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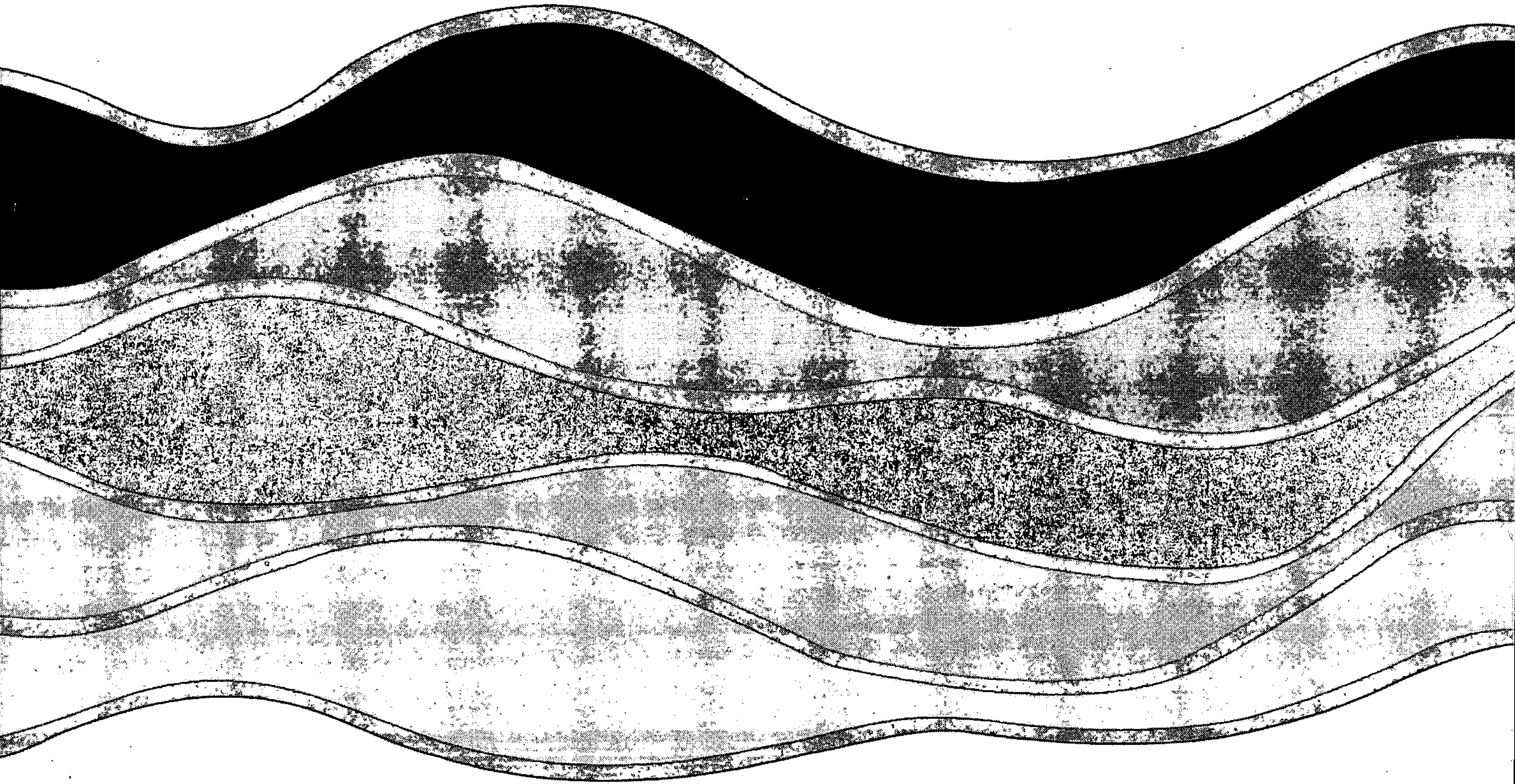

TRIFLURALIN STUDY IN FARM DUGOUTS IN NORTHERN ALBERTA

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NWRI Contribution No. 91-12

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Executive Summary

In 1988, a study of the herbicide trifluralin was initiated in two dugouts near Peace River, Alberta. Although trifluralin is considered to be relatively safe, there are uncertainties with respect to it's effects on aquatic ecosystems. It can be biomagnified and some metabolites persist adsorbed to soils. Since earlier work has shown that lime treatment can remove particulates from the water column and since most organic contaminates adsorb to particles, lime was evaluated as a treatment technique.

The dugouts were divided in half with translucent polyethylene seacurtains. Trifluralin was added to each side of both dugouts and lime ($Ca(OH)_2$) (100 mg/L) was added to one half of each dugout. The dissipation rate of trifluralin was relatively constant in both dugouts and both treatments. The lack of an effect of the lime treatment on trifluralin concentrations occurred in spite of substantial precipitation (sedimentation of approximately 200 mg/L of mixed lime/calcium/magnesium carbonates and 150 to 280 µg/L of the total phosphorus).

Trifluralin was bioconcentrated in leeches by 13,000 to 17,000 fold and two metabolites of trifluralin were observed in the resident leeches. The seasonal change in algal biomass in both dugouts indicates that the trifluralin enhanced algal biomass, probably by killing zooplankton. Thus, trifluralin would impair water quality by enhancing algal growth. Lime treatment is unlikely to reduce the effects of trifluralin on dugouts.

RÉSUMÉ POUR LA DIRECTION

En 1988, une étude de l'herbicide trifluraline a été entreprise dans deux fosses-réservoirs près de Peace River, en Alberta. Bien que cet herbicide soit considéré comme relativement inoffensif, il subsiste des incertitudes quant à ses effets sur les écosystèmes aquatiques. Il peut y avoir biomultiplication de la trifluraline et certains de ses métabolites persistent à l'état adsorbé aux sols. Étant donné que des travaux récents ont montré que le traitement à la chaux permettait d'éliminer les particules dans la colonne d'eau et qu'il y avait adsorption de la plupart des contaminants organiques sur ces particules, on en a conclu que la chaux pouvait être utilisée comme technique de traitement.

Les fosses-réservoirs ont été divisés en deux à l'aide de toiles marines en polyéthylène. On a ajouté de la trifluraline aux deux moitiés de chaque fosse-réservoir et de la chaux, $Ca(OH)_2$ (100 mg/L), à une moitié de chaque fosse-réservoir. Le taux de dissipation de la trifluraline était relativement constant dans les deux fosses-réservoirs et pour les deux traitements. L'absence d'effet du traitement à la chaux sur les concentrations de trifluraline a été observée en dépit d'importantes précipitations (sédimentation d'environ 200 mg/L de carbonates mixtes de calcium et de magnésium et de 150 à 280 μg/L de phosphore total).

La trifluraline a été bioconcentrée de 13 000 à 17 000 fois chez les sangsues et deux métabolites de la trifluraline ont été observés chez les sangsues de l'endroit. Les variations

saisonnières dans la biomasse des algues des deux fosses-réservoirs montrent que la trifluraline augmentait la biomasse algale, probablement en tuant le zooplancton. Ainsi, la trifluraline altérerait la qualité de l'eau en stimulant la croissance algale. Il est peu probable que le traitement à la chaux réduise les effets de la trifluraline sur les fosses-réservoirs.

Abstract

In 1988, a study of trifluralin toxicity was initiated in two dugouts near Peace River, Alberta. The dugouts were divided in half with translucent polyethylene seacurtains. Trifluralin was added to each side of both dugouts and lime ($Ca(OH)_2$) (100 mg/L) was added to one half of each dugout on. The dissipation rate of trifluralin was relatively constant in both dugouts and both treatments. The lack of an effect of the lime treatment on trifluralin concentrations occurred in spite of substantial precipitation (sedimentation of approximately 200 mg/L of mixed lime/ calcium/magnesium carbonates and 150 to 280 µg/L of the total phosphorus).

At the time of capture, the biological concentration factors for trifluralin in leeches were 13,000 for Desrosier dugout and 17,000 for Troup dugout. Two metabolites of trifluralin were observed in the leeches R1TRF and R2TRF.

In Desrosier dugout, trifluralin enhanced the toxicity of the water to Daphnia magna and Photobacterium and lime treatment reduced the toxicity. The toxicity that existed before the experiment began appears to have controlled the bioassay responses in Troup dugout. The seasonal change in algal biomass in both dugouts indicates that the trifluralin enhanced algal biomass, probably by killing zooplankton. Although biological reactions were important, volatilization of trifluralin may be the most important reaction regulating the half-life of trifluralin.

RÉSUMÉ

En 1988, on a entrepris une étude sur la toxicité de la trifluraline dans deux fosses-réservoirs près de Peace River en Alberta. Les fosses-réservoirs ont été divisés en deux à l'aide de toiles marines en polyéthylène. On a ajouté de la trifluraline aux deux moitiés de chaque fosse-réservoir et de la chaux, $Ca(OH)_2$ (100 mg/L), à une moitié de chaque fosse-réservoir. Le taux de dissipation de la trifluraline était relativement constant dans les deux fosses-réservoirs et pour les deux traitements. L'absence d'effet du traitement à la chaux sur les concentrations de trifluraline a été observée en dépit d'importantes précipitations (sédimentation d'environ 200 mg/L de carbonates mixtes de calcium et de magnésium et de 150 à 280 µg/L de phosphore total).

Au moment de leur capture, les facteurs de bioconcentration de trifluraline chez les sangsues étaient de 13 000 dans la fosse-réservoir de Desrosier et de 17 000 dans celle de Troop. Deux métabolites de la trifluraline ont été observés chez les sangsues R1TRF er R2TRF.

Dans la fosse-réservoir de Desrosier, la trifluraline augmentait la toxicité de l'eau pour Daphnia magna et Photobacterium, alors que le traitement à la chaux réduisait cette toxicité. La toxicité qui existait avant le début de l'expérience semble avoir déterminé les réponses de l'essai biologique dans la fosse-réservoir de Troop. La variation saisonnière de la biomasse algale dans les deux fosses-réservoirs montre que la trifluraline

augmente la biomasse algale, probablement en tuant le zooplancton. Même si les réactions biologiques étaient importantes, la volatilisation de la trifluraline est peut-être la réaction qui détermine en premier lieu la demi-vie de ce composé.

1 Introduction

The Peace River area of north western Alberta is a rich agricultural area with a limited supply of high quality water. More than 85% of the study area is used for agriculture with grain farming as the dominant land use. Precipitation in the Peace River area of northwestern Alberta is low and evaporation is high (375 mm annual precipitation for a 30-year average and 600 mm/yr mean annual evaporation, Fisheries and Environment Canada 1978). The town of Peace River processes the water of the Peace River and some farmers haul water by truck from the town. Groundwater in this area is usually a poor drinking water source; wells are deep and the water is often rich in iron and sulphides.

As is common throughout the prairies, farmers divert runoff from road ditches or fields into dugouts for domestic and agricultural water supplies. Dugouts collect runoff from farm fields and as such are potentially concentrated in herbicides, pesticides and nutrients. The high concentration of nutrients results in algal blooms, and in turn, poor taste and odour in the drinking water (Prepas and Murphy 1988).

Trifluralin is a pre-emergent herbicide that is used on many cereal grains. Its use has increased in western Canada in the last ten years. Trifluralin is lost from aerobic soils by chemical and biological processes, and by volatilization (Helling 1976, Soderquist et al. 1975). Although trifluralin is persistent in soils, adsorption of trifluralin to soils does not significantly reduce the dissipation rate of trifluralin (Smith et al. 1988).

2 Methods

In 1988, a study of trifluralin toxicity was initiated in two dugouts, Troup and Desrosier, near Peace River (56° 14′ N, 117° 17′ W, Table 1). The dugouts were divided in half with translucent polyethylene seacurtains. Ethefoam logs (15 cm diameter) were inserted into collars of ultraviolat (UV) resistant black polyethylene for flotation. A chain with 3 cm thick links was inserted into a loop of fabric on the bottom of the curtain. A diver pushed the chain into the sediment and placed large rocks on the bottom of the curtain. The sides of the curtains were buried in trenches. To minimize movement of the curtain, four anchors per curtain were tied at two points on the surface of each curtain.

Trifluralin was added to each side of both dugouts on June 27 by mixing it in a large container and pumping it throughout the dugouts. Desrosier and Troup dugouts received 1.76 L and 2.7 L of Treflan, respectively. The Treflan contained 539 μg/L of trifluralin and no contaminants were observed in electron capture gas chromatography analysis. The final concentration of trifluralin was calculated to be 500 μg/L.

Lime ($Ca(OH)_2$) was added to one half of each dugout on June 29 by mixing the lime in a slurry maker and spraying the slurry onto the dugouts (Murphy et al. 1989, Prepas et al. 1989). Desrosier and Troup dugouts received five and six bags (40-kg bags) of lime, respectively. The final concentration of lime was approximately 100 mg/L.

Water samples were collected from Troup dugout at depths of 1.0 and 2.5 m and from Desrosier dugout at 1.0 m from the surface with a Van Dorn sampler. Total and dissolved phosphorus (TP), ammonium, nitrite and nitrate analyses were done at the University of Alberta. Total phosphorus samples were transferred to culture tubes and analyzed according to Menzel and Corwin's (1965) potassium persulphate method. The following analyses were made at the National Water Research Institute (NWRI): chlorophyll a (Chla), calcium (Ca), magnesium (Mg), potassium (K), sulphate (SO_4), dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), particulate organic carbon (POC), particulate organic nitrogen (PON), total Kjeldahl nitrogen (TKN), iron (Fe), manganese (Mn), chloride (Cl), mercury (Hg), cadmium (Cd), cobalt (Co), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn). Most chemical analyses were conducted with Technicon procedures (Environment Canada 1979). Metals were analyzed by atomic absorption.

Samples for Chla analysis were filtered under low pressure (-50 KPa) through Whatman GF/C filters within 48 hours of collection. The filters were placed in petri dishes, wrapped in aluminum foil and frozen until analyzed. The concentration of Chla was determined with a dimethyl sulfoxide extraction technique (Burnison 1980).

Trifluralin was extracted with dichloromethane, purified using a modified method of Lee and Chau (1983a), and determined with electron capillary gas chromatography.

To determine the relative degree of trifluralin adsorption to glass and polyethylene, trifluralin solutions were incubated in both types of bottles for eight days at room temperature. Trifluralin was added to 500 mL of tap water to produce three concentrations; 15, 150 and 1960 µg/L. These samples all contained hexane extracted hydrochloric acid (final pH 1.0).

To determine if acid was necessary to prevent adsorption of trifluralin, trifluralin solutions were incubated with and without hydrochloric acid (final pH 1.0). Three concentrations of trifluralin (260, 500 and 1000 µg/L) were allowed to stand for eight days in amber glass bottles.

Containers for bioassays and chemical assays were placed into either steel or glass containers. Two sets of water samples were collected in 20-L stainless steel containers (Pepsi cans). These 20-L samples were shipped to NWRI by air where they were immediately filtered for analysis of dissolved and particulate trifluralin. Water samples for trifluralin analyses were kept in amber bottles with purified acid (final pH 1.0). Water samples for bioassays were chilled, and shipped by air to NWRI; these 4-L bottles were covered with tape to prevent photooxidation of the trifluralin.

The surface film of the dugouts was collected by immersing a glass plate (20 by 20 cm) into the pond five to six times and collecting the film each time with a squeegee. The plate was washed with methanol between samples. To suppress biological activity and loss of trifluralin by volatilization, 10 mL of dichloromethane was added to each sample with a dispenser and each bottle was sealed with Teflon tape. The trifluralin was concentrated in the dichloromethane. The dichloromethane formed a layer on the bottom of the container and by keeping the container upright, volatilization was suppressed.

Sediment samples were collected with a Tech-Ops corer (Mawhinney 1987) and subdivided into 1 cm sections. Sediments were collected September 26 from Desrosier dugout and September 27 from Troup dugout. Sections of sediment from 0 to 1 and 5 to 6 cm from both sides of the dugouts were shipped on ice to NWRI and dried by thorough blending with sufficient anhydrous sodium sulphate.

Leeches were collected July 25 from the unlimed sides of both dugouts for trifluralin analysis. They were shipped on ice to NWRI, identified to species, and dried by blending with anhydrous sodium sulphate.

Both the sediment and leech samples were purified by Soxhlet extraction with dichloromethane, and solvent exchange by a method of Lee and Chau (1983b). The purified extracts were analyzed by capillary electron capture gas chromatography.

Photobacterium bioassays were conducted on water samples shipped to NWRI. Analyses were done on a Beckman Microtox photometer.

Daphnia magna bioassays were conducted on water samples shipped to NWRI. Juvenile animals were used in 48 h incubations. _Daphnia_ were fed algae immediately before the bioassays. Controls were conducted with dechlorinated tap water. No analyses were used if more than 10% of the control animals died. Dugout water was diluted with dechlorinated tap water to enable determination of an LC_{50} (concentration of dugout water killing 50% of Daphnia).

Attempts to use clams to measure bioaccumulation of trifluralin were overcome by the poor survival of the clams in the dugouts. Attempts to use fathead minnows in laboratory bioassays were frustrated by the poor health of the minnows; they may have been diseased.

3 Results

3.1 Adsorption of trifluralin to sample bottles

After incubations of eight days, all the trifluralin in 15 µg/L and 150 µg/L solutions of trifluralin was recovered from glass bottles (Table 2). In the 1960 µg/g solution of trifluralin in glass bottles, approximately half of the trifluralin was recovered. Less than 16% of the trifluralin was recovered from solutions of 15 µg/L, 150 µg/L, and 1960 µg/L of trifluralin in the polyethylene containers. Because of these results, polyethylene bottles were not used for any field samples.

Water samples that were not acidified had at least 24% of the trifluralin adsorbed to the glass (Table 3). In this second set of incubations, an acidified concentration of 260 and 500 µg/L, but not 1000 µg/L of trifluralin, was completely recovered.

3.2 Water chemical analysis in the dugouts

The dissipation rate of trifluralin was relatively constant in both dugouts and both treatments (Fig. 1, Table 4). Relatively little trifluralin was concentrated in the surface slick (Table 4). The addition of lime to half of the dugouts had little effect on the concentrations of trifluralin in the water column. Adsorption of trifluralin to particles on day three removed 120 to 140 µg/L of trifluralin but it had no effect upon the trifluralin in solution (Table 4). Since the dissipation rate of trifluralin was unaffected by the lime sedimentation of trifluralin, the adsorbed trifluralin probably redissolved. The lack of an effect of the lime treatment on trifluralin concentrations occurred in spite of substantial precipitation. In addition to the sedimentation of 100 mg/L of added lime, approximately 100 mg/L of mixed calcium/magnesium carbonates and 60 to 63% (150 to 280 µg/L) of the total phosphorus precipitated from solution.

The precipitation reactions provided water quality markers that confirmed that the seacurtain in Troup dugout effectively sealed the lime treated from the control side of the dugout. For example, after lime addition, the 1.0 m deep water in the lime treated side of the dugout contained 2.0 mg/L of magnesium, whereas a corresponding water sample from the control side contained 8.0 mg/L of magnesium. This difference was maintained for over a month (Tables 5, 6).

The impermeability of the seacurtain in Desrosier dugout is less certain. The Ca, Mg, K, and DIC data all clearly indicate that exchange of water between the two sides was minimal for at least two weeks. After four weeks, only the K data continued to indicate that no water exchange occurred. Desrosier dugout was not stratified and a rapid exchange between the sediments and water column was apparently regulating ionic composition.

In both dugouts, sediment release of nutrients and major ions was exceptionally high. In the limed side of the bottom of the stratified Troup dugout, phosphorus concentrations increased from 900 µg/L to 1800 µg/L in 13 days. A sediment release approximately a week later in Desrosier dugout increased the phosphorus concentration by 260 µg/L. These releases of ions from the sediments had no major effect on the dissipation rate of trifluralin from the water column.

The sediment release of phosphorus was related to the microbial productivity of the water column and organic loading from the drainage basin. Troup dugout had a mean summer chlorophyll a concentration (42 µg/L on control side, n=11) twice that of Desrosier dugout (21 µg/L on control side, n=11). Also, leachate from a large pile of cattle manure on the hill next to Troup dugout may have stimulated bacterial metabolism. Desrosier dugout was adjacent to an open field. Although no direct measurements of microbial activity were made, Troup dugout appears to be much more productive than Desrosier dugout. The algal biomass was reduced by 70 to 90% (3 to 25 µg/L chlorophyll a) in the two lime treatments.

3.3 Trifluralin in the sediments

Sediment samples collected from both dugouts 91 to 92 days after the addition of trifluralin contained less than 1 ng/g of trifluralin (Table 7). A metabolite of trifluralin, 2-amino, 6-nitro, 4-trifluoromethyl-N,N,Ndipropylbenzamine (R1TRF), was also detected at concentrations estimated to be less than 1 ng/g (Table 7).

3.4 Bioaccumulation of trifluralin

Two species of leeches (Pacobdela ornatoa and Glosiphonids) collected on July 25 from the unlimed side of both dugouts indicated that trifluralin had biomagnified. Leeches from Desrosier (n=6) and Troup (n=2) dugouts contained 13 and 17 µg/g of trifluralin, respectively. The dugout water at this time contained approximately 1 µg/L of trifluralin (calculated from plotted decay slope, Fig. 1). At the time of capture, the biological concentration factors were 13,000 for Desrosier dugout and 17,000 for Troup dugout. Biological concentration factors for these samples are still considerable if one assumes a shorter period of exposure, i.e., 40 for day 1, 130 for day 6 and 1300 for day 26.

Two metabolites of trifluralin were observed in the leeches 2-amino,6-nitro,4-trifluoromethyl-N,N,Ndipropylbenzamine (R1TRF) and 2,6-diamino,4-trifluoromethyl-N,Ndipropylbenzamine (R2TRF).

3.5 Bioassays

In bioassays with water from Desrosier and Troup dugouts, trifluralin enhanced toxicity of dugout water to *Daphnia magna* (Fig. 2). Lime addition did not reduce the toxicity of the dugout water to *Daphnia*. The high background toxicity of water from both dugouts to *Daphnia magna* reduced the utility of this bioassay and may have masked the effect of lime treatment on trifluralin toxicity.

Photobacterium bioassays indicated significant but marginal increases in toxicity after the addition of trifluralin (Fig. 3, Table 8). Lime addition had no significant effect on the trifluralin induced toxicity.

4 Discussion

Although preliminary interpretations of field observations appear to minimize the significance of biological degradation of trifluralin, studies with Peace River area dugout sediment identified a reductive transformation of trifluralin. Microbes appear to mediate the formation of the two trifluralin metabolites (R1TRF and R2TRF). These trifluralin metabolites and trifluralin bioaccumulated in leeches in the treated dugouts. A tentative conclusion is that biological assimilation and degradation of trifluralin is important, but another reaction, apparently not biological, controls the dissipation of trifluralin.

Although these lime treatments were two of the least successful dugout water treatments conducted by our team, the short-term sedimentation was considerable. As well as the sedimentation of all the 100 mg/L of added lime, approximately 100 mg/L of mixed calcium/magnesium carbonates precipitated from solution. The dissipation rate of trifluralin was independent of the considerable amount of precipitation. This conclusion is consistent with observations of Smith et al. (1988) that adsorption of trifluralin to soil had no effect upon the dissipation rate of trifluralin. Although similar doses of lime improved the water quality of a number of dugouts, and higher doses of lime (250 mg/L) have consistently improved water quality, lime treatment is unlikely to reduce the effects of trifluralin in dugouts.

Future studies should attempt to resolve the toxicity of the bioaccumulated degradation compounds of trifluralin and attempts should be made to determine the reaction controlling the dissipation of trifluralin in dugouts. Volatilization of trifluralin may be the most important reaction regulating the half-life of trifluralin.

Effect of Aeration on the Persistence of Trifluralin

Given the volatile nature of trifluralin (Carey et al. 1978, Maguire et al. 1988), if volatilization is the major pathway for trifluralin dissipation, air bubbling may strip the trifluralin from dugouts. In laboratory experiments with soil and water, trifluralin readily volatilized (Sanders and Seiber 1983); the only uncertain aspect is the scaling factor in extrapolating to a dugout. Air bubbling is done in about half of the farm dugouts to improve taste and reduce odour. A test should use the same bubbling equipment that many farmers use.

It would be relatively easy to determine the effect of air bubbling on trifluralin volatilization. A dugout would be split in half with a seacurtain, both sides would be treated with trifluralin, one side of the dugout would be bubbled with air, and both sides of the dugout would be monitored for trifluralin and its degradation compounds. The experiment should confirm that volatilization is the major pathway for trifluralin loss in dugouts. Also, if air bubbling significantly reduced the residence time of trifluralin in dugouts, many farmers using trifluralin could easily improve the water quality of their dugouts by using aeration.

The Effect of Trifluralin on Zooplankton and Algal Biomass

Although trifluralin is a herbicide, the algal biomass of Desrosier and Troup dugouts was not reduced by trifluralin. Kosinski and Merkle (1984) were also unable to observe any inhibition of algae by trifluralin. Interpretation of the enhancement of algal biomass by trifluralin in Desrosier and Troup dugouts is speculative because no controls were used without trifluralin addition. The seasonal change in algal biomass indicates that the trifluralin enhanced algal biomass. In Troup dugout, the algal biomass began to increase shortly after trifluralin addition (control or unlimed side). In Desrosier dugout, the algal biomass was initially unaffected by trifluralin addition but after another week, the algal biomass increased.

The development of the algal blooms was not apparently related to nutrient availability. The concentration of nutrients in the water was high and the sediment release of nutrients occurred weeks after the algal bloom began. Unfortunately, zooplankton biomass or filtering rates were not assessed; thus, the possibility that the trifluralin indirectly stimulated algal growth by removing zooplankton grazing was not directly resolved.

In bioassays with water from Desrosier dugout, trifluralin enhanced toxicity of dugout water to Daphnia magna. However, the Daphnia bioassays in Troup dugout water did not indicate enhanced toxicity to trifluralin. The high background toxicity of the dugout water to Daphnia magna reduced the utility of this bioassay and may have masked the effect of trifluralin on native zooplankton. Daphnia magna may not be the best zooplankton for this bioassay. Sanders (1970) found the LC_{50} for Daphnia magna to treflan to be 560 µg/L. Naqvi et al. (1985) observed treflan LC_{50} values of 50 to 80 µg/L for four species of zooplankton isolated from a freshwater pond. The effects of trifluralin on zooplankton grazing and eutrophication need clarification. Trifluralin may impair water quality by reducing zooplankton grazing.

5 References

American Water Works Association (AWWA). 1971. Water Quality and Treatment. A Handbook of Public Water Supplies. Third ed., McGraw-Hill Co., New York.

Burnison, B.K. 1980. Modified dimethyl sulfoxide (DMSO) extraction for chlorophyll analysis of phytoplankton. Can. J. Fish. Aq. Sci. 37:729-733.

Carey, J.H., J.D. Fitzsimons, M.E. Fox, K.L.E. Kaiser, R.J. Maguire, and W.M.J. Strachan. 1978. Assessment of the environmental distribution and toxicity of the herbicide trifluralin. Canada Center for Inland Waters Report, Burlington, Ontario.

Environment Canada. 1979. Analytical Methods Manual. Inland Water Directorate. Water Quality Branch, Ottawa, Canada.

Fisheries and Environment Canada. 1978. Hydrological Atlas of Canada. Supply and Services, Ottawa, Canada. 34 maps.

Helling, C.W. 1976. Dinitroaniline herbicides in soils. J. Environ. Qual. 5:1-15.

Kosinski, R.J., and M.G. Merkle. 1984. The effect of four terrestrial herbicides on the productivity of artificial stream algal communities. J. Environ. Qual. 13:75-82.

Lee, H.B., and A.S.Y. Chau. 1983a. Determination of trifluralin, diallate, triallate, atrazine, barban, diclofop-methyl and benzoylprop-ethyl in natural waters at ppt levels. J. Assoc. Off. Anal. Chem. 66(3).

Lee, H.B., and A.S.Y. Chau. 1983b. Gas chromatographic determination of trifluralin, diallate, triallate, atrazine, barban, diclofop-methyl and benzoylprop-ethyl in sediments at ppb levels. J. Assoc. Off. Anal. Chem. 66(6).

Mawhinney, M. 1987. Operating manual for common corers and grab samplers. National Water Research Institute, Burlington, Ontario.

Maguire, R.J. J.H. Carey, M.E. Fox, B.G. Brownlee, and H.B. Lee. 1988. Assessment of environmental dynamics of selected pesticides of importance in western Canada. National Water Research Institute Contribution No. 88-20.

Menzel, D.W., and N. Corwin. 1965. The measurement of total phosphorus in seawater based on liberation of organically bound fractions by persulfate oxidation. Limnol. Oceanogr. 10:280-282.

Murphy, T.P., E.E. Prepas, J.T. Lim, J.M. Crosby, and D.T. Walty. 1989. Evaluation of $CaCO_3$ and $Ca(OH)_2$ as algicides in prairie drinking water dugouts. National Water Research Institute Contribution No. 89-13.

Naqvi, A.M., V.O. Davis, and R.M. Hawkins. 1985. Percent mortalities and LC_{50} values for selected microcrustaceans exposed to treflan, citrine-plus, and MSDA herbicides. Bull. Environ. Contam. Toxicol. 35:127-132.

Prepas, E.E., and T.P. Murphy. 1988. Sediment-water interactions in farm dugouts previously treated with copper sulfate. Lake Reserv. Man. 4(1):161-168.

Prepas, E.E., T.P. Murphy, J.M. Babin, and J.T. Lim. 1989. Farm water dugouts, a manual on the use of lime to provide good water quality. National Water Research Institute Contribution No. 90-16.

Sanders, P.F. 1970. Toxicities of some herbicides to six species of freshwater crustaceans. J. Water Poll. Cont. Fed. 42:1544-1550.

Sanders, P.F., and J.N. Seiber. 1983. Pesticides from model soil and water disposal systems. Chemosphere 12:999-1012.

Smith, A.E. 1982. Herbicides and the soil environment in Canada. Can. J. Soil Sci. 62:433-460.

Smith, A.E., A.J. Aubin, and D.A. Derksen. 1988. Loss of trifluralin from clay and loam soils containing aged and freshly applied residues. Bull. Environ. Contam. Toxicol. 41:569-573.

Soderquist, C.J., D.G. Crosby, K.W. Moilanen, J.N. Sieber, and J.E. Woodrow. 1975. Occurrence of trifluralin and its photoproducts in air. J. Agric. Fd. Chem. 23:304-309.

Table 1 Dugout size and location

Dugout	Lat.	Long.	Width	Length	Depth
Troup	56° 7′	117° 20′	19	63	2.7
Desrosier	56° 1′	117° 20′	20	66	1.8

*Lat. is latitude, long. is longitude, width length and depth in meters. Volume estimates for Desrosier and Troup assumed loss of volume of 20% and 10%, respectively, for side slopes.

Table 2 Trifluralin recovery from polyethylene and glass bottles

Trifluralin μg/l	% Recovery polyethylene	% Recovery glass
15	4	96
150	6	107
1960	15	53

Table 3 Effect of acid on recovery of trifluralin

Trifluralin µg/L	% recovery acidified	% recovery neutral
260	96	76
500	104	73
1000	77	49

TABLE 4: TRIFLURALIN CONCENTRATIONS IN ALBERTA DUGOUTS

DESROSIERS DUGOUT (ug/L)

DAY AFTER LIMING	WHOLE WATER 1m		SUSPENDED SOLIDS		FILTERED WATER		SUSP. SOLIDS & FILT. WATER		SURFACE FILM	
	Control	Limed	Control	Limed	Control	Limed	Control	Limed	Control	Limed
0	<1		---		---		---		---	
1	360	244								
2	186	190		185		120		305	0.32	0.64
6	218	80	194	46	114	124	308	170	0.55	0.34
13	48								<0.01	<0.01
26	12	5							0.05	0.02
47	1	<1							0.05	0.06
78	0.3	0.3							<0.01	<0.01

TROUP DUGOUT (ug/L)

DAY AFTER LIMING	WHOLE WATER 1m		WHOLE WATER 2.5m		SUSPENDED SOLIDS		FILTERED WATER		SUSP. SOLIDS & FILT. WATER		SURFACE FILM	
	Control	Limed	Control	Limed	Control	Limed	Control	Limed	Control	Limed	Control	Limed
0	<1		<1		---		---		---		---	
1	285	299	126	380								
2	159	196	48	396		186		142		328	0.97	1.05
6	184	432	80	202	122	67	120	135	242	202	0.81	0.55
13	50	37	3	12							0.04	0.16
26	6	13	2	1							0.10	0.06
47	<1	<1	<1	1							<0.01	<0.01
78	0.1	0.1	<0.1	<0.1							<0.01	<0.01

TABLE 5: WATER QUALITY - 1989 - TRIFLURALIN TREATED DUGOUTS

	DATE	TREATMENT	TKN mg/L	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	Cl mg/L	SiO2 mg/L	SO4 mg/L
TROUP 1 - 1m	June 27	PRE	3.001	35.3	8.5	41.2	3.37	10.1	4.63	37.4
- 2.5m			1.421	46.6	10.9	44.1	3.67	10.2	8.62	31.6
DESROS.PRETREAT.			1.648	21.3	25.0	1.48	50.70	4.1	1.04	11.6
DESROS. 2 L	June 27	TREFLAN	1.749	21.1	24.9	1.29	50.50	3.9	1.10	10.1
2 C		ADDED TO	1.448	21.2	24.7	1.25	50.50	3.8	1.06	9.5
TROUP 2 L-1m		ALL 4 SIDES	3.371	38.3	9.0	41.9	3.58	10.1	5.47	37.2
-2.5m			2.679	39.1	9.2	42.7	3.48	10.2	6.16	36.7
TROUP 2 C-1m			2.754	35.3	8.3	41.7	3.35	10.1	4.56	37.6
-2.5m			1.726	44.9	10.5	43.5	3.58	10.2	7.74	33.0
DESROS. 3 L	June 28	BEFORE	1.484	21.3	24.9	1.57	50.20	4.1	1.14	11.3
3 C		LIMING	1.526	21.1	25.1	1.28	50.00	3.9	1.14	9.9
TROUP 3 L-1m			2.688	36.6	8.7	41.4	3.51	10.1	4.91	36.1
-2.5m			4.702	40.5	9.6	42.9	3.53	10.2	6.61	37.0
TROUP 3 C-1m			2.888	35.2	8.2	41.7	3.35	10.2	4.96	37.4
-2.5m			7.983	45.0	10.7	44.1	3.65	10.2	8.51	34.2
TROUP 4 L-1m	June 29	AFTER	3.006	47.4	4.1	39.0	3.46	10.2	3.52	36.4
-2.5m		LIMING	4.300	41.8	11.0	43.0	3.48	10.2	5.98	36.4
TROUP 4 C-1m		ONE SIDE	2.407	36.4	8.5	42.0	3.53	10.2	4.75	38.1
-2.5m		OF EACH	6.354	43.5	10.5	43.5	3.58	10.4	7.67	37.1
DESROS. 4 L		DUGOUT	1.195	11.7	12.7	1.82	50.00	4.2	1.37	10.9
4 C			1.397	21.2	25.0	1.32	50.50	4.0	0.96	10.4
TROUP 5 L-1m	July 5		2.202	27.3	2.0	40.8	3.58	10.1	4.68	34.1
-2.5m			5.327	49.4	13.6	43.3	3.67	10.6	6.84	33.4
TROUP 5 C-1m			1.961	35.7	8.4	42.1	3.37	10.4	4.54	37.2
-2.5m			4.937	44.3	10.9	43.6	3.65	10.4	7.69	30.9
DESROS. 5 L			1.701	12.0	12.0	1.98	49.80	4.6	1.47	10.5
5 C			1.333	18.5	24.9	0.99	50.20	3.8	1.32	9.9
TROUP 6 L-1m	July 12		1.839	30.8	2.0	42.1	3.49	10.4	4.77	35.9
-2.5m			5.675	50.5	17.1	45	3.71	10.5	7.46	29
TROUP 6 C-1m			1.912	36.2	8.2	42.6	3.42	10.3	4.55	35.8
-2.5m			5.334	45.4	10.6	44	3.6	10.4	7.75	27.2
DESROS. 6 L			1.884	12.3	13.9	1.92	51.6	4.8	0.99	10.1
6 C			1.503	17.7	23.2	0.92	51.6	4	1.78	10.5
TROUP 7 L-1m	July 25		1.719	29	2.8	42.4	3.55	10.6	5.87	34.1
-2m			4.52	45.8	13.1	44.2	3.61	10.5	7.14	27.7
TROUP 7 C-1m			1.363	35.3	8.3	43.5	3.46	10.5	4.88	34.4
-2m			5.009	43	10.3	43.3	3.55	10.4	7.72	23.9
DESROS. 7 L			2.022	13.9	17.4	2.05	53.4	5.4	2.38	10.1
7 C			1.723	17.5	22.6	0.86	52.6	3.9	2.4	8.8
TROUP 8 C-1m	August 18		2.33	32.7	7.6	42.4	3.39	10.5	3.79	30.3
-2m			3.85	40	9.8	43.9	3.51	10.6	7.16	21.2
DESROS. 8 L			3.15	16.3	19.8	2.06	54.4	5.4	3.34	6.2
DESROS. 8 C			3.93	18.1	23	1.17	53.5	4.5	1.62	5
TROUP 8 L-1m			1.52	30.4	4.3	42.1	3.57	10.6	6.48	28.7
-2m			6.99	46.8	16.2	45.6	3.71	10.9	8.83	16.9

TABLE 5 CONT.: WATER QUALITY - 1989 - TRIFLURALIN TREATED DUGOUTS

	DATE	TREATMENT	DIC mg/L	DOC mg/L	POC mg/L	PON mg/L	Fe mg/L	Mn mg/L	Cd ug/L	Co ug/L
TROUP 1 - 1m	June 27	PRE	33.1	16.9	2.98	0.48	0.81	0.222	0.4	1.1
- 2.5m			52.5	16.7	10.70	1.65	10.80	0.883	0.5	3.4
DESROS.PRETREAT.			55.4	21.2	1.02	0.22	0.29	0.031	0.4	0.9
DESROS. 2 L	June 27	TREFLAN	58.6	21.8	1.59	0.30	0.69	0.049	0.3	1.0
2 C		ADDED TO	51.4	21.6	0.89	0.02	0.41	0.037	0.3	0.9
TROUP 2 L-1m		ALL 4 SIDES	37.2	17.6	5.32	0.19	2.19	0.181	0.3	1.3
-2.5m			38.7	16.9	6.16	0.79	2.61	0.532	0.3	2.1
TROUP 2 C-1m			32.4	15.7	7.47	1.50	0.65	0.091	0.3	0.9
-2.5m			47.6	16.7	9.74	1.42	5.64	0.786	0.4	2.4
DESROS. 3 L	June 28	BEFORE	59.4	22.2	1.59	0.44	0.66	0.049	0.3	1.0
3 C		LIMING	56.8	22.7	0.79	0.20	0.43	0.037	0.3	0.8
TROUP 3 L-1m			34.5	17.2	4.31	0.82	1.57	0.236	0.3	1.0
-2.5m			38.5	17.1	6.23	1.46	3.22	0.499	0.3	1.1
TROUP 3 C-1m			31.6	15.9	3.15	0.30	0.75	0.151	0.3	<0.5
-2.5m			47.5	17.6	9.34	1.15	5.60	0.803	0.3	1.7
TROUP 4 L-1m	June 29	AFTER	10.4	14.0	3.84	0.60	0.88	0.111	0.3	0.8
-2.5m		LIMING	25.1	15.7	5.88	0.84	2.81	0.258	0.3	1.4
TROUP 4 C-1m		ONE SIDE	32.7	16.8	3.32	0.10	0.83	0.171	0.3	0.7
-2.5m		OF EACH	41.1	15.7	7.06	0.97	5.97	0.826	0.4	1.9
DESROS. 4 L		DUGOUT	19.7	18.1	1.34	0.20	0.22	0.018	0.2	<0.5
4 C			50.1	21.9	2.17	0.30	1.06	0.056	0.2	1.5
TROUP 5 L-1m	July 5		6.3	13.0	1.29	0.61	0.34	0.036	0.3	<0.5
-2.5m			47.9	16.4	8.36	2.52	5.94	0.655	0.3	2.8
TROUP 5 C-1m			32.8	15.9	3.88	1.37	0.37	0.093	0.2	0.7
-2.5m			52.0	17.3	5.80	1.81	5.94	0.794	0.3	2.0
DESROS. 5 L			29.4	19.9	0.54	0.19	0.06	0.01	0.3	<0.5
5 C			49.1	23.1	0.57	0.18	0.12	0.03	0.3	<0.5
TROUP 6 L-1m	July 12		18.6	13.5	2.24	0.678	0.232	0.023	0.3	<0.5
-2.5m			65.4	18.9	10.10	2.39	4.73	0.64	0.3	1.5
TROUP 6 C-1m			34.1	13.3	3.57	0.908	0.451	0.09	0.3	<0.5
-2.5m			52.3	17	10.40	2.35	7.01	0.884	0.3	1.7
DESROS. 6 L			33.1	21.5	2.50	0.784	0.085	0.018	0.3	<0.5
6 C			44.3	22	1.93	0.48	0.102	0.029	0.2	<0.5
TROUP 7 L-1m	July 25		16.7	14	4.46	1.21	0.15	0.018	0.3	<0.5
-2m			47.9	17.2	12.50	2.77	2.12	0.45	0.5	1.3
TROUP 7 C-1m			30.8	14.8	3.55	0.956	0.42	0.122	0.3	0.8
-2m			46.8	16.5	10.60	2.25	3.42	1	0.3	0.8
DESROS. 7 L			40.9	26	0.39	0.129	0.119	0.052	0.6	1.3
7 C			46.8	25.5	2.17	0.582	0.262	0.046	0.9	1.6
TROUP 8 C-1m	August 18		21.6	15.4			0.227	0.03	0.7	0.8
-2m			41.1	17			1.22	0.851	0.5	0.7
DESROS. 8 L			45.5	27.1			0.305	0.114	0.5	0.9
DESROS. 8 C			47.2	26.4			0.175	0.06	0.3	<0.5
TROUP 8 L-1m			23.2	16			0.272	0.013	0.3	0.7
-2m			53.5	19.4			1.23	0.633	0.3	0.8

TABLE 5 CONT.: WATER QUALITY - 1989 - TRIFLURALIN TREATED DUGOUTS

	DATE	TREATMENT	Cu ug/L	Ni ug/L	Pb ug/L	Zn ug/L	Hg ug/L	C mg/L	N mg/L
TROUP 1 - 1m	June 27	PRE	11.2	10.4	<0.7	2.9	<0.01	2.98	0.48
- 2.5m			13.6	1.9	2.2	8.3	0.01	10.7	1.65
DESROS.PRETREAT.			4.3	6.4	2.4	3	<0.01	1.02	0.22
DESROS. 2 L	June 27	TREFLAN	10.8	6.3	1.5	4.9	<0.01	1.59	0.3
2 C		ADDED TO	14.7	4.1	0.9	3.3	<0.01	0.89	0.02
TROUP 2 L-1m		ALL 4 SIDES	11.8	4.7	1.3	4.8	<0.01	5.32	0.19
-2.5m			24.5	6.6	1.9	6.2	<0.01	6.16	0.79
TROUP 2 C-1m			10.1	4.1	1.4	2.2	<0.01	7.47	1.5
-2.5m			18.2	6	2.4	6.6	<0.01	9.74	1.42
DESROS. 3 L	June 28	BEFORE	18.5	5.1	1.7	5	0.02	1.59	0.44
3 C		LIMING	11.0	4.4	1.2	3.1	<0.01	0.79	0.2
TROUP 3 L-1m			11.4	3.8	1.1	4.6	0.01	4.31	0.82
-2.5m			8.1	3.9	2.2	4.9	0.02	6.23	1.46
TROUP 3 C-1m			9.2	2.6	1.3	2.2	0.04	3.15	0.3
-2.5m			5.4	4.5	1.6	4.9	<0.01	9.34	1.15
TROUP 4 L-1m	June 29	AFTER	11.5	2.5	1.1	3.7	<0.01	3.84	0.6
-2.5m		LIMING	10.6	4.4	1.5	4.2	0.01	5.88	0.84
TROUP 4 C-1m		ONE SIDE	10.5	3.1	2.8	3.3	<0.01	3.32	0.1
-2.5m		OF EACH	5.9	4.3	4.1	4.9	<0.01	7.06	0.97
DESROS. 4 L		DUGOUT	5.1	2.7	0.8	2	0.01	1.34	0.2
4 C			9.5	5.3	2.8	7.1	<0.01	2.17	0.3
TROUP 5 L-1m	July 5		2.7	2.3	2.1	2.3	<0.01	1.29	0.61
-2.5m			10.9	7	2.3	6.6	0.03	8.36	2.52
TROUP 5 C-1m			4.6	3.1	0.9	1.3	<0.01	3.88	1.37
-2.5m			9.2	4.3	1.5	2.9	<0.01	5.8	1.81
DESROS. 5 L			9.9	2.9	3	3	0.01	0.54	0.19
5 C			7.8	2.9	1.2	2	0.01	0.57	0.18
TROUP 6 L-1m	July 12		5.8	6.2	1.2	4.2	0.02	2.24	0.68
-2.5m			5.3	6.5	2	3.3	<0.01	10.1	2.39
TROUP 6 C-1m			3.8	3.6	1	1.8	0.01	3.57	0.91
-2.5m			3.7	4.6	1.4	3.5	0.01	10.4	2.35
DESROS. 6 L			5.4	3.5	<0.7	2.1	0.02	2.5	0.78
6 C			2.9	2.9	0.8	1.4	<0.01	1.93	0.48
TROUP 7 L-1m	July 25		7.9	4.2	1.5	5.2	<0.01	4.46	1.21
-2m			18.7	3.4	1.8	5.1	0.02	12.5	2.77
TROUP 7 C-1m			10.7	4.7	2	2.7	<0.01	3.55	0.96
-2m			3.2	3.2	<0.7	3.4	<0.01	10.6	2.25
DESROS. 7 L			4.1	3.9	1.2	4.6	<0.01		
7 C			12.2	4.4	3.1	4.4	<0.01		
TROUP 8 C-1m	August 18		11.7	4.4	2.5	6.7	<0.01	1.72	0.27
-2m			17.6	4.9	3	7.5	0.02	9.11	1.55
DESROS. 8 L			15.6	4.8	0.8	4.5	0.02	9.77	1.87
DESROS. 8 C			14.6	3.4	<0.7	2.1	<0.01	4.57	0.75
TROUP 8 L-1m			11.7	3.2	1.4	4.7	0.04	3.03	0.48
-2m			5	3.4	0.9	6.9	0.02	19.5	3.98

TABLE 6: PEACE RIVER DUGOUTS, SUMMER 1989

(water samples obtained from 1 m except where noted)

DESROSIER	May 4	May 24	June 6	June 12	June 27 (D1)	June 27 (D2C)	June 27 (D2L)	June 28 (D3C)	June 28 (D3L)	June 29 (D4C)	June 29 (D4L)	July 5 (D5C)
Temp. (C)												
Surface	10.3	14.0	17.0	---	15.5	---	12.0	---	---	---	---	19.3
TP (ug/L)	237	137	116	85.8	160	159	187	228	246	198	95.0	118
TDP (ug/L)	32.1	37.4	32.6	47.9	127	137	119	182	192	108	42.1	90.4
Chla (ug/L)	16.2	13.6	14.9	3.57	2.58	3.54	4.03	3.51	3.97	---	---	4.22
Secchi depth (m)	0.30	0.40	0.90	---	1.10	---	---	---	---	0.50	0.25	1.60
Color (mg/L as pt)	25.0	30.0	25.0	---	25.0	25.0	25.0	25.0	30.0	30.0	20.0	25.0
Turbidity (NTU)	18.5	8.05	7.75	---	5.65	8.25	18.0	9.33	18.3	33.5	23.5	3.60
Cond. (uS/cm)	560	599	470	580	560	455	485	500	512	503	470	530
pH	7.79	8.22	8.46	8.86	9.19	8.90	8.89	9.18	9.06	9.12	10.1	9.60
Tot. Alkalinity (mg/L as CaCO3)	246	332	260	261	281	290	283	276	275	282	207	264
Carbonate (mg/L)	0.00	0.00	2.64	18.5	44.4	40.1	44.1	41.7	33.2	37.7	100	65.3
Bicarbonate (mg/L)	299	405	311	281	253	272	255	252	268	268	48.4	189
NO2 + NO3 (ug/L)	18.4	3.3	5.1	10.2	33.3	34.2	35.3	25.4	26.7	24.0	23.0	1.1
NH4+ (ug/L)	137	76.4	98.3	53.1	90.6	61.3	103	88.7	152	153	70.0	5.9
Sodium (mg/L)	40.2	45.2	46.4	---	33.2	---	---	---	---	---	---	---
Potassium (mg/L)	2.60	2.76	2.19	---	1.19	---	---	---	---	---	---	---
Calcium (mg/L)	26.4	29.8	29.3	---	21.7	---	---	---	---	---	---	---
Magnesium (mg/L)	21.7	20.5	24.0	---	28.9	---	---	---	---	---	---	---
TDS (mg/L)	270	356	328	---	---	---	---	---	---	---	---	---
NFR (mg/L)	28.4	8.20	10.2	---	---	---	---	---	---	---	---	---

TABLE 6 CONT.: PEACE RIVER DUGOUTS, SUMMER 1989
(water samples obtained from 1 m except where noted)

DESROSIER CONT.	July 5 (D5L)	July 12 (D6C)	July 12 (D6L)	July 25 (D7C)	July 25 (D7L)	Aug 17 (D8C)	Aug 17 (D8L)	Sept 7[a] (D9C)	Sept 7[a] (D9L)	Sept 26 (D10C)	Sept 26 (D10L)
Temp. (C)											
Surface	19.0	22.2	22.0	20.5	18.5	20.0	20.0	13.0	13.0	---	---
TP (ug/L)	98.4	161	123	376	381	477	595	329	499	332	433
TDP (ug/L)	73.4	115	79.6	311	250	288	392	192	334	117	303
Chla (ug/L)	1.27	5.84	10.1	12.3	29.6	73.0	61.6	41.9	39.2	37.7	41.1
Secchi depth (m)	1.45	0.90	1.00	0.45	0.50	0.20	0.20	0.55	0.40	0.60	0.45
Color (mg/L as pt)	20.0	40.0	40.0	50.0	60.0	60.0	65.0	50.0	30.0	50.0	40.0
Turbidity (NTU)	3.50	5.33	3.83	8.15	5.75	5.90	8.00	3.25	5.90	5.00	9.40
Cond. (uS/cm)	450	440	385	412	380	530	550	541	539	525	520
pH	10.1	9.74	9.89	9.57	9.49	9.48	9.26	9.45	8.65	9.26	8.74
Tot. Alkalinity (mg/L as CaCO3)	191	256	202	231	212	252	233	252	230	251	233
Carbonate (mg/L)	81.3	79.0	78.5	57.0	45.2	55.3	33.7	67.1	12.6	44.7	24.1
Bicarbonate (mg/L)	67.1	151	86.3	166	161	195	215	171	255	215	235
NO2 + NO3 (ug/L)	10.6	6.6	6.0	27.0	8.8	16.2	18.4	8.1	8.9	4.2	9.8
NH4+ (ug/L)	274	0.2	3.9	112	22.5	590	24.8	377	473	125	302
Sodium (mg/L)	---	44.1	38.9	25.0	24.2	55.6	50.6	41.7	54.6	54.7	53.6
Potassium (mg/L)	---	0.58	1.69	0.79	1.88	1.12	2.18	1.54	2.00	1.31	1.48
Calcium (mg/L)	---	17.5	11.8	16.6	29.2	19.8	18.0	22.7	20.3	21.4	20.7
Magnesium (mg/L)	---	25.8	13.1	23.8	12.5	27.4	21.3	26.1	22.3	24.7	20.8
TDS (mg/L)	---	272	166	---	244	327	282	279	331	294	320
NFR (mg/L)	---	11.3	8.50	9.09	14.8	6.25	25.9	6.51	7.50	6.11	18.0

TABLE 6: PEACE RIVER DUGOUTS (continued)

TROUP	May 4*	May 24*	June 6*	June 12	June 27 (T1)	June 27 (T2C)	June 27 (T2L)	June 28 (T3C)	June 28 (T3L)	June 29 (T4C)	June 29 (T4L)	July 5 (T5C)
Temp. (C)												
0.0 m	10.6	13.2	19.0	---	16.5	---	---	---	---	---	---	22.0
DO (mg/L)												
1.0 m	0.48	---	---	---	---	---	---	---	---	---	---	---
TP (ug/L)												
1.0 m	507	820	663	705	364	363	442	459	445	360	296	270
2.5 m				1763	2620	2027	2583	2968	1462	1362	900	2061
TDP (ug/L)												
1.0 m	413	618	556	491	150	206	299	250	370	198	53.8	120
2.5 m				791	269	333	393	901	251	262	237	273
Chla (ug/L)												
1.0 m	122	51.3	1.01	3.68	52.5	41.8	46.2	23.6	32.1	---	---	27.3
Secchi depth (m)	0.33	0.70	1.6	1.8	0.75	---	---	---	---	0.75	0.60	0.55
Color (mg/L as pt)												
1.0 m	120	100	100	---	50.0	55.0	70.0	60.0	50.0	55.0	25.0	50.0
2.5 m				---	60.0	70.0	70.0	60.0	70.0	70.0	70.0	70.0
Turbidity (NTU)												
1.0 m	6.80	5.25	5.13	---	5.70	4.45	15.3	5.53	9.73	5.40	15.3	6.25
2.5 m				---	24.5	27.5	26.0	30.0	21.0	26.5	33.0	26.0
Cond. (uS/cm)												
1.0 m	340	316	324	570	449	420	430	400	467	421	660	460
2.0 m				380	610	555	505	540	457	495	400	590
pH												
1.0 m	8.08	7.96	7.65	7.36	7.45	7.29	7.21	7.55	7.35	7.79	10.9	8.51
2.5 m				7.00	7.09	---	7.37	7.22	7.01	7.08	9.24	---
Tot. Alkalinity (mg/L as CaCO3)												
1.0 m	90.3	147	103	110	149	204	169	146	152	152	151	146
2.5 m				182	220	---	175	209	177	204	188	---
Carbonate (mg/L)												
1.0 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	79.8	3.24
2.5 m				0.00	0.00	---	0.00	0.00	0.00	0.00	49.5	---
Bicarbonate (mg/L)												
1.0 m	110	179	126	135	181	249	205	178	186	185	(70.8)	171
2.5 m				221	269	---	213	255	216	249	123	---

* Chemistry samples obtained from a 0-1 m composite sample

() indicates hydroxide form

TABLE 6: PEACE RIVER DUGOUTS (continued)

Troup (cont'd)	July 5 (T5L)	July 12 (T6C)	July 12 (T6L)	July 25 (T7C)	July 25 (T7L)	Aug 17 (T8C)	Aug 17 (T8L)	Sept 7* (T9C)	Sept 7* (T9L)	Sept 26* (T10C)	Sept 26* (T10L)
Temp. (C)											
0.0 m	21.0	19.8	20.0	20.0	19.5	21.5	21.0	14.0	14.0	---	---
DO (mg/L)											
1.0 m	---	---	---	---	---	---	---	---	---	---	---
TP (ug/L)											
1.0 m	166	292	201	329	311	354	361	641	684	627	303
2.5 m	1281	2441	1817	1318	1228	1094	1868				
TDP (ug/L)											
1.0 m	83.4	189	116	162	166	262	235	340	356	58.0	55.2
2.5 m	626	421	1158	722	938	861	1486				
Chla (ug/L)											
1.0 m	2.60	12.5	13.1	27.2	29.8	26.4	16.9	72.0	61.1	70.3	55.9
Secchi depth (m)	0.75	0.55	0.70	0.50	0.60	0.90	0.60	0.40	0.50	0.75	0.75
Color (mg/L as pt)											
1.0 m	20.0	60.0	25.0	55.0	50.0	100	80.0	50.0	45.0	40.0	40.0
2.5 m	70.0	75.0	100	90.0	80.0	80.0	120				
Turbidity (NTU)											
1.0 m	8.45	7.20	4.28	6.78	6.00	3.90	6.10	5.50	7.25	8.40	6.30
2.5 m	21.0	21.3	26.5	10.8	16.0	8.95	12.0				
Cond. (uS/cm)											
1.0 m	450	420	415	364	294	410	430	460	419	380	445
2.0 m	550	600	630	430	419	520	660				
pH											
1.0 m	10.3	8.58	9.91	9.03	9.64	9.56	9.12	8.13	7.82	7.50	7.84
2.5 m	---	7.54	7.94	7.68	8.57	7.39	7.55				
Tot. Alkalinity (mg/L as CaCO3)											
1.0 m	134	149	127	140	95.1	132	115	147	140	133	154
2.5 m	---	225	264	186	207	185	254				
Carbonate (mg/L)											
1.0 m	73.2	8.03	49.8	14.2	28.0	35.6	17.0	0.00	0.00	0.00	0.00
2.5 m	---	0.00	0.00	0.00	3.48	0.00	0.00				
Bicarbonate (mg/L)											
1.0 m	13.9	165	53.3	142	58.9	88.9	106	179	171	162	188
2.5 m	---	275	322	227	245	226	310				

* Chemistry samples obtained from composite 0-1 m samples

TABLE 6: PEACE RIVER DUGOUTS (continued)

Troup (cont'd)	May 4*	May 24*	June 6*	June 12	June 27 (T1)	June 27 (T2C)	June 27 (T2L)	June 28 (T3C)	June 28 (T3L)	June 29 (T4C)	June 29 (T4L)	July 5 (T5C)
NO2 + NO3 (ug/L)												
1.0 m	1327	4.4	37.5	46.3	23.3	28.1	23.7	15.0	12.3	13.7	16.1	9.90
2.5 m				9.40	22.4	26.2	24.0	15.1	16.3	14.6	11.5	1.00
NH4+ (ug/L)												
1.0 m	971	271	452	626	929	792	2562	728	1326	804	1222	116
2.5 m				3366	6895	5096	3129	4854	2527	4278	3069	7084
Sodium (mg/L)												
1.0 m	3.23	1.51	1.86	---	2.36	---	---	---	---	---	---	---
2.5 m				---	---	---	---	---	---	---	---	---
Potassium (mg/L)												
1.0 m	39.1	36.8	40.3	---	40.5	---	---	---	---	---	---	---
2.5 m				---	---	---	---	---	---	---	---	---
Calcium (mg/L)												
1.0 m	22.1	26.3	26.4	---	39.9	---	---	---	---	---	---	---
2.5 m				---	---	---	---	---	---	---	---	---
Magnesium (mg/L)												
1.0 m	6.21	7.03	5.83	---	10.0	---	---	---	---	---	---	---
2.5 m				---	---	---	---	---	---	---	---	---
TDS (mg/L)												
1.0 m	212	222	243	---	---	---	---	---	---	---	---	---
2.5 m				---	---	---	---	---	---	---	---	---
NFR (mg/L)												
1.0 m	12.5	0.600	4.00	---	---	---	---	---	---	---	---	---
2.5 m				---	---	---	---	---	---	---	---	---
Iron (mg/L)												
1.0 m	---	---	---	---	---	---	---	---	---	---	---	---
2.0 m	---	---	---	---	---	---	---	---	---	---	---	---

* Chemistry samples obtained from composite 0-1 m samples

TABLE 6: PEACE RIVER DUGOUTS (continued)

Troup (cont'd)	July 5 (T5L)	July 12 (T6C)	July 12 (T6L)	July 25 (T7C)	July 25 (T7L)	Aug 17 (T8C)	Aug 17 (T8L)	Sept 7* (T9C)	Sept 7* (T9L)	Sept 26* (T10C)	Sept 26* (T10L)
NO2 + NO3 (ug/L)											
1.0 m	51.9	9.70	26.9	11.7	11.4	25.8	12.5	9.1	6.7	4.8	3.1
2.5 m	15.2	6.60	7.70	10.5	18.1	13.8	15.3				
NH4+ (ug/L)											
1.0 m	1379	174	2160	5406	106	187	59.6	1096	948	142	260
2.5 m	8536	6454	8784	169	4008	1914	7152				
Sodium (mg/L)											
1.0 m	---	3.47	3.55	2.51	2.64	2.37	2.54	4.46	5.35	2.43	2.51
2.5 m	---	4.11	3.83	2.83	3.14	2.54	2.81				
Potassium (mg/L)											
1.0 m	---	42.0	43.3	28.4	40.4	40.2	40.4	18.3	12.7	20.4	43.7
2.5 m	---	41.8	46.6	39.1	36.5	38.7	38.6				
Calcium (mg/L)											
1.0 m	---	33.8	38.3	35.4	27.9	33.8	24.4	38.5	25.7	32.9	39.0
2.5 m	---	44.8	49.2	49.3	43.1	31.5	52.6				
Magnesium (mg/L)											
1.0 m	---	6.96	1.64	7.91	2.58	7.62	4.12	6.78	7.46	8.12	8.74
2.5 m	---	9.48	17.0	6.95	10.3	9.03	17.9				
TDS (mg/L)											
1.0 m	---	239	250	312	177	232	244	247	258	249	251
2.0 m	---	248	321	248	468	180	335				
NFR (mg/L)											
1.0 m	---	18.0	13.8	7.50	10.4	2.60	0.00	6.60	8.60	2.60	14.2
2.0 m	---	62.0	70.0	31.9	33.3	1.80	26.5				
Iron (mg/L)											
1.0 m	---	---	---	---	---	---	---	---	---	0.579	0.342
2.0 m	---	---	---	---	---	---	---	---	---	---	---

TABLE 7: TRIGLURALIN IN THE SEDIMENTS

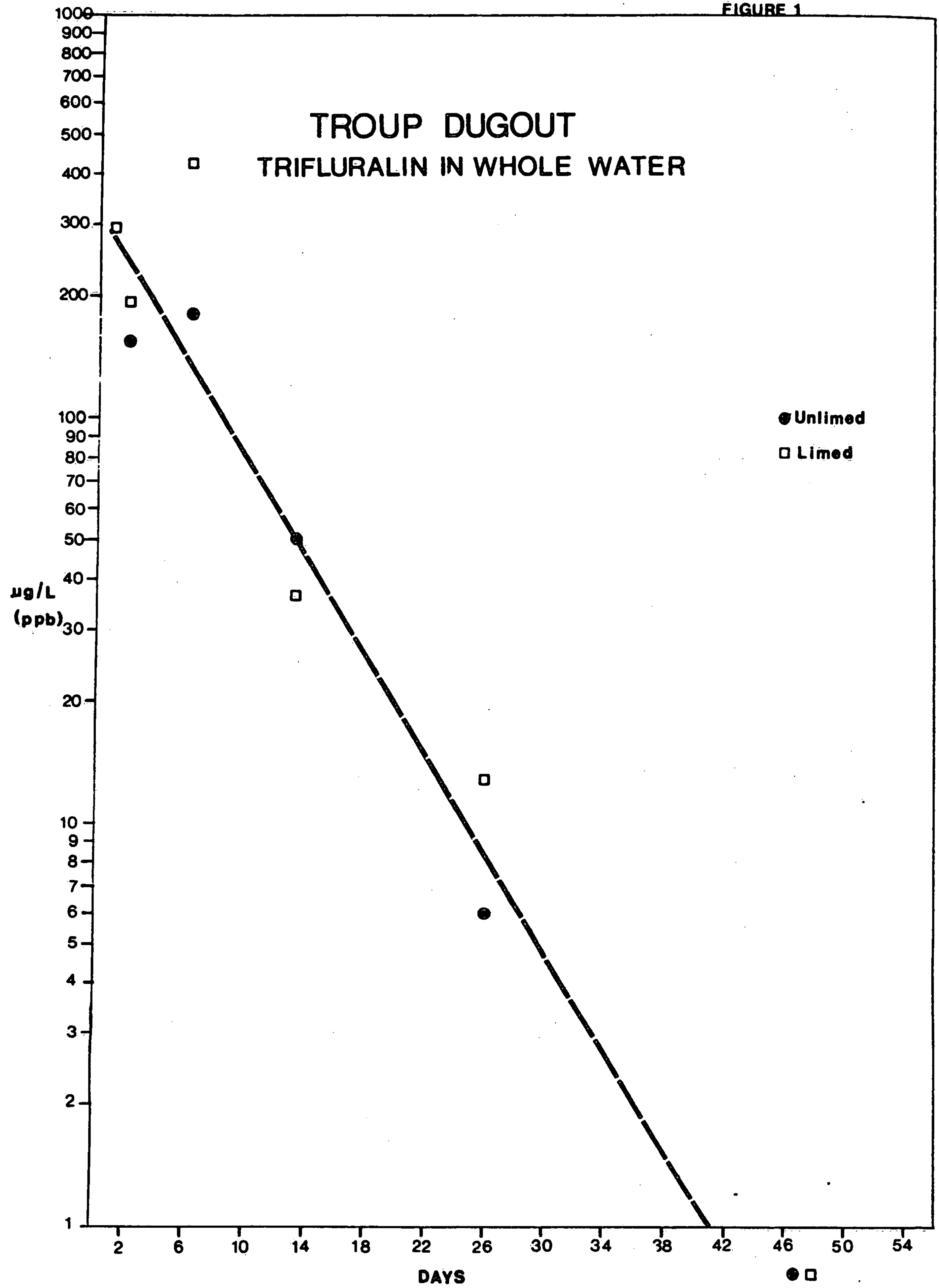
DUGOUT	TREATM.	DEPTH (cm)	#	DRY WT. (g)	TRF (ng/g)	DEG. PROD. *
Des.	control	0-1	1	11.19	<1	+
			2	8.46	<1	+
Des.	lime	0-1	1	7.96	<1	+
			2	6.13	<1	+
Des.	control	5-6	1	8.38	nd	−
			2	5.79	<1	+
Des.	lime	5-6	1	8.94	nd	+
			2	7.41	nd	−
Troup	control	0-1	1	8.12	<1	+
			2	5.36	<1	+
Troup	lime	0-1	1	3.34	<1	+
			2	6.90	<1	+
Troup	control	5-6	1	8.36	nd	+
			2	4.67	nd	+
Troup	lime	5-6	1	8.17	nd	+
			2	9.93	nd	−

* Quantitation not possible at present; estimated at 0-1 ng/g.
DEG. PROD. - Degradation product

TABLE 8: MICROTOX - ALBERTA DUGOUTS, TROUP AND DESROSIERS

Sample	Day of Expt.	MICROTOX # reps.	% of cont.	S.D.
T1-1m	1	4	86	1
T2L-1m	2	4	71	4.4
T3L-1m	3	4	60	1.7
T4L-1m	4	4	130	12
T5L-1m	5	8	92	15
T6L-1m	6			
T7L-1m	7			
T1-1m	1	4	86	1
T2C-1m	2	4	70	2.5
T3C-1m	3	8	73	10
T4C-1m	4	8	137	26
T5C-1m	5	4	155	19
T6C-1m	6			
T7C-1m	7			
T1-2.5m	1	8	84	13
T2L-2.5m	2	4	67	6.7
T3L-2.5m	3	7	62	7.3
T4L-2.5m	4	4	104	15
T5L-2.5m	5	4	73	3.2
T6L-2.5m	6			
T7L-2.5m	7			
T1-2.5m	1	8	84	13
T2C-2.5m	2	6	93	8.6
T3C-2.5m	3	8	71	29
T4C-2.5m	4	4	86	12
T5C-2.5m	5			
T6C-2.5m	6			
T7C-2.5m	7			
D1	1	4	71	10
D2C	2	4	46	2.6
D3C	3	4	42	2.6
D4C	4	4	130	13
D5C	5	8	154	26
D6C	6			
D7C	7			
D1	1	4	71	10
D2L	2	4	58	4.4
D3L	3	7	47	9.2
D4L	4	4	119	7
D5L	5			
D6L	6			
D7L	7			

FIGURE 1



TROUP DUGOUT
TRIFLURALIN IN WHOLE WATER
Unlimed
Limed
µg/L
(ppb)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
2
6
10
14
18
22
26
30
34
38
42
46
50
54
DAYS

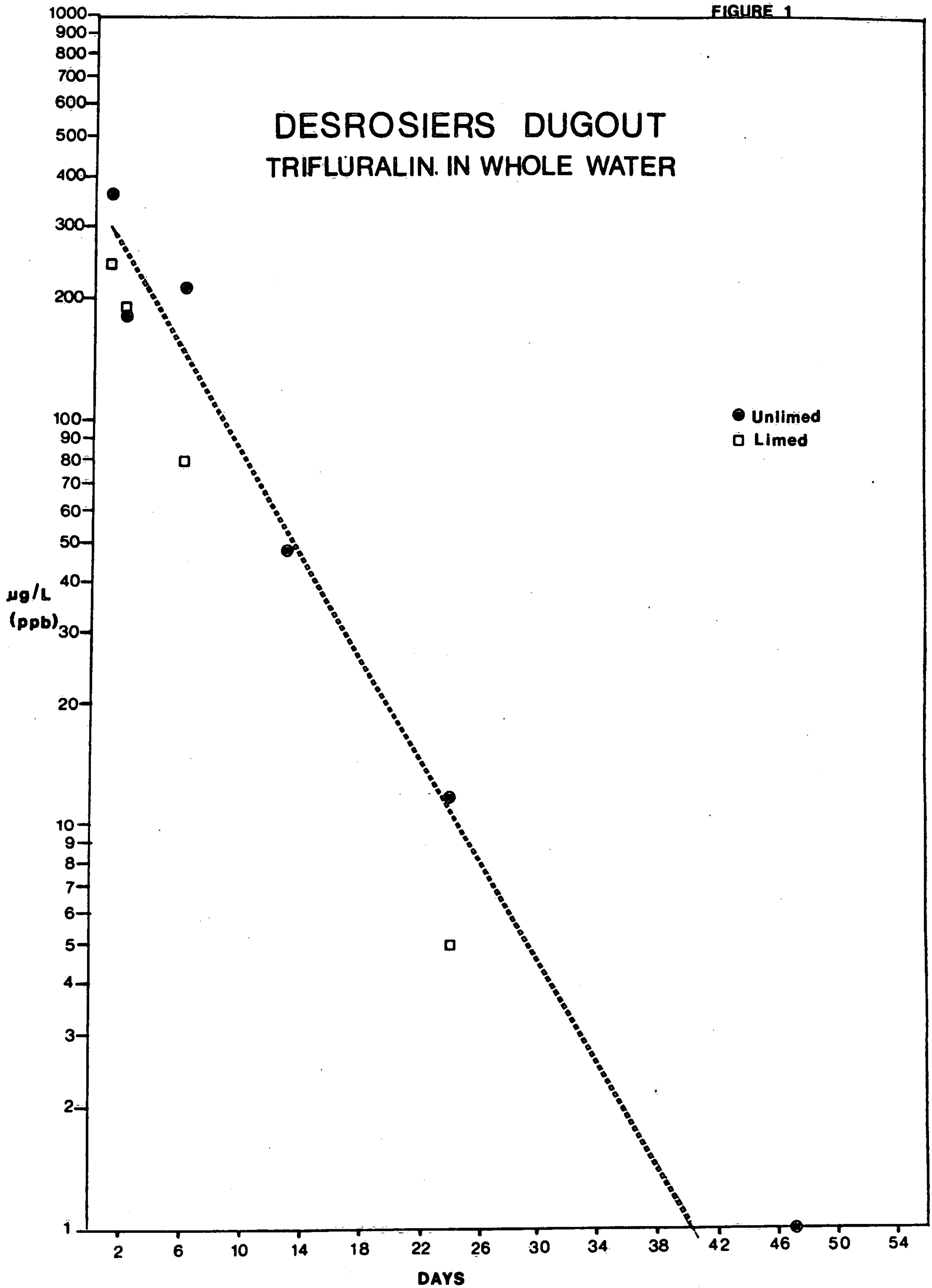


FIGURE 1
DESROSIERS DUGOUT
TRIFLURALIN IN WHOLE WATER
Unlimed
Limed
µg/L
(ppb)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
2
6
10
14
18
22
26
30
34
38
42
46
50
54
DAYS

FIGURE 2

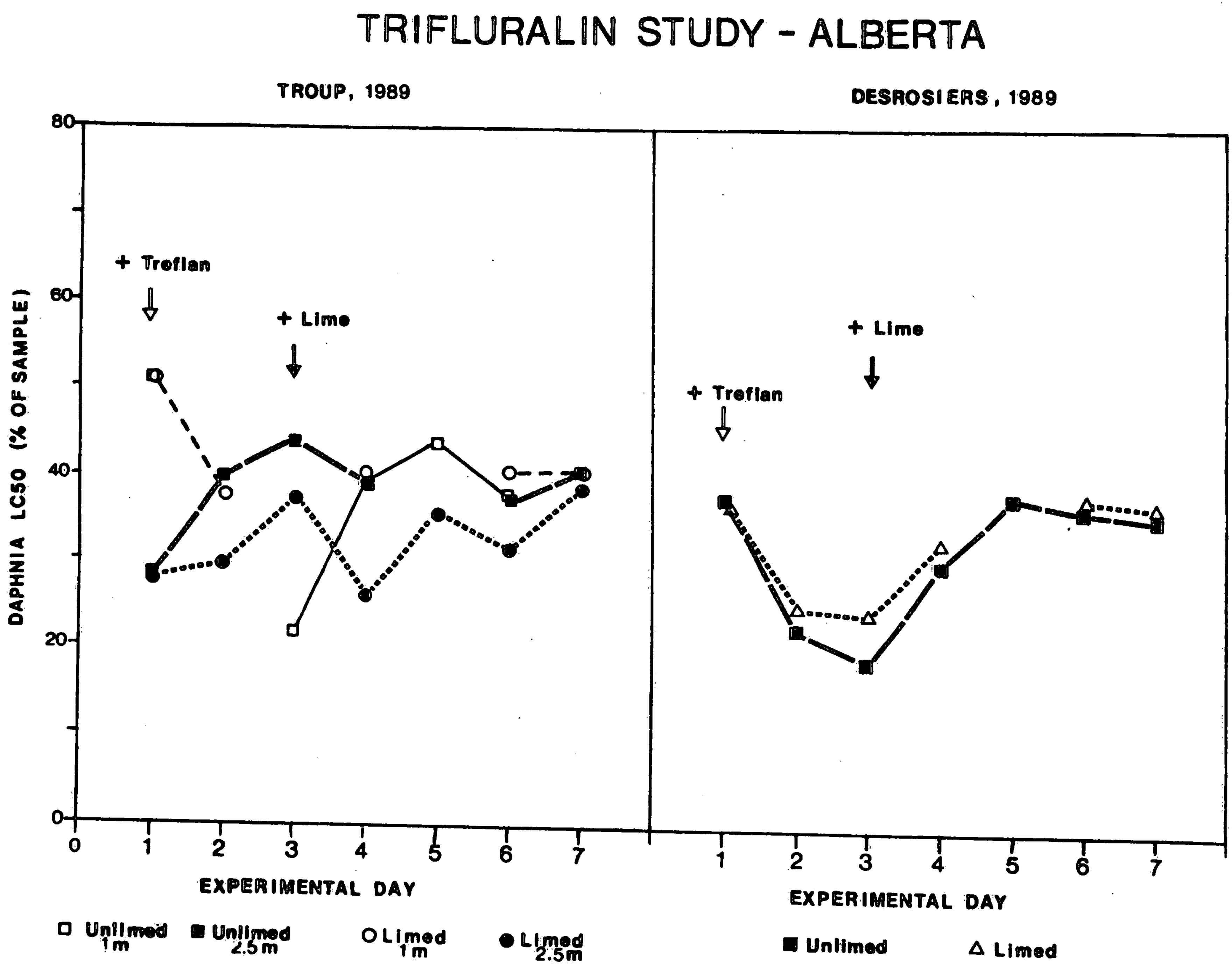
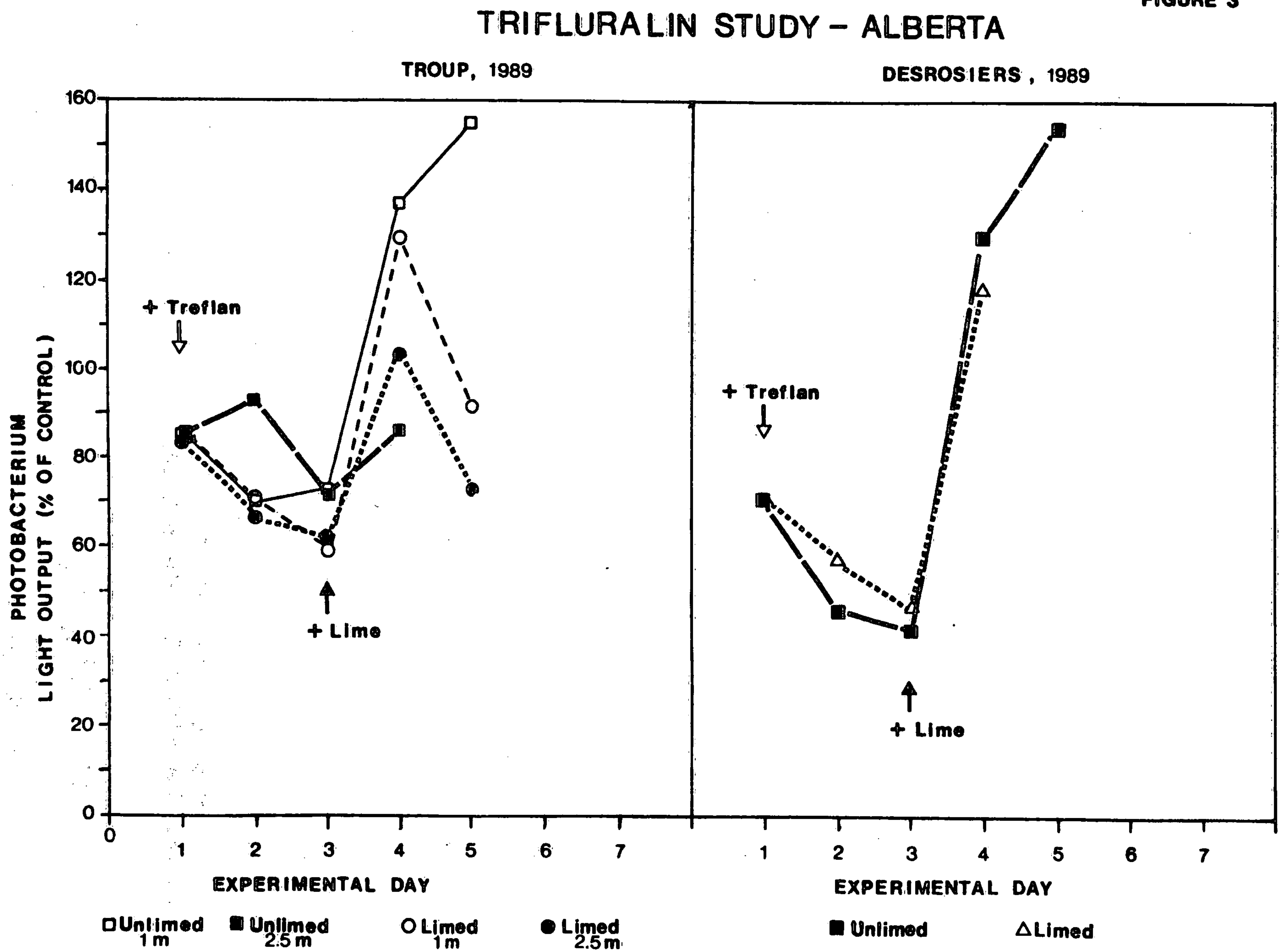

TRIFLURALIN STUDY - ALBERTA
TROUP, 1989
DESROSIERS, 1989
DAPHNIA LC50 (% OF SAMPLE)
80
60
40
20
0
+ Treflan
+ Lime
0 1 2 3 4 5 6 7
EXPERIMENTAL DAY
Unlimed 1m
Unlimed 2.5m
Limed 1m
Limed 2.5m
+ Treflan
+ Lime
1 2 3 4 5 6 7
EXPERIMENTAL DAY
Unlimed
Limed

FIGURE 3



TRIFLURALIN STUDY - ALBERTA
TROUP, 1989
DESROSIERS, 1989
PHOTOBACTERIUM
LIGHT OUTPUT (% OF CONTROL)
160
140
120
100
80
60
40
20
0
+ Treflan
+ Lime
+ Treflan
+ Lime
0
1
2
3
4
5
6
7
EXPERIMENTAL DAY
1
2
3
4
5
6
7
EXPERIMENTAL DAY
Unlimed 1 m
Unlimed 2.5 m
Limed 1 m
Limed 2.5 m
Unlimed
Limed

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