UPTAKE AND COMPARATIVE PHYTOTOXICITY
OF TEBUTHIURON

By

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CHAPTER I

INTRODUCTION

The production potential of pastures and rangelands may be increased by the proper use of weed and brush control procedures. Phenoxy herbicides such as 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) are most commonly used. Certain problems such as resprouting, variability in results, chemical drift, and manufacturing impurities are associated with their use. In view of this, alternative compounds need to be examined.

Tebuthiuron, N-[5(1,1 dimethylethyl)-1,3,4-thiadiazol 2-yl]N,N-dimethylurea, has shown prospects for being a good herbicide for the control of herbaceous weeds and brush. Soil treatments of 2.24 kg/ha on mixed brush stands has given excellent control of elms (*Ulmus* spp.) and oaks (*Quercus* spp.). Weed control in established bermudagrass (*Cynodon dactylon* (L.) Pers.) has been observed with rates as low as 0.56 to 1.12 kg/ha.

It is possible that tebuthiuron could also be used for selective control of certain species. This selectivity may vary by method of application since tebuthiuron has shown good postemergence activity on annual grasses and broadleaf weeds.

The objectives of this research were to establish the relative susceptibility of several species to tebuthiuron and to evaluate its uptake and activity on various established plants.

CHAPTER II

LITERATURE REVIEW

Tebuthiuron is a member of the substituted urea family of herbicides. (Chemical names for all herbicides reviewed are listed in Table I). Unlike the other substituted urea herbicides it has a thiadiazol group substituted instead of a phenyl group (Figure 1).

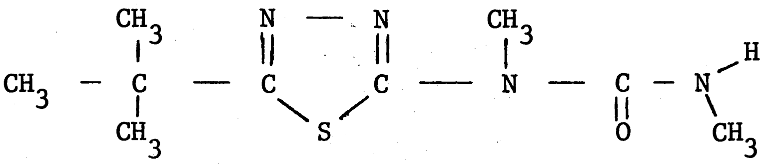

Figure 1. Chemical Structure of Tebuthiuron

Tebuthiuron has a water solubility of 2500 ppm at 25 C. It is one of the most water soluble urea herbicides (Table I). Only fenuron with a solubility of 3850 ppm is more water soluble. Tebuthiuron is light stable and dissipates in soil primarily by microbial degradation (Walker *et al.* 1973).

At low rates urea herbicides have been widely accepted as selective preemergence and postemergence herbicides. At higher rates they have been used extensively as general soil sterilants (McWhorter

TABLE I

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common name	Chemical name	Solubility in H_2O (ppm)
Chloroxuron	3-[p-(p-chlorophenoxy)phenyl]-1,1-dimethyl urea	4 (20 C)
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	42 (25 C)
Fenuron	3-phenyl-1,1-dimethylurea	3850 (25 C)
Fluometuron	1,1-dimethyl-3-(α,α,α-trifluro-m-tolyl) urea	90 (25 C)
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea	75 (25 C)
Monuron	3-(p-chlorophenyl)-1,1-dimethylurea	230 (25 C)
Siduron	1-(2-methylcyclohexyl)-3-phenylurea	18 (25 C)
Tebuthiuron	N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N-N'-dimethylurea	2500 (25 C)

1963). However, little information has been published on the properties of tebuthiuron relating to its phytotoxicity and uptake and translocation on established plants. For this reason most references in this review will discuss work done with other urea herbicides.

It has been found that certain species of plants appear to have an inherent resistance to some of the urea herbicides. (Common and scientific names of all plant species reviewed are listed in Table II). Ashton and Crafts (1973) reported that citrus species, turkey mullein and common groundsel are examples of plants resistant to monuron. Carder (1963) using field studies reported that monuron prevented quackgrass re-establishment for up to seven years while allowing for satisfactory growth of cereal crops for ten years or more.

Cotton is resistant to postemergence applications of diuron. Relatively low absorption and/or translocation may be responsible. Strang and Rogers (1971) found ^{14}C-diuron accumulated to marked concentrations in the lysigenous or pigment glands of cotton leaves and in trichomes. They concluded that this binding of diuron may be a major factor in the tolerance of cotton to diuron. However, Smith and Sheets (1967) could not account for the 10-fold difference in ED_{50} (effective dosage to cause 50% growth reduction) values between soybeans and cotton by differential absorption or distribution of root applied ^{14}C-diuron. They attributed the tolerance in cotton to metabolism of diuron as no diuron was identified in cotton leaves but was found in soybean leaves. Differences in susceptibility to diuron among oat, soybean, and corn appeared to be related more to differential absorption. However, Bayer and Yamaguchi (1965) concluded that there did not appear to be a species difference between bean, soybeans or barley

TABLE II

COMMON AND SCIENTIFIC NAMES OF PLANTS

Common name	Scientific name	Common Name	Scientific Name
Alfalfa	*Medigo sativa* L.	Downey brome	*Bromus tectorum* L.
Bahiagrass	*Paspalum notatum* Flugge.	Grape	*Vitis vinifera* L.
Barley	*Hordeum vulgare* L.	Henbit	*Lamium amplexicaule* L.
Bean	*Phaseolus vulgaris* L.	Marestail	*Erigeron canadensis* L.
Bermudagrass	*Cynodon dactylon* (L.) Pers.	Oats	*Avena sativa* L.
Carrot	*Daucus Carota* L.	Quackgrass	*Agropyron repens* (L.) Beauv.
Citrus	*Citrus* spp.	Small flower galinsoga	*Galinsoga paraviflora* Cav.
Common groundsel	*Senecio vulgaris* L.	Sorghum	*Sorghum bicolor* L. Moench.
Common ragweed	*Ambrosia artemisiifolia* L.	Soybeans	*Glycine max* (L.) Merr.
Corn	*Zea mays* L.	Turbinella oak	*Quercus turbinella* Greene
Cotton	*Gossypium hirsutum* L.	Turkey mullein	*Eremocarpus setigerus* Benth.
Cowpea	*Vigna unguiculata* (L.) Walp.	Turkey oak	*Quercus laevis* Walt.
Crabgrass	*Digitaria* spp.	Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees
Cucumber	*Cucamis sativa* L.		
		Wild buckwheat	*Polygonum convolvulus* L.

plants in the absorption, distribution and accumulation of ^{14}C-diuron. Selective use of diuron has been reported in several crops. Peeper and Santelmann (1969) showed that postemergence applications of 1.68 kg/ha of diuron did not reduce yield of two forage bermudagrasses. Satisfactory control of henbit and marestail was obtained by Arnold and Santelmann (1970) on dormant alfalfa stands with diuron at 3.36 kg/ha applied either in December or late winter. Smith and Moore (1969) found that spring applications of diuron and linuron controlled 60 percent of the downey brome without injuring native grass.

Postemergence treatments of linuron can be used for annual weed control in carrots (Ashton and Crafts 1973). One reason for this selectivity has been offered by Kuratle (1968). He observed variation in the degradation of linuron in carrot and common ragweed. Carrots, a resistant species, had 89 percent of the total radioactivity in a non-toxic form while common ragweed, a susceptible species, had only 13 percent in non-toxic form.

Differences in the response of various species to applications of chloroxuron have been reported by Geissbuhler _et_ _al_. (1963). They found small flower galinsoga absorbed and translocated about twice as much chloroxuron as wild buckwheat.

Rogers and Funderburk (1968) found cucumber to be susceptible to fluometuron while cotton was not. They concluded that although differential absorption did not account for the differential selectivity, differential translocation and metabolism may be involved. In citrus, Goren (1969) found that fluometuron was not present in sufficient quantity in the leaves to affect photosynthesis, respiration, dry weight, or chlorophyll content following high rates of application to the soil. Autoradiograph studies showed that the radioactivity, presumably fluometuron, accumulated in the roots and lower stem following an application to the roots. However, photosynthesis in leaf disks was inhibited 70 percent by 80 mg/L of fluometuron, showing that if the herbicide had been present in the leaves of the intact plant, photosynthesis would have been inhibited. He concluded that the resistance of citrus to fluometuron either involves the lack of translocation or demethylation or both.

Chang (1975) reported that oats was more sensitive than soybeans or corn to tebuthiuron on three soil types. Baur and Bovey (1975) working with unlabelled tebuthiuron found the rate of tebuthiuron necessary to cause 50 percent inhibition in growth indicated that sorghum seedlings were more sensitive than cowpea seedlings.

Some urea herbicides have been noted to be phytotoxic to various oak species. Wagle and Schmutz (1963) indicated that applications of fenuron resulted in good control of turbinella oak while allowing for significant increases in grass production and quality. Rodgers et al. (1962) reported that 11.2 kg/ha of monuron or diuron was effective in controlling Turkey oak. Furthermore, bahiagrass and weeping lovegrass could be established satisfactorily on treated soil.

It is apparent that the activity of a particular urea herbicide varies, depending upon the species treated. Selectivity, due to differential absorption and/or translocation has been obtained in certain species with some urea-type herbicides.

The urea herbicides are generally regarded as being rapidly translocated in the xylem following the translocation stream to the leaves where they exert their effect by inhibiting photosynthesis

(Bayer and Yamaguchi 1965, Geissbuhler _et al_. 1963). Bucha and Todd (1951), concluded from their original greenhouse studies with monuron that it was readily absorbed by the plants root system and translocated to the leaves. Haun and Peterson (1954) using ^{14}C-labeled monuron on several species found that absorption by roots was very rapid but downward translocation from a foliar application was nil. Autoradiographs of ^{14}C-monuron in barley plants (Crafts 1959) show that translocation of foliar applied monuron is only upward from the point of application. Pickering (1965) investigated the foliar penetration pathway of monuron in bean plants by histoautoradiographic techniques and concluded that it entered the leaf and became evenly distributed throughout the treated tissue. Other investigators, Minshall (1954), Muzik _et al_. (1954), and Smith and Sheets (1967), have studied the absorption and translocation of monuron in a variety of species. Their conclusions were that monuron was absorbed rapidly by roots but at much slower rates by other organs and it is almost exclusively translocated via the apoplastic system.

Similar results have been reported with other urea herbicides. Nishimoto and Warren (1971) using a divided pot technique reported that roots of corn plants clearly accounted for most of the ^{14}C-diuron taken up. Prendeville _et al_. (1967) found diuron to enter primarily through the roots of corn and pea plants. Primary movement of ^{14}C-diuron in bean, soybeans and barley plants was shown to be in the apoplast with the transpiration stream by Bayer and Yamaguchi (1965). They did not eliminate the possibility that very small amounts of diuron may enter the symplast and move with the plant assimilates (phloem movement). However, autoradiographs did indicate that if diuron moved into the symplast it was restricted and the movement of diuron out of the area of application by phloem movement was very limited. The restricted phloem translocation of diuron was again confirmed by Leonard and Glenn (1968). ^{14}C-diuron was not transported in the phloem in detached bean leaves. Only movement in the xylem was observed. ^{14}C-diuron was mobile only in the xylem or cell walls (apoplastic system) of Thompson seedless grapes (Leonard _et_ _al_. 1966). Rapid movement of diuron from the roots to the shoots with root applications was observed.

Geissbuhler _et_ _al_. (1963) report that chloroxuron was readily absorbed by roots of small flower galinsoga and wild buckwheat and translocated into the stems and leaves. However, from a leaf application there was no translocation of chloroxuron into the neighboring leaves but some transport occurred within the treated leaf from the site of application at the base of the leaf toward the apex. Rogers and Funderburk (1968) reported no basipetal translocation of fluometuron from a foliar application in either cucumber or cotton, although cucumber absorbed more of the herbicide than cotton.

Foliar activity has been reported with linuron (Kuratle _et_ _al_. 1969). Linuron was found to be absorbed both by roots and foliage of common ragweed.

Results similar to those already discussed were reported by Splittstoesser and Hopen (1968) working with siduron. Rapid absorption of siduron by barley and crabgrass roots was observed and translocation via the apoplastic system was evident.

Information on uptake and translocation of tebuthiuron is limited. In a recent study Baur and Bovey (1975) reported that an application of tebuthiuron to the basal hypocotyl of cowpea seedlings was much more effective in inhibiting growth than applications to one unifoliolate leaf. The rate necessary for 50 percent inhibition in growth of cowpea first internode was reduced by a factor of five (relative to a leaf application) when basal hypocotyl applications were made. On the basis of their findings they suggest that tebuthiuron translocation is limited to the apoplast or non-living tissue. These researchers found tebuthiuron to be more toxic when applied to the second true leaf of sorghum than when applied to a mature unifoliolate leaf of cowpea. They attributed their results to the probability that tebuthiuron was placed in direct contact with the growing point of sorghum, whereas in cowpea, tebuthiuron was not translocated to the growing point from applications to a mature unifoliolate leaf.

These same workers reported that phytotoxic levels of tebuthiuron were found to be absorbed by both cowpea and sorghum seedlings within five minutes after initial application of tebuthiuron to the foliage.

CHAPTER III

METHODS AND MATERIALS

The top four inches of a Teller sandy loam soil collected from Perkins, Oklahoma was used in all studies involving soil. Characteristics of this soil are given in Table III. A soil with low clay and organic matter content and a low cation exchange capacity was chosen so that theoretically a large percentage of the herbicide applied to the soil would be in the soil solution phase and available for uptake by the bioassay plants.

TABLE III

CHEMICAL AND PHYSICAL PROPERTIES OF SOIL USED IN THIS STUDY

Soil Property	Value
Soil source	Perkins
Textural class	Sand
Percent sand	94.7
Percent silt	3.0
Percent clay	2.0
Percent organic matter	0.3
*Cation exchange capacity	0.6
pH	6.7

*Milliequivalents per 100 grams soil.

Comparative Phytotoxicity

Growth chamber bioassay procedures were used to compare the relative susceptibilities of nine plant species to tebuthiuron. Soil was collected from the field, air dried and screened to remove large clods and foreign objects. Various rates of tebuthiuron (80 percent a.i. wettable powder) were suspended in water and then applied to the soil in plastic bags and thoroughly mixed. Styrofoam cups containing 250 grams of treated soil, replicated four times in a completely randomized design, were planted with the following species: Japanese brome (Bromus japonicus Thunb.), common ragweed, bermudagrass var. Guymon, oats var. Cimarron, wheat (Triticum aestivum L. (em. Thell)) var. Triumph 64, rye (Secale cereale L.) var. Elbon, mustard (Brassica juncea var. crisspifolia Cass.) var. Tender Green, soybeans var. Cutler, and corn var. Gold Rush. After emergence the plants in each pot were thinned to uniform stands for each species. The position of each pot in the growth chamber was rotated periodically to reduce variables in growth due to location. The seedlings were grown under continuous fluorescent light at a light intensity of 159 microeinsteins m^{-2} sec^{-1} with a room temperature of 26 C. Watering was to the soil surface when required. Periodic waterings were made with Hoaglands nutrient solution (Hoagland and Arnon 1950) to insure adequate soil nutrient levels.

Approximately nineteen days after planting, when injury symptoms had become apparent and differences were noted, soybeans were harvested at the cotyledonary node and the fresh weight determined. Above ground plant parts were harvested and weighed for all other species. The relative susceptibility of each species to tebuthiuron was then determined by calculating a GR_{50} value for each species (Sheets 1959). The GR_{50} was considered to be the herbicide concentration required to reduce plant growth by 50 percent as compared to untreated plants. It was derived by plotting the fresh weight of treated plants as a percentage of the untreated check plants against the logarithm of the herbicide concentration. The antilogarithm of the point of intersection of the curve and the 50 percent yield level gave an estimate of the GR_{50} in ppmw.

Response of Plants to Type of Application

Activity of postemergence applications of tebuthiuron to foliage and soil were evaluated using procedures similar to those described by Carlson et al. (1975) working with pronamide, 3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide. Styrofoam cups containing 250 grams of the air-dried sandy soil previously described were planted with the following species: Japanese brome, common ragweed, mustard var. Tender Green, rye var. Elbon, soybeans var. Cutler and corn var. Gold Rush. Pots were then placed in the growth chamber under continuous fluorescent light at a light intensity of 159 microeinsteins m^{-2} sec^{-1} with a room temperature of 26 C. Pots were rotated periodically to reduce variables in germination and growth due to location. Watering was to the soil surface as needed. Occasional waterings were made with Hoaglands nutrient solution to insure adequate soil nutrient levels.

After emergence the plants were thinned to uniform stands for each species.

Tebuthiuron (80 percent a.i. wettable powder) was applied to each species. (The growth stage at time of treatment for each species at the three rates of application are listed in Table IV.) The study was conducted as a randomized complete block design with four replications. The three types of application were: (1) Foliar applied tebuthiuron sprayed over the plants and containers after covering the soil surface with an adsorbent (perlite); (2) root applied tebuthiuron pipetted onto the soil surface without wetting the foliage; and (3) topical applied tebuthiuron sprayed over the tops of the plants and containers without covering the soil surface. Untreated control plants for each species were included for comparison.

Perlite, an adsorbent volcanic material, was placed on the soil surface immediately preceding foliar treatments to adsorb the tebuthiuron which reached the soil level and to prevent root uptake. After treatment the perlite was removed with compressed air. Care was taken when watering foliar treatments not to wet the foliage to prevent washing any herbicide remaining on the plants onto the soil surface where it could be taken up by the plant roots.

Foliar and topical treatments of tebuthiuron were applied with a laboratory chamber type sprayer at 1.2 kg/cm^2 pressure with a total volume of 287 L/ha.

After treatment all pots were returned to the growth chamber. After two weeks all above ground plant parts were harvested and weighed. Visual ratings were taken at time of harvest to correlate herbicide activity with percent growth response. Ratings were made on the basis of 0 to 10 with 0 being no injury and 10 being complete plant kill.

Activity of the various applications was evaluated on the basis of percent growth compared to untreated control plants. Percent

TABLE IV

GROWTH STAGES AT TREATMENT OF VARIOUS PLANT SPECIES

Species	Growth stage	Height (cm)	Rates applied (kg/ha)
Japanese brome	first true leaf	11	0.14,0.28,0.56
Ragweed	2nd-3rd pair true leaves	5	0.14,0.28,0.56
Mustard	2nd-4th true leaves	6	0.14,0.28,0.56
Rye	first true leaf	11	0.28,0.56,1.12
Soybeans	expanding trifoliolate leaves	12	0.28,0.56,1.12
Corn	third true leaf	20	0.28,0.56,1.12

growth was estimated by dividing the fresh weight of treated plants by the fresh weight of untreated control plants.

Activity of Labeled Tebuthiuron

Common ragweed and rye var. Elbon were used to evaluate the activity of ^{14}C-tebuthiuron on established plants. Growth chamber studies were performed under the following environmental conditions: photoperiod 14 hours, day temperature 29 C, night temperature 21 C and light intensity 1100 microeinsteins m^{-2} sec^{-1}.

Seeds were germinated in 26 by 52 cm plastic flats filled to a depth of 4.5 cm with vermiculite. Seventeen days after planting, when ragweed plants were expanding the third pair of true leaves and rye had three leaves, plants were transferred to well-aerated half strength Hoaglands nutrient solution in 75 ml green bottles, one plant per bottle. After an equilibrium period of 24 hours, plants were transferred to bottles containing 75 ml of full strength Hoagland nutrient solution. Treatments were made nine days after transfer to nutrient solution culture. Ragweed plants were expanding the fifth pair of true leaves and rye plants were in the eight leaf stage. Both foliage and root uptake was evaluated. Foliage uptake was evaluated by spotting the labeled herbicide on a leaf. Ten μl containing 0.1 μc of ^{14}C-tebuthiuron (carbonyl labeled sp. act. 16.9 μc/mg) in ethanol was spotted on one side of one second true leaf of ragweed and spread over the area of two lobes of the leaf. An equal amount was spotted on the fourth leaf of rye plants about 2.54 cm from the tip of the leaf and spread over the middle of the leaf downward 3.75 cm from that point.

Root uptake was evaluated by placing labeled tebuthiuron into the nutrient solution. Nutrient bottles were brought to a volume of 75 ml with distilled water. Then 6 µl of ^{14}C-tebuthiuron in ethanol were added to each bottle. This gave a concentration of 0.05 ppm of tebuthiuron. All treatments were replicated eight times in a completely randomized design.

After 24 hours of additional time in the growth chamber all plants were removed from nutrient culture, pressed between wire screens to afford a flat surface for autoradiography and frozen. Plants were then freeze-dried to remove all moisture and four plants of each treatment for each species were autoradiographed following procedures outlined by Eastin and Basler 1972.

After autoradiographs were developed, plants were divided into various parts. Foliar treatments were divided into treated leaf, remainder of foliage (tops) and roots. Plants treated through the growth medium were divided into tops and roots. Dry weights of each plant part were taken.

Plant parts were homogenized in 5 ml of 95 percent ethanol in preparation for liquid scintillation counting. One-tenth ml of the homogenate was then transferred to 15 ml of scintillation counting fluid. One liter of counting fluid contained 5 g PPO (P-bis-o-methyl-styryl-benzene), 80 g napthalene, 230 ml ethanol, 385 ml p-dioxone and 385 ml xylene. Vials were counted for 20 minutes or until counting was within 3 percent.

The nutrient solution growth media of each plant was also quantitated for ^{14}C-tebuthiuron by liquid scintillation counting. After removal of plants, nutrient solution was brought to 75 ml volumes with distilled water. Counting vials were evacuated and the counting fluid collected and saved. Five ml of nutrient solution from each bottle was transferred to counting vials and quick frozen. Vials with frozen nutrient solution were freeze-dried to produce the dry matter. Scintillation counting fluid was readded and the vials capped and counted as previously described.

CHAPTER IV

RESULTS AND DISCUSSION

Comparative Phytotoxicity

Response curves for several plant species to tebuthiuron treated soil are given in Figures 2, 3, and 4. The GR_{50} values for all of the species tested are listed in Table V. Japanese brome was the most susceptible species studied with a GR_{50} of 0.016 ppmw. Mustard, ragweed and bermudagrass followed in order of susceptibility with GR_{50} values of 0.023, 0.026 and 0.031 ppmw respectively. Seedling bermudagrass appeared to be susceptible to relatively small amounts of tebuthiuron in the soil. However, from previous research it is known that up to 1.12 kg/ha of tebuthiuron may be applied to dormant established bermudagrass in the field without suppressing forage yield. Rye, oats and wheat were less susceptible to tebuthiuron treated soil. GR_{50} values of the three species were 0.049, 0.049, and 0.099 ppmw respectively. The GR_{50} value for wheat was approximately twice that for rye and oats, indicating wheat to be more tolerant of tebuthiuron than rye or oats. Soybeans with a GR_{50} of 0.311 ppmw and corn with a GR_{50} of 0.436 ppmw were the least susceptible species in this study to tebuthiuron treated soil. There was a rather wide range of susceptibility noted among species based on relative GR_{50} values. Differences in the response of various plant species to a given rate of tebuthiuron may or

TABLE V

EFFECTS OF TEBUTHIURON TO NINE PLANT SPECIES

Species	0**	Tebuthiuron rate (ppmw)																GR$_{50}$ (ppmw)	Corr. Coeff.	LSD$_{.05}$
		.005	.01	.015	.02	.025	.03	.04	.05	.06	.08	.10	.16	.25	.50	.75	1.0			
									*Weight in grams											
Japanese brome	.80	0.53	0.61	-	-	-	0.24	-	-	0.12	-	-	-	-	-	-	-	.016	92	0.27
Mustard	9.89	10.09	9.49	-	7.71	-	-	1.58	-	-	-	-	-	-	-	-	-	.023	99	3.55
Ragweed	1.0	0.87	-	0.60	-	-	0.62	-	0.13	-	-	0.04	-	-	-	-	-	.026	94	0.26
Bermuda-grass	.74	-	-	-	-	0.66	-	-	-	-	-	0.32	-	0.04	-	-	-	.031	96	0.38
Rye	2.65	-	2.20	-	2.33	-	-	1.80	-	-	0.88	-	0.40	-	-	-	-	.049	96	0.71
Oats	3.61	3.39	3.00	-	2.89	-	-	2.49	-	-	1.19	-	-	-	-	-	-	.049	94	0.68
Wheat	4.70	-	3.81	-	3.90	-	-	-	-	-	3.20	-	1.65	-	-	-	-	.099	90	0.62
Soybeans	1.48	-	-	-	-	-	-	-	-	-	-	1.33	-	0.58	0.39	0.40	0.43	.311	90	0.21
Corn	5.54	-	-	-	-	-	-	-	-	-	-	4.93	-	3.21	2.77	1.77	1.83	.436	98	1.15

*Values represent the average weight in grams of four replications.
**Values represent average fresh weight (grams) of untreated check plants.

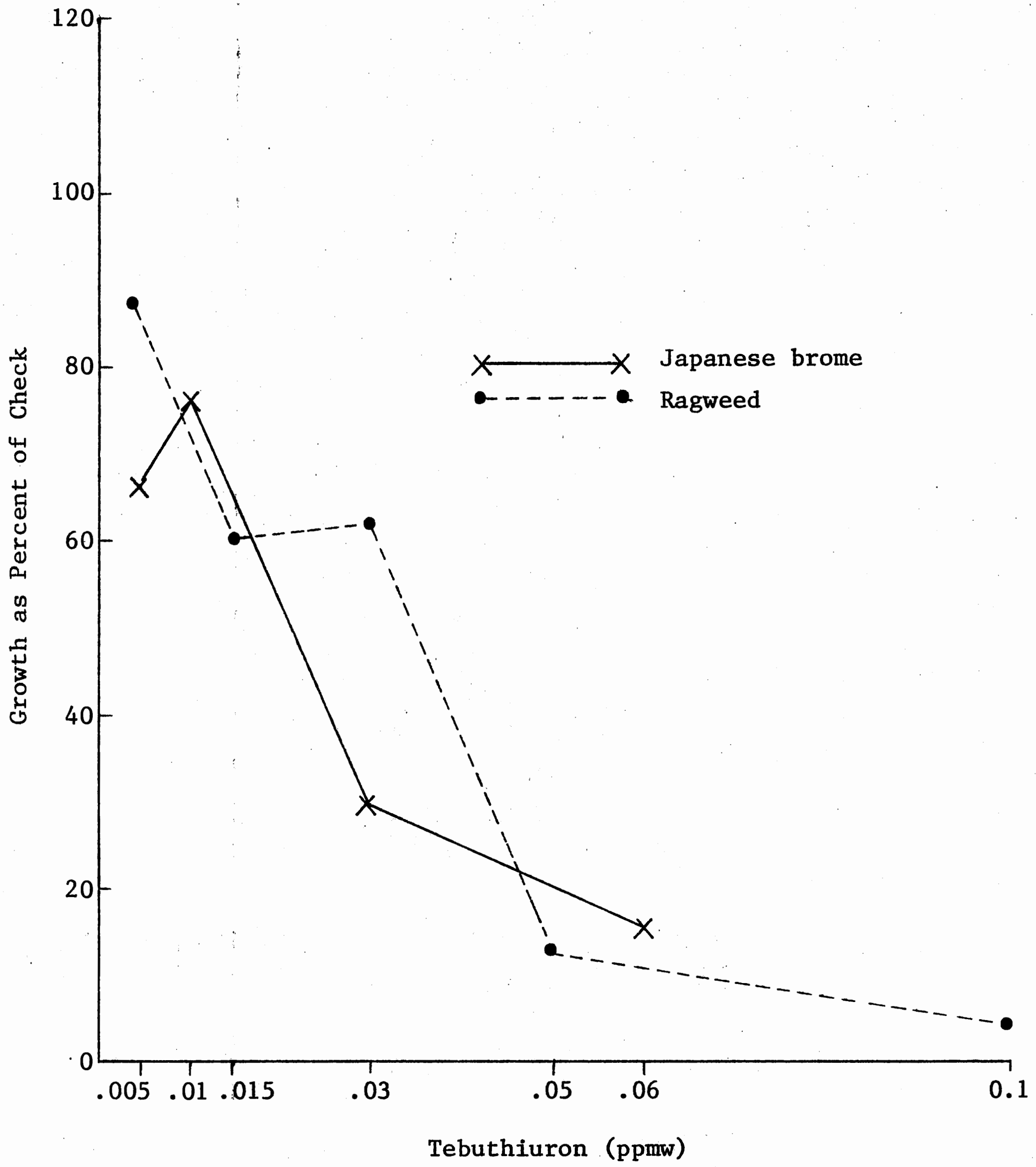

Figure 2. Response of Japanese Brome and Ragweed to Various Tebuthiuron Concentrations

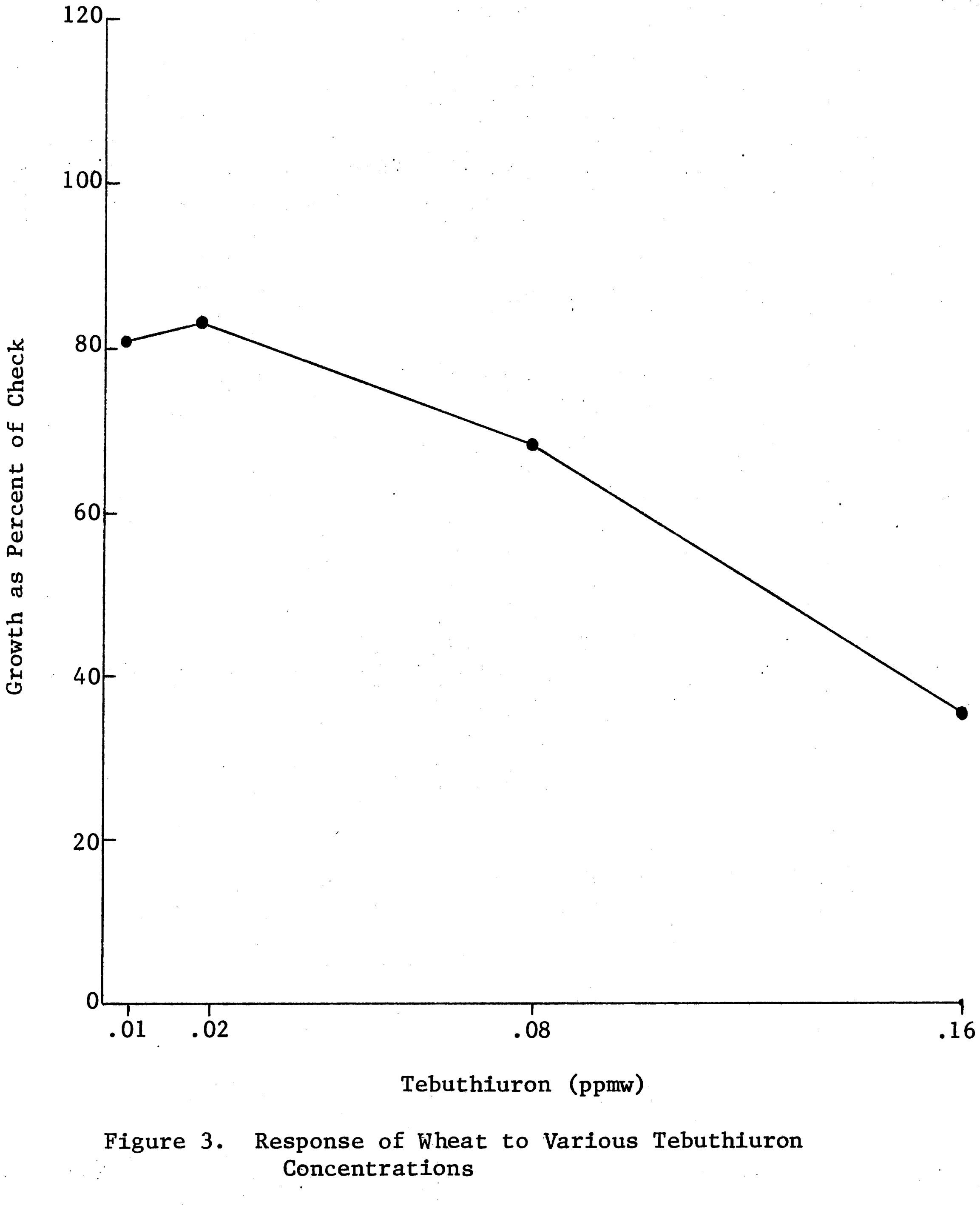

Figure 3. Response of Wheat to Various Tebuthiuron Concentrations

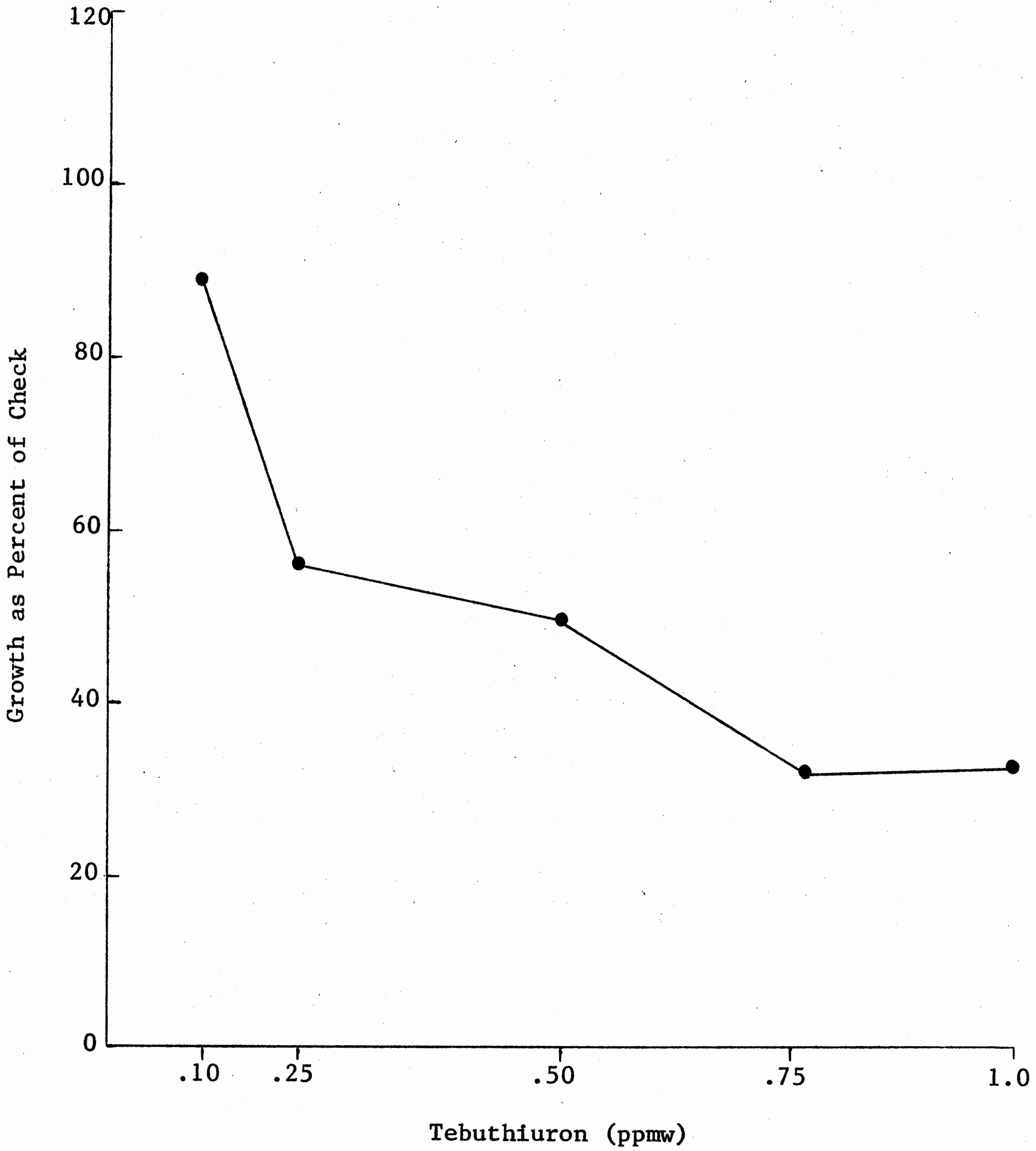

Figure 4. Response of Corn to Various Tebuthiuron Concentrations

may not be great enough to allow for selective use of the chemical. Reasons for the variation in herbicidal effects of tebuthiuron between species may be similar to those shown for other urea herbicides. Differential absorption, translocation and plant metabolism have been offered as evidence for differences in the response of various species to certain urea herbicides (Ashton and Crafts 1973).

The response of Japanese brome and ragweed (Figure 2) to tebuthiuron show these weedy species to be susceptible to low tebuthiuron concentrations. Japanese brome and ragweed seeded into relatively high levels of tebuthiuron would die soon after emergence from the soil. The growth response curve of wheat is shown in Figure 3. Wheat plants seeded into soil treated with relatively high levels of tebuthiuron would emerge and grow normally for 24 to 48 hours before herbicidal effects were noted. Corn had the greatest tolerance for tebuthiuron in this study (Figure 4). In soil with relatively high rates of tebuthiuron (0.75 and 1.0 ppmw) plants would emerge from the soil and grow actively for 48 to 72 hours before effects of the herbicide were noted. Even at high rates of herbicide corn plants were never killed. Growth was slowed and plants were in a weakened condition compared to non-treated plants.

As shown in Table V the correlation coefficients were 90 or higher. Least significant differences at the .05 level are also given for each species in Table V.

Response of Plants to Type of Application

The visual damage of various plant species to postemergence applications of tebuthiuron is given in Table VI. Soil treatments were

TABLE VI

VISUAL RATINGS* OF POSTEMERGENCE EFFECTS OF TEBUTHIURON ON SIX PLANT SPECIES

Treatments (kg/ha)	Species					
	Ragweed	Japanese brome	Mustard	Rye	Soybeans	Corn
			Visual Rating			
Soil						
0.14	1.8	7.0	4.2	-	-	-
0.28	8.8	9.5	6.2	5.5	4.2	0.8
0.56	9.8	9.8	6.2	8.5	6.8	2.2
1.12	-	-	-	9.8	7.2	5.8
Topical						
0.14	0.0	0.0	0.2	-	-	-
0.28	0.0	0.0	4.8	0.8	0.5	0.0
0.56	5.8	6.8	7.5	3.5	4.5	0.0
1.12	-	-	-	9.5	7.2	5.2
Foliar						
0.14	0.0	0.0	1.0	-	-	-
0.28	0.5	0.0	2.8	0.0	0.0	0.0
0.56	2.6	0.5	3.5	1.2	4.0	0.0
1.12	-	-	-	1.8	4.2	0.0
Check	0.0	0.0	0.8	0.0	0.0	0.0
$LSD_{.05}$	0.5	0.9	3.7	0.5	0.6	0.8

*Visual rating at time of harvest, average of four replications; 0 = no injury, 10 = complete kill. A (-) means no treatment applied.

more phytotoxic than foliar treatments which indicates that the post-emergence activity of tebuthiuron is primarily due to root uptake. There was some foliar uptake with certain species at the higher rates, as significant injury was noted on ragweed, rye, and soybeans.

The growth response of established plants to tebuthiuron is given in Tables VII and IX. Comparison of these values with visual injury ratings indicate that there was growth of all species at phytotoxic levels of tebuthiuron. For example, a growth response of 16 percent for ragweed corresponded to plants being in an extremely weakened condition and near death at time of harvest. Growth response values and visual ratings were nearly alike in evaluating the phytotoxicity of tebuthiuron on established plants. It was found that the relative species response to tebuthiuron was similar to that indicated by comparative GR_{50} values. This was attributed to the fact that root uptake was primarily responsible for the activity of tebuthiuron.

There was also a tendency toward increased growth with sublethal dosages of topical and foliar applied tebuthiuron on certain species (Table VII) although these increases were not statistically significant. Topical treatments at low rates on ragweed, Japanese brome, mustard, and rye appeared to increase the fresh weight of treated plants relative to untreated plants. Growth of Japanese brome and mustard appeared to increase with foliar treatments at the low rate of herbicide. Ashton and Crafts (1973) have reported that growth stimulation has been observed with sublethal applications of members of other herbicide families.

The type of interaction for method of treatment with rate of tebuthiuron is illustrated with Japanese brome in Figure 5. Growth

TABLE VII

GROWTH RESPONSE* OF VARIOUS PLANT SPECIES TO POSTEMERGENCE APPLICATIONS OF TEBUTHIURON

Treatments (kg/ha)	Species					
	Ragweed	Japanese brome	Mustard	Rye	Soybeans	Corn
			*Growth Response (%)			
Soil						
0.14	62 bc	29 c	60 b	-	-	-
0.28	19 d	20 c	55 b	33 d	51 d	64 d
0.56	16 d	19 c	36 b	16 d	51 d	74 cd
1.12	-	-	-	12 d	49 d	46 e
Topical						
0.14	109 a	102 a	110 a	-	-	-
0.28	97 a	70 b	50 b	122 ab	96 a	97 ab
0.56	45 c	34 c	28 b	74 c	74 bc	85 abc
1.12	-	-	-	11 d	56 cd	45 e
Foliar						
0.14	97 a	109 a	106 a	-	-	-
0.28	105 a	91 ab	63 b	133 a	93 ab	96 ab
0.56	73 b	78 b	59 b	100 abc	91 ab	93 ab
1.12	-	-	-	91 bc	69 cd	81 bcd

*Percent growth of treated plants compared to untreated plants, numbers are average of four replications. Numbers in the same column followed by the same letter are not significantly different at the .05 level. A (-) means no treatment applied.

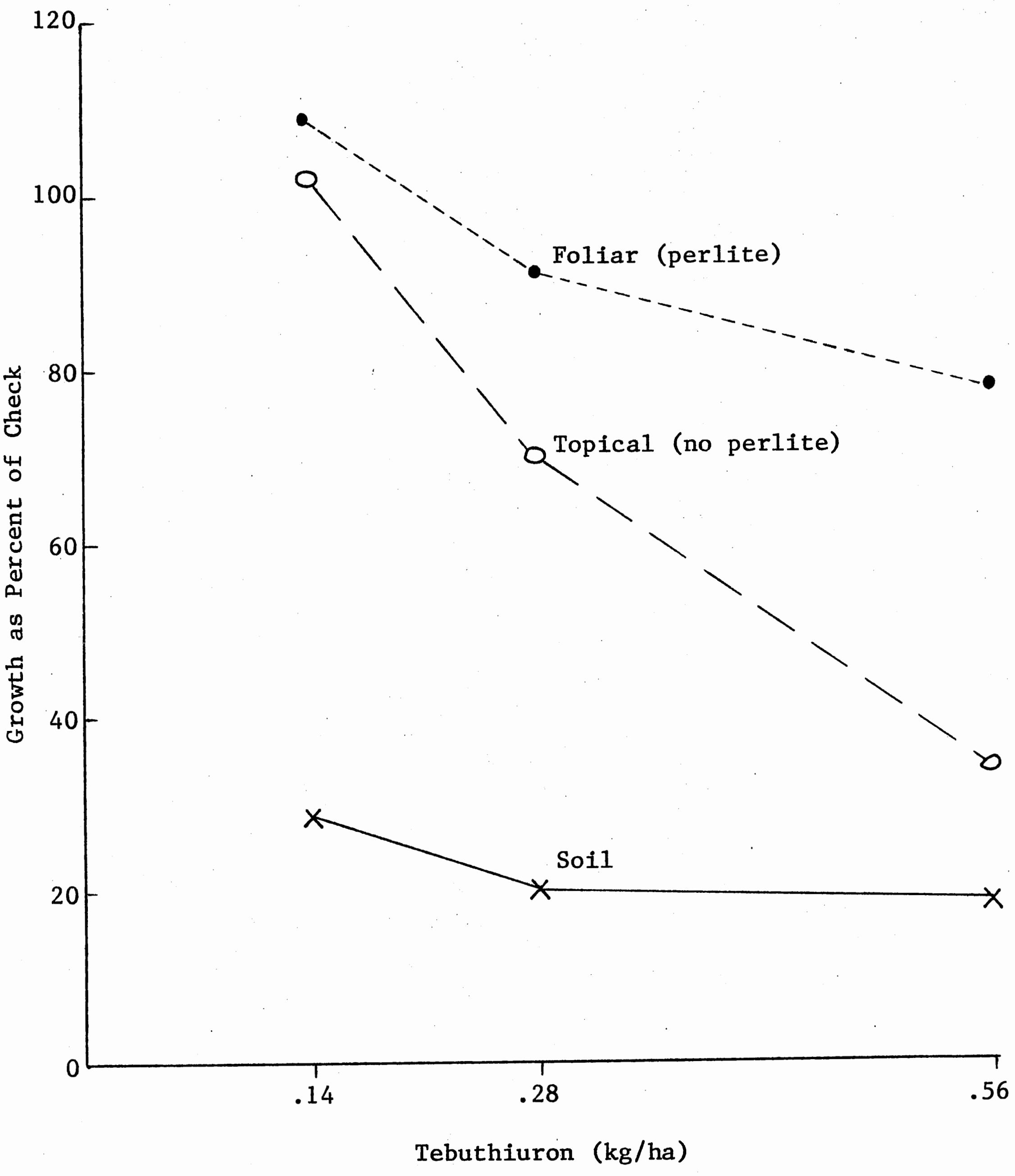

Figure 5. Activity of Tebuthiuron on Japanese Brome as Affected by Treatment and Rate

response from all of the rates applied to the soil were less than 30 percent whereas growth response from topical treatments went from no effect at 0.14 kg/ha down to only 35 percent growth at 0.56 kg/ha. This implies that the effects of foliage interception and low foliar uptake may be overcome by increasing the rate of application. Any washoff of chemical from foliage onto the soil would also increase activity.

Activity of Labeled Tebuthiuron

Distribution of foliar and root-applied tebuthiuron on ragweed and rye, 24 hours after treatment, is listed in Table VIII. Accumulation of labeled material in ragweed plants is shown by autoradiography (Figures 6 and 7). Most of the recovered activity was still in the treated area. Translocation and distribution of root-applied tebuthiuron (Figure 6) appeared to differ from that of foliar-applied herbicide (Figure 7). The most significant translocation was the 24.5 percent recovered in the tops of ragweed plants treated through the nutrient solution. Ragweed is more susceptible than rye to tebuthiuron and it may be due to its greater uptake and translocation of tebuthiuron to the leaves.

There was some uptake and translocation of tebuthiuron with the foliar application on ragweed, but activity was primarily through root uptake. However, translocation of tebuthiuron out of the treated area did occur. The labeled material moved across the leaf and also out of the leaf into the stem and apical portions of the plant (Figure 7).

No large differences were noted in the percent translocated to the tops of rye plants between foliar and nutrient solution applications.

TABLE VIII

DISTRIBUTION (AS PERCENT OF RECOVERED HERBICIDE) OF FOLIAR AND ROOT-APPLIED ^{14}C-TEBUTHIURON IN RAGWEED AND RYE AFTER 24 HR.

Species and plant part	Type of application			
	Foliar		Nutrient solution	
	Untreated area	Translocated*	Untreated area	Translocated*
	(%)	(%)	(%)	(%)
Ragweed				
Treated leaf	92.2			
Tops		4.5		24.5
Roots		2.7		4.9
Nutrient solution		0.6	70.6	
Rye				
Treated leaf	91.3			
Tops		5.3		7.3
Roots		2.1		1.9
Nutrient solution		1.3	90.8	

*$LSD_{.05}$ for percent translocated = 2.6

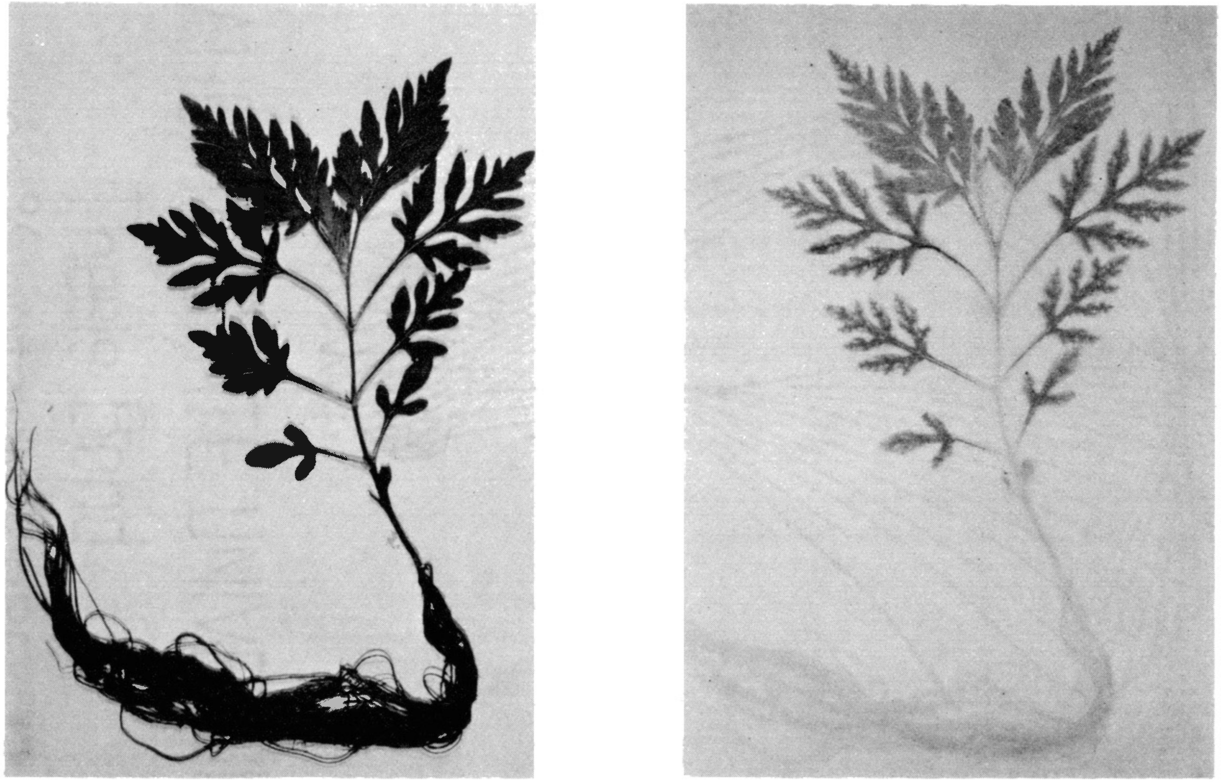

Figure 6. Distribution of ^{14}C-tebuthiuron from Root Treatment on Ragweed. Left, the Plant; Right, the Autoradiograph.

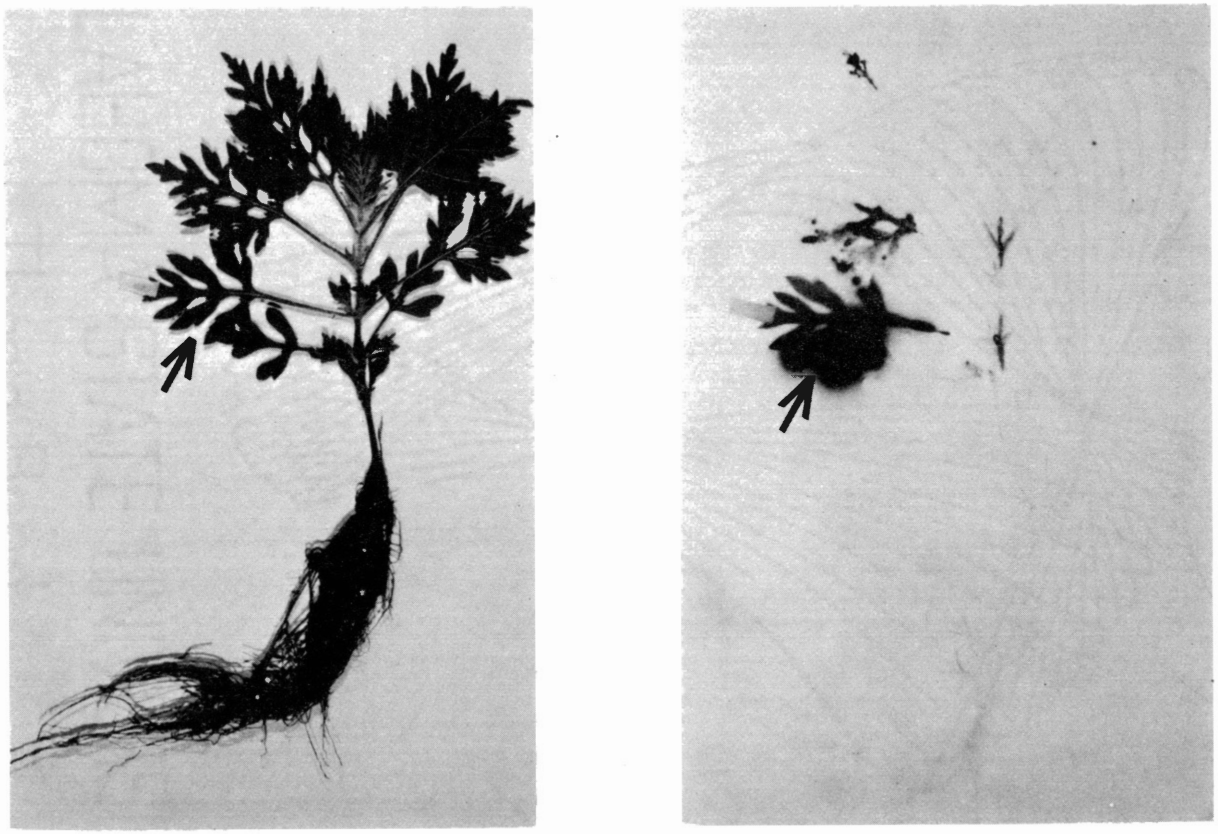

Figure 7. Distribution of ^{14}C-tebuthiuron from Foliar Treatment on Ragweed. Left, the Plant; Right, the Autoradiograph.

However, slightly more tebuthiuron was in the tops of the nutrient solution treatments.

With respect to uptake and translocation, tebuthiuron appears to be similar to the common phenylurea herbicides monuron and diuron (Ashton and Crafts 1973 and Bayer and Yamaguchi 1965).

CHAPTER V

SUMMARY

Growth chamber and laboratory studies were carried out to determine the phytotoxicity, method of uptake, and translocation of tebuthiuron.

Growth chamber studies, using a sand growth medium, showed there were differences in the relative susceptibility of nine plant species to tebuthiuron, based on calculated GR_{50} values. Japanese brome, mustard, and bermudagrass were found to be the most susceptible and soybeans and corn least susceptible. Rye, oats, and wheat were intermediate in susceptibility. The order of decreasing susceptibility was Japanese brome, mustard, ragweed, bermudagrass, rye, oats, wheat, soybeans, and corn. The GR_{50} values ranged from 0.016 ppm for brome to 0.436 ppm by weight for corn. Concentrations of tebuthiuron below certain levels had little effect upon plant growth. However, once a critical amount was reached, herbicidal effects were dramatic.

Activity of applications of tebuthiuron to six established plant species was measured by percent plant growth compared to control plants. Activity was found to be due primarily to root uptake. Foliar activity was noted on ragweed, Japanese brome and mustard. Topical treatments in which the herbicide was sprayed over the tops of the plants and permitted to reach the soil surface generally exhibited more activity than foliar applications, but less activity than where all of the herbicide was applied to the soil.

Uptake and translocation of labeled tebuthiuron was evaluated with established ragweed and rye plants in nutrient solution culture. Treatments were made to the foliage of one group of plants for each species. Translocation, as measured by percent recovered, was greatest (24.5%) in the tops of ragweed plants treated through the nutrient solution. Ragweed plants absorbed and translocated more tebuthiuron via a root treatment than did rye plants. This may be responsible for differences in susceptibility.

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APPENDIX

TABLE IX

RESPONSE* OF VARIOUS PLANT SPECIES TO POSTEMERGENCE APPLICATIONS OF TEBUTHIURON

Treatments (kg/ha)	Species					
	Ragweed	Japanese brome	Mustard	Rye	Soybeans	Corn
			*Weight (grams)			
Soil						
0.14	1.14	0.27	1.84	-	-	-
0.28	0.36	0.19	1.68	0.60	2.21	5.96
0.56	0.29	0.18	1.11	0.30	2.21	6.82
1.12	-	-	-	0.21	2.14	4.23
Topical						
0.14	2.01	0.98	3.39	-	-	-
0.28	1.80	0.67	1.55	2.23	4.23	9.00
0.56	0.84	0.33	0.87	1.36	3.24	7.87
1.12	-	-	-	0.20	2.48	4.15
Foliar						
0.14	1.79	1.05	3.27	-	-	-
0.28	1.95	0.87	1.95	2.37	4.07	8.85
0.56	1.35	0.75	1.83	1.83	3.98	8.63
1.12	-	-	-	1.67	3.03	7.51
Check	1.85	0.96	3.08	1.83	4.39	9.26
$LSD_{.05}$	0.36	0.21	0.87	0.59	0.89	1.51

*Weight in grams of plants harvested at ground level, numbers are average of four replications. A (-) means no treatment applied.

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