuron depending on the adjuvant used.

Absorption of triflusulfuron into velvetleaf leaves appears to be a major obstacle for velvetleaf control. With the exception of Herbimax, the amount of ^{14}C-triflusulfuron absorbed is proportional to the amount of velvetleaf dry weight reduction by triflusulfuron plus the respective adjuvant. Averaged over all treatments, 100% of ^{14}C-triflusulfuron applied to velvetleaf leaves was recovered in the rinsate solution at 0 HAT (data not presented), however in treatments containing Herbimax only 90% of ^{14}C-triflusulfuron was recovered. The Herbimax plus ^{14}C-triflusulfuron combinations may have associated with the epicuticular wax on the velvetleaf leaves and not absorbed into the leaf. The wax was not removed by the rinsate solution, therefore the ^{14}C-triflusulfuron associated with the wax may have been falsely identified as absorbed by the velvetleaf plant. This error could explain the poor velvetleaf control, yet high apparent levels of absorption of ^{14}C-triflusulfuron plus Herbimax treatments.

Velvetleaf control at three application timings. Triflusulfuron applied at $\geq$ 8.8 + 8.8 g ai ha^{-1} reduced cotyledon stage velvetleaf dry weight more than first or second true leaf stage velvetleaf (Figure 1). Triflusulfuron at 17.5 + 17.5 or 35 + 35 g ai ha^{-1} reduced the dry weight of first true leaf velvetleaf more than second true leaf velvetleaf (Figure 1). These greenhouse results suggest triflusulfuron is most effective in controlling velvetleaf in the cotyledon growth stage.

Triflusulfuron alone or in combination with any adjuvant did not injure sugarbeet in the greenhouse. The addition of an adjuvant to triflusulfuron is essential for velvetleaf control. However, when desmedipham plus phenmedipham was applied with an adjuvant sugarbeet injury increased. The addition of triflusulfuron to desmedipham plus phenmedipham plus an adjuvant increased, decreased, or did not affect sugarbeet response depending on the adjuvant used. Adjuvant efficacy differed within the same classification category. With the exception of Hasten, any adjuvant which was effective for velvetleaf control also greatly increased sugarbeet injury. This injury may be unacceptable if desmedipham plus phenmedipham plus an adjuvant is applied under conditions conducive for crop injury (morning application, high temperature, and/or high relative humidity) (17).

The addition of desmedipham plus phenmedipham to triflusulfuron plus Dash, Dash plus UAN, Herbimax plus UAN, Sylgard 309 plus UAN, X-77 and X-77 plus UAN decreases ^{14}C-triflusulfuron absorption, possibly resulting in decreased velvetleaf control. Field experiments have resulted in equal velvetleaf control by triflusulfuron plus an adjuvant and triflusulfuron plus desmedipham plus phenmedipham plus an adjuvant (3, 21). However, decreased velvetleaf control could result if desmedipham plus phenmedipham is tankmixed with triflusulfuron plus an adjuvant when less than optimal field environmental conditions such as drought make postemergence weed control difficult.

ACKNOWLEDGEMENTS

The authors wish to thank E. I. DuPont for financial support and for supplying the ^{14}C-triflusulfuron for this research. The authors would also like to thank Michigan Sugar Company and Monitor Sugar Company for their financial support. Our sincere gratitude is extended to Melody Davies and C. J. Palmer for their technical assistance.

Literature Cited

1. Anderson, R. N., R. M. Menges, and J. S. Conn. 1985. Variability in velvetleaf (*Abutilon theophrasti*) and reproduction beyond its current range in North America. Weed Sci. 33:507-512.

2. Beckett, T. H., and E. W. Stoller. 1991. Effects of methylammonium and urea ammonium nitrate on foliar uptake of thifensulfuron in velvetleaf (*Abutilon theophrasti*). Weed Sci. 39:333-338.

3. Dexter, A. G., J. L. Luecke, and M. W. Bredehoeft. 1992. Postemergence control of broadleaf weeds in sugarbeet. Proc. North Cent. Weed Sci. Soc. 47:125.

4. Dexter, A. G., J. L. Luecke, and M. W. Bredehoeft. 1993. Postemergence herbicide combinations in sugar beet. Proc. North Cent. Weed Sci. Soc. 48:90.

5. Falk, R. H., R. Guggenheim, and G. Schulke. 1994. Surfactant-induced phytotoxicity. Weed Technol. 8:519-525.

6. Fielding, R. J. 1990. Effects of additives on the efficacy, uptake, and translocation of the methyl ester of thifensulfuron. Weed Sci. 38:172-178.

7. Fielding, R. J., and E. W. Stoller. 1990. Effects of additives on efficacy, uptake, and translocation of chlorimuron ethyl ester. Weed Technol. 4:264-271.

8. Hagood, E. S. Jr., T. T. Bauman, J. L. Williams, Jr., and M. M. Schreiber. 1980. Growth analysis of soybeans (*Glycine max*) in competition with velvetleaf (*Abutilon theophrasti*). Weed Sci. 28:729-734.

9. Hinz, J. R., and M. D. K. Owen. 1994. Effect of drought stress on velvetleaf (*Abutilon theophrasti*) and bentazon efficacy. Weed Sci. 42:76-81.

10. Levene, B. C., and M. D. K. Owen. 1994. Movement of ^{14}C-bentazon with adjuvants into common cocklebur (*Xanthium stumarium*) and velvetleaf (*Abutilon theophrasti*). Weed Technol. 8:93-98.

11. Mitch, L. W. 1991. Intriguing world of weeds. velvetleaf. Weed Technol. 5:253-255.

12. Reese, K. D., and M. M. Loux. 1992. Efficacy and timeliness of DPX-66037 for weed control in sugar beets. Proc. North Cent. Weed Sci. Soc. 47:124.

13. Renner, K. A., and T. M. Crook. 1992. Postemergence weed control in sugar beets with DPX-66037. Proc. North Cent. Weed Sci. Soc. 47:126.

14. Renner, K. A., and G. E. Powell. 1991. Velvetleaf (*Abutilon theophrasti*) control in sugarbeet (*Beta vulgaris*). Weed Technol. 5:97-102.

15. Roeth, F. 1987. Velvetleaf. Coming on strong. Crops and Soils Mag. March: pp. 10-11.

16. Roggenbuck, F. C., R. F. Burow, and D. Penner. 1994. Relationship of leaf position to herbicide absorption and organosilicone adjuvant efficacy. Weed Technol. 8:582-585.

17. Prodoehl, K. A., L. G. Campbell, and A. G. Dexter. 1992. Phenmedipham + desmedipham effects on sugarbeet. Agron J. 84:1002-1005.

18. Schweizer, E. E., and L. D. Bridge. 1982. Sunflower (*Helianthus annuus*) and velvetleaf (*Abutilon theophrasti*) interference in sugarbeets. (*Beta vulgaris*). Weed Sci. 30:514-519.

19. Schmenk, R. E., Jr. 1994. Velvetleaf *(Abutilon theophrasti* (Medik.)) competitiveness in corn as affected by preemergence herbicides. Master's Thesis, Michigan State University. pp. 64.

20. Spencer, N. R. 1984. Velvetleaf *(Abutilon theophrasti* (Malvaceae)), history and economic impact in the united states. Econ. Bot. 38:407-416.

21. Starke, R. J. and K. A. Renner. 1993. Velvetleaf *(Abutilon theophrasti)* response to triflusulfuron methyl. Proc. North Cent. Weed Sci. Soc. 48:88-89.

22. Warwick, S. I., and L. D. Black. 1990. The biology of Canadian weeds. *(Abutilon theophrasti)*. Can. J. Plant Sci. Journal of Plant Sci. 68:1069-1085.

23. Zhao, C. C. 1990. Factors affecting the activity of thifensulfuron. Weed Sci. 38:553-557.

Table 1. **Reduction in sugarbeet dry weight by triflusulfuron, desmedipham plus phenmedipham and various adjuvants[a,b].**

		Sugarbeet dry weight reduction	
Adjuvants	Rate	Des/phen[e]	Triflusulfuron[d] + Des/phen[e]
	-- % v/v --	------- % -------	
No adjuvant	--	3	15
UAN[c]	4.0	22	40
Dash	1.0	27	37
Herbimax	1.0	37	29
Herbimax + UAN	1.0+4.0	36	23
Scoil	1.0	36	42
Sylgard 309	0.3	43	45
Sylgard 309 + UAN	0.3+4.0	50	43
X-77	0.3	21	23
X-77 + UAN	0.3+4.0	45	37
Chempro 6000	1.0	55	63
Dyne-amic	0.5	52	32
Hasten	0.8	21	23
Induce	0.3	66	49
K2000	1.0	51	44
LSD(0.05) =		------- 13 -------	

[a]Calculated as 100 - ((plant dry weight)(untreated plant dry weight)$^{-1}$ * 100).
[b] Triflusulfuron alone or in combination with any of the adjuvants did not cause a significant reduction in sugarbeet dry weight ($P \leq 0.05$).
[c]UAN, 28% liquid urea ammonium nitrate.
[d]Triflusulfuron applied in split applications of 4.4 + 4.4 g ai ha^{-1}.
[e]Desmedipham plus phenmedipham applied in split applications of 370 + 370 g ai ha^{-1}.

Table 2. Reduction in velvetleaf dry weight by triflusulfuron, desmedipham plus phenmedipham and various adjuvants[ab].

Adjuvants	Rate	Velvetleaf dry weight reduction: Triflusulfuron[d]	Velvetleaf dry weight reduction: Triflusulfuron[d] + Des/phen[e]
	-- % v/v --	------- % -------	
No adjuvant	--	0	2
UAN[c]	4.0	14	31
Dash	1.0	63	68
Herbimax	1.0	10	12
Herbimax + UAN	1.0+4.0	60	67
Scoil	1.0	80	74
Sylgard 309	0.3	68	66
Sylgard 309 + UAN	0.3+4.0	84	73
X-77	0.3	28	13
X-77 + UAN	0.3+4.0	73	56
Chempro 6000	1.0	35	27
Dyne-amic	0.5	57	57
Hasten	0.8	52	67
Induce	0.3	30	32
K2000	1.0	30	54
	LSD(0.05) =	-------- 12 --------	

[a]Calculated as 100 - ((plant dry weight)(untreated plant dry weight)$^{-1}$ * 100).
[b]Desmedipham plus phenmedipham alone or in combination with any of the adjuvants did not cause a significant reduction in velvetleaf dry weight ($P \leq 0.05$).
[c]UAN - 28% liquid urea ammonium nitrate.
[d]Triflusulfuron applied in split applications of 4.4 + 4.4 g ai ha^{-1}.
[e]Desmedipham plus phenmedipham applied in split applications of 370 + 370 g ai ha^{-1}.

Table 3. Absorption of ^{14}C-triflusulfuron (triflu) by cotyledon and first true leaves of velvetleaf at 4 h in combination with adjuvants, 28% urea ammonium nitrate (UAN) and desmedipham plus phenmedipham (des/phen)[a].

		Cotyledon		First true leaves	
Adjuvant	Rate	Triflu	Triflu + Des/phen	Triflu	Triflu + Des/phen
	-- % v/v --	% of applied			
No adjuvant	--	11	10	9	9
UAN	4.0	39	34	7	4
Dash	1.0	65	12	10	13
Dash + UAN	1.0 + 4.0	73	38	40	19
Herbimax	1.0	72	52	32	4
Herbimax + UAN	1.0 + 4.0	78	48	15	9
Scoil	1.0	33	47	17	42
Scoil + UAN	1.0 + 4.0	76	65	33	17
Sylgard 309	0.3	90	89	48	16
Sylgard 309 + UAN	0.3 + 4.0	77	47	71	12
X-77	0.3	18	9	19	8
X-77 + UAN	0.3 + 4.0	48	41	20	4
	LSD (0.05)[b] =	11			

[a]Absorption calculated as 100*((total ^{14}C applied - rinsate ^{14}C)(total ^{14}C applied)$^{-1}$).
[b]Comparisons valid within and between columns.

Table 4. Absorption of ^{14}C-triflusulfuron (triflu) by cotyledon and first true leaves of velvetleaf at 24 h in combination with adjuvants, 28% urea ammonium nitrate (UAN) and desmedipham plus phenmedipham (des/phen)[a].

		Cotyledon		First true leaves	
Adjuvant	Rate	Triflu	Triflu + Des/phen	Triflu	Triflu + Des/phen
	-- % v/v --	---------- % of applied ----------			
No adjuvant	--	15	11	12	13
UAN	4.0	48	30	6	7
Dash	1.0	71	35	42	18
Dash + UAN	1.0 + 4.0	79	47	52	29
Herbimax	1.0	67	71	28	27
Herbimax + UAN	1.0 + 4.0	85	49	40	39
Scoil	1.0	71	80	40	39
Scoil + UAN	1.0 + 4.0	90	82	53	47
Sylgard 309	0.3	90	84	56	14
Sylgard 309 + UAN	0.3 + 4.0	76	58	64	35
X-77	0.3	51	27	35	12
X-77 + UAN	0.3 + 4.0	72	39	46	16
	LSD (0.05)[b] =	---------- 10 ----------			

[a]Absorption calculated as 100*((total ^{14}C applied - rinsate ^{14}C)(total ^{14}C applied)$^{-1}$).
[b]Comparisons valid within and between columns.

Figure1. Velvetleaf dry weight reduction by triflusulfuron at three application timings.