THE FATE AND DISPOSITION OF METOLACHLOR AND 2,4-D UNDER IRRIGATED CORN AND TURF

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ABSTRACT

A field lysimeter experiment was conducted during the summers of 1993 and 1994, at the River Laboratory, Utah State University, Logan, Utah. The intent was to study the fate and disposition of metolachlor and 2,4-D in a one dimensional soil system. Metolachlor was applied to corn and 2,4-D was applied to turf. The mobility, persistence, and degradation of these herbicides were investigated in the field lysimeters using four irrigation treatment levels on corn and two irrigation levels on turf. The four irrigation levels applied to corn were 0, 30, 60, and 120 percent of potential evapotranspiration. The two irrigation levels applied to turf were 75 and 120 percent of potential evapotranspiration.

The experimental design is a randomized block design with each irrigation treatment replicated three times. Soil moisture content was measured in all lysimeters at five depths twice weekly before and after irrigation to monitor soil moisture fluctuation. A neutron probe was used to measure soil moisture content. Potential evapotranspiration was determined from a weather station at the site. Irrigation amount was then computed based on actual plant evapotranspiration demand.

Pesticide mobility and persistence was determined by collecting soil samples from four depths once every week after the second irrigation. Samples were collected from all lysimeters to determine the effect of irrigation level on pesticide mobility.

Results indicate that under field conditions irrigation levels for both metolachlor and 2,4-D have no effect on pesticide mobility and concentration in the soil lysimeters. Neither the amount of water applied nor the irrigation system used significantly affected pesticide leaching in the lysimeters especially if the amount of applied water was less than the crop potential evapotranspiration. Irrigation levels also seem to have little effect on pesticide half-life. Metolachlor half-life ranged from 12 to 18 days in 1993, and from 15 to 25 days in 1994. The half-life of 2,4-D was about 18 days in 1993 and 16 days in 1994.

The metolachlor adsorption coefficient was found to range between 0.4 and 0.57 in the top 0-30 cm and between 0.21 and 0.45 in the 30-60 cm interval. The degradation coefficient for 2,4-D could not be determined in the laboratory. The reason for failing to determine the adsorption of 2,4-D is not known. It might be due to the high volatility of the compound.

A pesticide simulation model using chemical and soil parameters determined in this field experiment was applied. It indicated that proper herbicide and irrigation management would allow enough time for the pesticide to degrade in the soil and prevent its leaching to the water table. The rate at which a herbicide reaches the water table depends also on the depth to the water table and the presence of preferential flow paths in the soil. Proper consideration of these factors is essential to prevent groundwater contamination.

CHAPTER I

INTRODUCTION

A. Background

To serve their intended purpose, lawns and agricultural crops should receive a well balanced supply of essential nutrients and other chemicals throughout the growing season. A balanced supply of nutrients is essential for maintaining good growth. An abundance of weeds and infectious diseases is evidence of unsatisfactory conditions for growth.

Unmanaged application of pesticides can result in groundwater contamination. In the 1970s, pesticides were detected in groundwater in the United States. Parsons and Witt (1989) indicated that most states have a groundwater problem resulting from pesticide migration. Herbicides are usually incorporated within the soil to control undesirable plants. Once in the soil, these chemicals can either degrade, volatilize, leach or can be sorped and retained by the soil matrix. The exact pathway a chemical follows depends on the soil, climate, and chemical characteristics. Leaching through the soil to the water table causes groundwater contamination.

Mathematical models are often used to simulate pesticide movement in the vadose zone. These models require input of soil, crop, and chemical parameters. Soil parameters include organic matter, bulk density, water content at field capacity, and water content at wilting point. Crop parameters include crop potential evapotranspiration, root zone depth, crop growth stages, and growing season. Chemical parameters are chemical half-life, and chemical soil-water distribution coefficient. Variability in these parameters result from soil heterogeneity, climatic conditions, and soil properties.

Accurate determination of these parameters in the laboratory and field are influenced by the uncertainty in experimental protocol and conditions under which they were determined. Errors resulting from using regression models and linear or nonlinear adsorption isotherms to determine soil-water distribution coefficients can increase the error. Field mobility studies used routinely in pesticide screening and registration programs are a follow-up to laboratory studies that have identified potentially mobile compounds. Although these studies offer the advantage of examining pesticide behavior under field conditions, it is impossible to fully account for the disposition of mobile compounds that move below the soil core sampling zone. Another problem with field studies is the difficulty in predetermining how deep one must sample to include all of a mobile pesticide within the sampling zone. It might be impossible to routinely take soil samples cores much below 30 cm to 40 cm because of soil penetration problems during dry summer months.

Computer simulation models are used to predict herbicide persistence and mobility in the field. Parameters needed for simulation should be determined for every soil, crop, and chemical system. The intent of this study is to provide such parameters. The experimental approach used is valuable because it is under field conditions. No previous study in Utah, determined these parameters under field conditions.

B. Objectives

1. To make a detailed quantification of water movement in the one-dimensional soil system.

2. To study the movement of metolachlor and 2,4-D and their spatial disposition in the soil profile resulting from irrigation.

3. To estimate chemical half-life, chemical retardation factor, and partitioning coefficient data needed for the soil and site to aid environmental protection. These parameters are necessary for applying a chemical simulation model to predict pesticide movement and decay in areas where pesticide application poses an environmental hazard.

CHAPTER II

LITERATURE REVIEW

To keep up with increasing population demand for food, recreation, and housing, pesticides and fertilizers have become widely used. The U.S. Environmental Protection Agency (1972) reported that more than 34,000 registered pesticide products are manufactured from 900 different chemical compounds. By 1987 that number increased to 45,000 registered products manufactured from 1,400 chemical compounds. In 1992-1993, the EPA reported 860 registered active ingredients (EPA, 1994). The EPA (1994) also reported that in 1993 the quantity of pesticides used in non-agricultural sectors of the U.S. ranged up to 15 million pounds active ingredient (ai). Pimentel and Levitan (1986) reported that the use of pesticides in the United States (primarily synthetic organic pesticides) had reached almost 500 million kg each year. About 68% of these were used on agricultural lands, of which 60% are herbicides, 24% are insecticides, and 16% are fungicides. Fifty-five million kg of pesticides were used on government and industrial lands, 4 million kg were used on forest land, and 55 million kg were used on household lands.

Chemicals used to control weeds and diseases in lawn areas can potentially leach and contaminate underlying ground water. Pimentel and Levitan (1986) reported that the amount of pesticide reaching target pests is generally very small in relation to the total amount applied. The rest degrades and/or pollutes the environment by contaminating soil and water, perhaps affecting nontarget organisms. Cohen et al., (1984) reported that 17 pesticides had been detected in the ground water of 23 states. Pesticide concentrations ranged from a mere trace to several hundred parts per million.

Ground water contamination by pesticides, fertilizers, or other organic materials is of great concern, especially in places where ground water supplies most of the drinking water. Ground water supplies domestic water for about 50% of the U.S. population (Leonard et al., 1988). Waddell (1987) reported that 63 percent of Utah's population is dependent on ground water for drinking supplies. Rural areas are almost totally dependent on ground water for their domestic water needs.

A goal of the Ground Water Protection Program of the Utah Department of Agriculture (1988 and 1989) is to manage the use of fertilizers and pesticides to protect ground water resources. Regions of the state that are relatively vulnerable to contamination by pesticides have been identified by Eisle et al., (1989) and Ehteshami et al., (1990). In arid Utah, pesticide contamination usually occurs where there is irrigation. When applied to agricultural crops or lawns, pesticides can potentially leach through the root zone and the unsaturated zone to the water table (top of the saturated zone in an aquifer). The time required for pesticides to reach ground water depends on irrigation efficiency, type of chemical, quantity applied, distance to the water table, hydrology, stratigraphy, climate, and topography.

Ground water contamination is widely regarded as one of the major environmental problems associated with pesticide use in the 1980's, and beyond (Pye et al., 1983). According to Parsons (1988), whether or not pesticides have been detected in the ground water of a state depends on whether they have been monitored for. Cohen et. al., (1984) reported that as of 1986, 17 different pesticides, including some of the most widely used chemicals in the United States, have been detected in U.S. ground water.

In Utah, Eisele et al., (1989) identified and ranked sites with different potential hazards for ground water contamination for 29 counties. They initially used a rapid screening procedure, DRASTIC (Aller et al., 1985). They then used a one dimensional model, CMLS, (Nofziger and Hornsby, 1986) to simulate the movement of pesticides in unsaturated soils in locations of higher risks. Results indicated that significant contamination of extremely shallow aquifers can be expected in some locations. Simulations for specific locations indicated that of the 64 chemicals applied in Utah, 22 might reach a depth of 3.0 m within one year, with 18 reaching this depth in significant concentrations.

The potential for a pesticide to reach ground water depends upon its physical-chemical properties, soil characteristics, method and rate of application, climate, and amount and timing of irrigation water. Physical-chemical properties include: water solubility, sorption, degradation, chemisorption and binding of residues, and ionization. Soluble pesticides that do not quickly degrade and are not strongly adsorbed are most likely to contaminate ground water. The concentration of the pesticide moving with soil water decreases as adsorption increases. Degradation might or might not produce less active intermediate products. Table 1 shows the chemodynamic properties for several pesticides.

Soil properties influencing pesticide leaching include clay content, texture and structure, soil organic matter, and soil depth. The organic fraction of the soil results from the bacterial decay of plant and animal products. The humic substances have been thought of as large aromatic polymers made of N-heterocycles, quinones, phenols, and benzoic acid. Hydrophobic nonionic organic chemicals tend to sorp to the soil because of the hydrophobic character of the soil organic matter. Positive, negative, and neutrally charged functional groups attached on the organic carbon surfaces are responsible for the sorption of ionizable organic chemicals. The inorganic fraction of the soil is composed of crystalline and noncrystalline primary and secondary minerals. These consist of clay minerals, iron and manganese oxides and hydroxides, carbonates, and amorphous alumino silicates. Mineral surfaces also have hydrophobic characteristics. This character is important for the sorption of nonionic hydrophobic compounds.

Soil texture and structure influence water movement in the soil and thus pesticide leaching to the ground water. The interstitial water acts as a solvent for pesticides allowing transport to the soil surface where sorption occurs, or leaching to the groundwater after pesticide sorption ceases. Leaching occurs as

Pesticide	S (mg/l)	K_{oc} (ml/g)	K_h	V_p (Pa)	$t_{1/2}$ (days)
Alachlor	2.42E+02[1]	1.90E+02	1.30E-06	2.90E-03	7
Aldicarb	9.00E+03	1.00E+01	1.00E-04	1.30E-02	28
Atrazine	3.20E+01	1.60E+02	2.50E-07	4.00E-05	71
Bromacil	8.20E+02	7.20E+01	3.70E-08	3.30E-05	350
Captan	3.30E+00	3.30E+01	4.90E-05	1.30E-03	3
Carbaryl	4.00E+01	2.29E+02	1.40E-03	6.70E-01	22
Carbofuran	3.20E+02	2.80E+01	3.10E-07	2.70E-03	40
Chlordane	1.00E+00	3.80E+04	2.20E-04	1.30E-03	3500
Chorpyrifos	2.00E+00	6.07E+03	1.80E-04	2.50E-03	63
Cyanazine	1.71E+02	1.68E+02	1.20E-04	2.00E-01	108
2,4-D	9.00E+02	2.00E+01	5.60E-09	5.30E+01	15
DBCP	1.00E+03	7.00E+01	1.70E-02	1.06E+02	180
DDT	3.00E-03	2.40E+01	2.00E-03	2.50E-05	3837
Diazinon	4.00E+01	8.50E+01	5.00E-05	9.70E-05	32
Dieldrin	1.50E-01	1.20E+04	6.70E-04	4.00E-02	868
Disulfoton	2.50E+01	1.60E+03	1.10E-04	2.40E-02	5
Diuron	3.70E+01	3.80E+02	5.40E-08	4.10E-04	328
EDB	3.40E+03	4.40E+01	3.50E-02	1.50E+03	3650
EPTC	3.70E+02	2.80E+02	5.90E-04	4.50E+00	30
Fenamiphos	7.00E+02	1.71E+02	2.40E-08	1.33E-04	10
Fonofos	1.30E+01	6.80E+01	2.20E-04	2.80E-02	60
Heptachlor	5.60E+02	2.40E+04	1.45E-01	5.30E-02	2000
Lindane	7.50E+02	1.30E+03	1.30E+04	5.60E-03	266
Linuron	8.10E+01	8.60E+02	2.50E-06	2.00E-03	75
Malathion	1.45E+02	1.80E+03	5.00E-06	5.30E-03	1
Methyl-Bromide	1.30E+04	2.20E+01	1.50E+00	5.20E-05	55
Methyl-Parathion	5.70E+01	5.10E+03	4.40E-06	1.30E-03	15
Monuron	2.60E+02	1.80E+02	7.60E-09	6.70E-05	166
Napropamide	7.30E+01	3.00E+02	7.90E-07	5.30E-04	70
Oxamyl	2.80E+05	6.00E+00	9.90E-09	3.10E-02	6
Parathion	2.40E+02	1.10E+04	6.10E-06	5.00E-03	18
Phorate	5.00E+01	6.60E+04	3.10E-04	8.50E-05	82
Picloram	4.20E+02	2.60E+01	1.90E-08	8.20E-05	138
Prometryne	4.80E+01	6.10E+02	5.60E-07	1.30E-04	60
Propachlor	6.10E+02	4.20E+02	4.40E-06	3.10E-02	7
Simazine	5.00E+00	1.40E+02	3.40E-08	8.10E-07	75
Terbacil	7.10E+02	4.60E+01	8.20E-09	6.50E-05	50
Triallate	4.00E+00	3.60E+03	7.90E-04	1.60E-02	100
Trifluralin	3.00E-01	7.30E+03	6.70E-03	1.40E-02	132

Source: Rao et al. (1985): Adapted from Jury et al. (1984).

[1] $2.42E+02 = 2.42 * 10^2 = 242$

Table 1. Solubility (S), Organic Carbon Partition Coefficient (K^{oc}), Henry's Constant (K^h), Vapor Pressure (V^p), and Degradation Half-Life ($t^{1/2}$) for Several Pesticides (Ehteshami et al., 1990)

pesticides move with water by capillary and mass flow (Merkle et al., 1967, and Davidson et al., 1968). The downward movement of water through the soil profile occurs mainly through medium to large soil pores. However, fast movement of water through preferential paths (cracks or channels in the root zone or subsoil), permits dissolved substances to reach ground water more rapidly than otherwise expected.

Chemical characteristics affecting pesticide leaching include sorption and degradation. Sorption results from the physical and chemical forces between the solid matrix and charges of the compound. These forces include Van Der Waals forces, hydrogen bonding, dipole-dipole interactions, ion exchange, covalent bonding, protonation, ligand exchange, cation bridging, and water bridging. Sorption is described as a hydrophobic partitioning between the solution and soil solid phases. Weber et al., (1986) attributed the decrease of extractability of a herbicide to physical trapping in the soil micropores.

Degradation is a phenomena where a pesticide disappears from the soil solution. Degradation can be chemical or biological. Authors have quantified the effect of degradation on pesticide removal for a number of soil-pesticide combinations.

Regulations alone cannot guarantee the protection of ground water from chemical contamination. Some on-site practices can reduce the potential for contaminating ground water by pesticides. Holden (1986) listed some agricultural management practices to mitigate pesticide/ground water quality.

problems. These practices include: 1. Improving irrigation efficiency. Applying sufficient water to meet crop water evapotranspiration and satisfy salinity leaching requirements without causing excessive deep percolation can reduce the depth that pesticide reaches. 2. Utilizing best management practices for pesticide use. Following label instructions and carefully calibrating pesticide spray equipment can minimize the mass of the leaching chemical.

According to Eisele et al., (1989), pesticide selection and agricultural practices such as irrigation and time and rate of pesticide application can significantly influence pesticide movement. Peralta et al., (1994) show how to determine the best irrigation application rates for a particular site, crop, and pesticide. Aly and Peralta (1993) presented software (CANDI) to aid developing best management practices for pesticide and irrigation management.

Ranja et al., (1991b and 1992a) examined how the use of appropriate management techniques (sprinkler irrigation system design and pesticide selection) can reduce pesticide leaching and potential ground water contamination. They present procedures for selecting an appropriate sprinkler system design and pesticide. Ranja et al., (1991a and 1992b) simulated pesticide movement under different furrow irrigation designs, water management practices (irrigation scheduling), soil type, and pesticide parameters. They used a hydrodynamic-wave irrigation model to estimate water infiltration for different furrow lengths. They concluded that potential ground water contamination can be reduced by integrated use of best management practices (BMPs). Considered BMPs include, careful selection and use of pesticides, efficient furrow irrigation designs and improved water management (irrigation scheduling).

Chemical application on lawns in residential, commercial, and recreational areas should also be managed carefully. Olson (1991) discussed ways of minimizing the need for lawn chemicals while obtaining a healthy and beautiful lawn. Alternatives include: 1)- choosing a grass variety that is compatible with soil and climatic conditions in the area, 2)- mowing at frequent intervals, never removing more than the top third of the grass blade, 3)- leaving grass clippings to decompose naturally in the soil, 4)- using sharp mower blades which will not shred the grass leaf and will thereby prevent disease, 5)- using lawncare products in the recommended rates.

Schroeder (1991) recommended reading and following label instructions and the manufacturer-provided Material Safety Data Sheet. He also discussed environmentally safe alternatives for pesticide use and presented some less toxic and environmentally safer compounds.

Montana State University, Utah State University, and the University of Wyoming extension services (Dewey et al., 1994-1995) listed the kinds, rate, and time, of registered herbicides for use on lawns and ornamentals (Table 2). If not used according to label instructions these herbicides can potentially contaminate underlying ground water.

Table 2. Chemicals for Weed Control on Lawns and Turf (Source: Weed Control Handbook)

1994 MT-UT-WY HORTICULTURE WEED CONTROL HANDBOOK

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
asulam (Asulox)	Rate:	2 lbs ai/A
	Time:	Apply to established turf after emergence of crabgrass and goosegrass.
	Remarks:	For use on St. Augustinegrass and Tifway 419 bermudagrass turf.
	Caution:	Follow all label precautions and restrictions. Do not use a surfactant. Do not apply to turf which is under stress or freshly mowed. One application per season.
benefin (Balan) (Benefin)	Rate:	2 to 3 lbs ai/A
	Time:	Apply to established turf prior to crabgrass germination.
	Remarks:	Primarily for the control of crabgrass and other annual grassy weeds in established lawns and turf. May give partial control of some annual broadleaf weed species.
	Caution:	Follow all label precautions and restrictions.
benefin + oryzalin (XL)	Rate:	2 to 3 lbs ai/A
	Time:	Apply to established turf prior to emergence of weeds.
	Remarks:	For selective control of many annual grasses and some annual broadleaf weeds in established warm-season turf (bermudagrass, St. Augustinegrass, tall fescue, etc.).
	Caution:	Follow all label precautions and restrictions.
benefin + trifluralin (Team)	Rate:	2 to 3 lbs ai/A
	Time:	Apply to established turf in the spring 1 to 2 weeks prior to the onset of conditions favorable for annual weed grass germination.
	Remarks:	For control of annual bluegrass, smooth and hairy crabgrass, goosegrass, barnyardgrass, and green and yellow foxtail in established Kentucky bluegrass, perennial ryegrass, fescue, and bentgrass turfgrasses. Optimum weed control performance will be obtained if treated areas are irrigated soon after application.
	Caution:	Will not control established weeds. Stands of fine-leaved fescue varieties may be thinned at rates above 2.0 lbs ai/A. See label for reseeding restrictions.
bensulide (Bensumec) (Betasan) (Lescosan)	Rate:	7.5 to 15 lbs ai/A
	Time:	Apply to established lawn or turf in the early spring before crabgrass germinates.
	Remarks:	Controls crabgrass, annual bluegrass, barnyardgrass, henbit, and other annual weeds in well-established lawns and turf.
	Caution:	Follow all label precautions and restrictions.

Table 2 (Cont.)

1994 MT-UT-WY HORTICULTURE WEED CONTROL HANDBOOK

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES *(Always* read label for complete instructions)
bensulide + oxadiazon (Scott's Goosegrass and Crabgrass control)	Rate:	7.5 lbs ai/A
	Time:	Before grasses germinate in the spring.
	Remarks:	Prevents crabgrass and other annual grasses.
	Caution:	Read and follow all label instructions.
bentazon (Basagran)	Rate:	1.0 to 2.0 lbs ai/A
	Time:	Apply after most nutsedge plants have emerged and are actively growing. Additional treatments may be necessary at intervals of 10 to 14 days.
	Remarks:	For control of yellow nutsedge in established bluegrass, bentgrass, fescue, ryegrass, or bermudagrass turf. Delay mowing for 3 to 5 days before or after spraying.
	Caution:	Do not apply more than 3 quarts per acre per season. Do not apply on golf course greens. Avoid over-the-top spraying of adjacent trees, shrubs, or flowers.
bromoxynil (Buctril)	Rate:	0.375 to 0.5 lbs ai/A
	Time:	After desirable grass has emerged, but before broadleaf weeds exceed the two- to four-leaf stage.
	Remarks:	Controls annual broadleaf weeds in newly planted or established turf. Does not control any grasses. Weeds beyond the specified growth stage will not be controlled. No longer a restricted-use herbicide.
	Caution:	For use only on non-residential turf, industrial sites, and non-crop areas. Approved only for application through boom-type sprayers.
chlorsulfuron (Lesco TFC)	Rate:	(See label for specific rate instructions)
	Time:	Use when grass is actively growing and not stressed by cold weather or drought.
	Remarks:	Selectively controls tall fescue and ryegrass in Kentucky bluegrass, fine fescue, bentgrass, and bermudagrass turf. Also controls a wide variety of broadleaf weeds. Use a non-ionic surfactant.
	Caution:	Do not use on bentgrass shorter than ½ inch. Use only on well-established, actively growing lawns. Do not apply near trees or other desirable plants where roots may extend into treated soil.
dazomet (Basamid)	Rate:	346 lbs ai/A
	Time:	Apply when soil temperature is between 54° and 64° F.

Table 2 (Cont.)

1994 MT-UT-WY HORTICULTURE WEED CONTROL HANDBOOK

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
	Remarks:	A non-selective, granular soil fumigant for control of weeds, nematodes, and many soil-borne diseases prior to seeding of new turf grasses, or for killing all weeds and existing turf grass areas prior to complete renovation.
	Caution:	This product is toxic to all plants. Do not apply within 4 feet of desirable plants or within the drip line of trees and large shrubs. Follow all label instructions, precautions, and restrictions.
DCPA (Dacthal)	Rate:	10 to 15 lbs ai/A
	Time:	Apply in early spring before crabgrass germinates.
	Remarks:	For control of crabgrass in established lawns and turf. Lawn should be watered immediately after herbicide application.
	Caution:	Follow all label precautions and restrictions.
dicamba (Banvel)	Rate:	0.05 to 0.25 lb ai/A
	Time:	Apply to established grass when weeds are actively growing.
	Remarks:	Controls many annual and perennial broadleaf weeds in established lawns and turf. Weeds controlled include plantain, spurges, clovers, knotweed and yarrow. Often included in garden-store formulations containing 2,4-D or 2,4-D + mecoprop.
	Caution:	Do not treat within the drip line of trees or in areas where downward movement of herbicide into the soil or surface washing of soil may cause contact of dicamba with roots of trees, shrubs, or other desirable plants. Follow all other label precautions.
dithiopyr (Dimension)	Rate:	0.25 to 0.5 lb ai/A
	Time:	Can be applied preemergence or after the crabgrass has become visible.
	Remarks:	For control of many annual broadleaf and grassy weeds in established lawns and turf. Weeds controlled include prostrate spurge, chickweed, annual bluegrass, and smooth crabgrass.
	Caution:	Do not apply to trees, shrubs, flowers, or vegetables. Keep off treated area until spray has dried. Do not repeat applications during a growing season.
ethofumesate (Prograss)	Rate:	0.75 to 1.95 lbs ai/A
	Time:	Established Kentucky bluegrass: September 1 to December 1. Established perennial ryegrass: 2 to 4 weeks prior to main period of annual bluegrass germination in early fall or late spring, up to 30 days after emergence.

Table 2 (Cont.)

1994 MT-UT-WY HORTICULTURE WEED CONTROL HANDBOOK

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
	Remarks:	For use on ornamental turf sites such as golf courses and parks. Not for use on homeowner lawns. Primarily for control of annual bluegrass in established Kentucky bluegrass and perennial ryegrass turfs. One to three applications, allowing 21 to 30 days between treatments.
	Caution:	Lower rates required on Kentucky bluegrass. Golf course applications are restricted to fairways and roughs. Do not apply within 8 weeks following application of any plant growth regulator.
fenoxaprop (Acclaim) (Horizon)	Rate:	0.03 to 0.35 lb ai/A
	Time:	Apply to turf when grassy weeds are in the one-leaf to three-tiller stage.
	Remarks:	For control of crabgrass, barnyardgrass and foxtail species, and suppression of johnsongrass and bermudagrass. Does not control broadleaf weeds. May be applied to established perennial ryegrass, fine and tall fescue, bentgrass, and Kentucky bluegrass turfs. Bentgrass must be established for at least one growing season. Other species should be established at least 4 weeks and tillered, prior to treatment.
	Caution:	Temporary stunting or yellowing can occur on some cultivars of Kentucky bluegrass. Do not exceed 0.25 lb ai/A on Kentucky bluegrass turf. Do not apply to bentgrass putting greens. Consult label for tank mix options.
glyphosate (Roundup) (Avail)	Rate:	0.75 to 1.1 lb ae/A (annuals); 1.5 to 3.0 lbs ae/A (perennials)
	Time:	Apply before planting grass. Weeds should be actively growing and in the growth stage specified on the label.
	Remarks:	Controls annual and perennial grasses and broadleaf weeds prior to establishment or renovation of lawns or turf. Allow at least 3 days before tillage when controlling annuals, and at least 7 days when controlling perennial weeds.
	Caution:	Will kill or severely injure any desirable grasses present at time of spraying.
imazaquin (Image)	Rate:	0.25 to 0.5 lb ai/A
	Time:	Apply to established turf after weed emergence.
	Remarks:	For use only on established warm-season turf grasses, including St. Augustinegrass, and bermudagrass. Controls sandbur, nutsedge, chickweed, henbit, wild onion, and some other weeds.
	Caution:	Follow all label precautions and restrictions.
isoxaben (Gallery)	Rate:	0.5 to 1.0 lb ai/A
	Time:	Apply in fall or spring prior to broadleaf weed germination.

Table 2 (Cont.)

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
	Remarks:	A preemergent herbicide for use in established turf grass. Controls many annual broadleaf weeds, including chickweed, filaree, knotweed, mustards, pigweed, plantains, prostrate spurge, purslane, and woodsorrel (oxalis). High label rates provide partial control of annual bluegrass, barnyardgrass, crabgrass, and foxtails. Activate with 0.5 inch of water after application but before weeds begin to emerge.
		Also formulated with a granular fertilizer and marketed as 'Galleria'.
	Caution:	Do not apply to seedling turf. Do not use on golf course greens. Do not use on grass grown for seed. Established turf may be reseeded in the fall following a spring application.
MCPA (Rhonox)	Rate:	0.5 to 1.4 lbs ae/A
	Time:	Apply when annual broadleaf weeds are growing vigorously. Spring or fall application will give best results.
	Remarks:	Controls many broadleaf weeds including dandelion, plantain, purslane, and bull thistle. For use only in established grass areas.
	Caution:	Ester formulation. Follow all label precautions and restrictions. Do not use on bentgrass lawns. Do not mow within 2 days before or after application.
mecoprop (MCPP)	Rate:	1.0 to 1.5 lbs ae/A
	Time:	Apply in the spring or fall after grass is well established and weeds are actively growing.
	Remarks:	Controls annual and perennial broadleaf weeds, including clovers and knotweed. For use in established lawns and turf. Commonly included in garden-store formulations with 2,4-D or 2,4-D + dicamba.
	Caution:	Follow all label precautions and restrictions.
metolachlor (Pennant)	Rate:	4 lb ai/A
	Time:	Apply before yellow nutsedge emerges.
	Remarks:	For yellow nutsedge control only in established warm-season turf grass (bermudagrass, St. Augustinegrass, etc.).
	Caution:	Do not use more than once per year. Do not use on cool-season turf grasses.
metsulfuron (Scott's DMC)	Rate:	0.01 to 0.04 lbs ai/A
	Time:	Apply to emerged weeds when turf is actively growing and not stressed by cold weather or heat.

Table 2 (Cont.)

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
	Remarks:	Controls a wide variety of broadleaf weeds in established turf grasses including Kentucky bluegrass, fine fescue, and bermudagrass. Weeds include hoary cress, clover, dandelion, prostrate spurge, and oxalis. Addition of non-ionic surfactant improves control.
	Caution:	Do not apply to turf under stress, or if daily high temperature exceeds 85° F. Do not apply to turf less than 1 year old. Do not exceed 0.02 lb ai/A per season on Kentucky bluegrass or fine fescue turf.
MSMA or DSMA (arsenicals)	Rate:	2.7 to 4.6 lbs ai/A
	Time:	Apply to established lawns or turf when crabgrass is in the five-leaf stage or more.
	Remarks:	Controls crabgrass, sandbur, and other annual grasses in established lawns and turf. Two or more applications at 10-to 14-day intervals may be needed. Causes tip-burn on bluegrass.
	Caution:	Follow all label precautions and restrictions.
oxadiazon (Ronstar)	Rate:	2.0 to 4.0 lbs ai/A
	Time:	Apply to established turf prior to crabgrass germination.
	Remarks:	Controls many annual grasses (including crabgrass) and annual broadleaf weeds in established lawns and turf. Is not effective in controlling prostrate spurge.
	Caution:	Follow all label precautions and restrictions.
pendimethalin (PRE-M) (Pendulum) (Stomp)	Rate:	1.5 to 3.0 lbs ai/A
	Time:	Apply to established turf prior to weed germination.
	Remarks:	Controls crabgrass, prostrate spurge, chickweed, henbit, and other annual grasses and broadleaf weeds in established lawns and turf.
	Caution:	Follow all label precautions and restrictions.
prodiamine (Barricade)	Rate:	0.33 to 0.75 lbs ai/A
	Time:	Apply prior to germination of weeds.
	Remarks:	A selective preemergence herbicide that will control certain grass and broadleaf weeds in established grass turf. Weeds controlled include crabgrass, annual bluegrass, prostrate spurge, henbit, common chickweed, and knotweed. Must be incorporated by 0.5 inch of rainfall or irrigation as soon as possible after application (not longer than 14 days). Will not harm most nearby established ornamental trees, shrubs, and flowers.

LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
	Caution:	The species of turf determines the maximum amount of this product that may be applied during a year. Do not apply more than 0.75 lb ai/A in a single application, or more than a total of 1.5 lbs ai/A per season on any turf species. Do not apply through any type of irrigation system.
siduron (Tupersan)	Rate:	2 to 6 lbs ai/A (new plantings); 8 to 12 lbs ai/A (established plantings)
	Time:	Apply to established lawn or turf in the spring before emergence of annual grasses.
	Remarks:	Controls many annual grasses, including crabgrass, in established lawns and turf. Irrigate within 1 week after application if no rainfall has occurred.
	Caution:	Follow all label precautions and restrictions.
triclopyr (Turflon Ester)	Rate:	0.5 to 1 lb ae/A
	Time:	Apply after grass is well established and weeds are actively growing.
	Remarks:	Controls many annual broadleaves and some perennial broadleaf weeds in established lawns and turf, including ground ivy, oxalis, and wild violet. Use only on tall fescue, perennial bluegrass, or perennial ryegrass lawns and turf. May be tank mixed with 2,4-D.
	Caution:	Do not allow spray drift to contact desirable broadleaf plants. Do not spray if temperature exceeds 80° F.
triclopyr + clopyralid (Confront)	Rate:	0.28 to 0.56 lb ae/A
	Time:	Apply to established turf when weeds are actively growing.
	Remarks:	A non-2,4-D product that provides postemergent control of many annual and perennial broadleaf weeds. Especially effective against clover.
	Caution:	Use only on perennial ryegrass, perennial bluegrass, or tall fescue. Spray in a manner to avoid contact with non-target plants.
2,4-D (various brands)	Rate:	(Varies by product)
	Time:	Apply after grass is well established and weeds are actively growing.
	Remarks:	Controls many annual and perennial broadleaf weeds in established lawns and turf. Applications in both spring and fall may be necessary to control some difficult weeds. No more than two broadcast applications may be made per year.
	Caution:	There are many amine and ester formulations containing 2,4-D alone or in combination with other herbicides. Adhere strictly to all label instructions for the particular product used. Do not spray if wind is blowing or if air temperatures exceed label limits (usually 80° to 85° F).

Table 2 (Cont.)

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
2,4-D + 2,4-DP + MCPP (Triamine) (Dissolve) (Tri-Ester)	Rate:	(Varies by product)
	Time:	Apply in the spring or early fall when weeds are actively growing.
	Remarks:	Controls many annual and perennial broadleaf weeds in established lawns and turf. Both amine and ester formulations are available. Spot applications may be made at any time during the growing season.
	Caution:	Do not apply to newly seeded grasses. Do not use on bentgrass. Do not apply under conditions where drift or volatilization may result (see label for temperature limitations). Do not irrigate within 24 hours after application. Do not make more than two broadcast applications per year.
2,4-D + MCPP + dicamba (Trimec Classic) (Three-Way) (Triplet)	Rate:	(Varies by product)
	Time:	Apply in the spring or early fall when weeds are actively growing.
	Remarks:	Amine formulations. Controls many annual and perennial broadleaf weeds including dandelion, mallow, clover, black medic, chickweed, plantains, prostrate spurge, and other weeds on residential and other turf sites.
	Caution:	Do not apply to newly seeded grasses. Do not apply more than 0.75 lb ae/A on closely mowed bentgrass (putting greens). Do not broadcast apply when air temperature exceeds 85° F. Do not irrigate within 24 hours after application. Do not make more than two broadcast applications per year. Be careful not to exceed specified dosage within the drip line of trees.
2,4-D + 2,4-DP + dicamba (Trimec Super)	Rate:	1.1 to 1.7 lbs ae/A
	Time:	Apply in the spring or early fall when weeds are actively growing.
	Remarks:	Ester formulation. Controls dandelion, mallow, clover, black medic, chickweed, plantains, prostrate spurge, and many other broadleaf weeds on residential and other turf sites, excluding sod farms. Apply in 20 to 260 gallons of water per acre. Spot applications may be made at any time during the growing season.
	Caution:	Do not apply to newly seeded grasses. Do not use on bentgrass. Do not apply when air temperature exceeds 85° F. Do not irrigate within 24 hours after application. Do not make more than two broadcast applications per year. Be careful not to exceed specified dosage within the drip line of trees.
MCPA + MCPP + dicamba (Trimec Encore) (Tri-Power)	Rate:	(Varies by product)
	Time:	Apply in the spring or early fall when weeds are actively growing.
	Remarks:	Amine formulations. Also available in water soluble packets as a dry soluble concentrate (Encore DSC). Does not contain 2,4-D. Controls dandelion, mallow, clover, black medic, chickweed, plantains, prostrate spurge, and many other broadleaf weeds on residential and other turf sites.

Table 2 (Cont.)

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LAWNS AND TURF

HERBICIDE		GENERAL GUIDELINES (*Always* read label for complete instructions)
	Caution:	For use only by professional turf maintenance or landscaping personnel, or commercial applicators. Do not apply to newly seeded grasses. Do not apply more than 1.0 lb ae/A on closely mowed bentgrass (putting greens). Do not broadcast apply when air temperature exceeds 85° F. Do not irrigate within 24 hours after application. Be careful not to exceed specified dosage within the drip line of trees.
2,4-D + MCPP + MSMA + dicamba (Quadmec)	Rate:	2.88 lbs ae/A
	Time:	Apply in the spring or early summer to emerged weeds.
	Remarks:	Amine formulation. For use on residential and other turf sites, excluding sod farms. Controls crabgrass in addition to the broadleaf weeds normally killed by other Trimec products. Requires a second application at the same rate 10 to 14 days after the first application. Spring applications should be made to newly emerged crabgrass and broadleaf weeds. Early summer applications could be made to more mature crabgrass and broadleaf weeds.
	Caution:	Do not apply to newly seeded grasses. Do not apply this product when air temperatures exceed 80° F. Be careful not to exceed specified dosage within the drip line of trees. Do not make more than two broadcast applications per year.

CHAPTER III

METHODOLOGY

A. FIELD EXPERIMENT

1. TREATMENTS AND REPLICATES

There are thirty two field lysimeters in the River Laboratory. Of these, 18 were utilized for the current study. In both 1993 and 1994 twelve lysimeters were planted with corn. The other six were used to grow turf. Both crops (corn and turf) received different irrigation treatments (Figure 1). Four irrigation treatment levels were applied to corn and two irrigation levels were applied to turf. Each type of irrigation treatment had three replicates. Detailed description of field layout and different irrigation levels are discussed in the following sections.

2. LYSIMETER DESCRIPTION

Each lysimeter is 2.44 m wide, 6.1 m long, and 0.61 m deep. Wood and concrete are used along the perimeters to separate lysimeters from each other. At the bottom of each lysimeter a layer of fine sand was placed over a layer of fine gravel to act as a filter for preventing downward soil-particle migration with the drainage water (Figure 2).

All utilized lysimeters contain the same soil (Kidman Fine Sandy Loam). The physical and chemical characteristics of the soil (soil type, water content at field capacity, water content at wilting point, bulk density, and

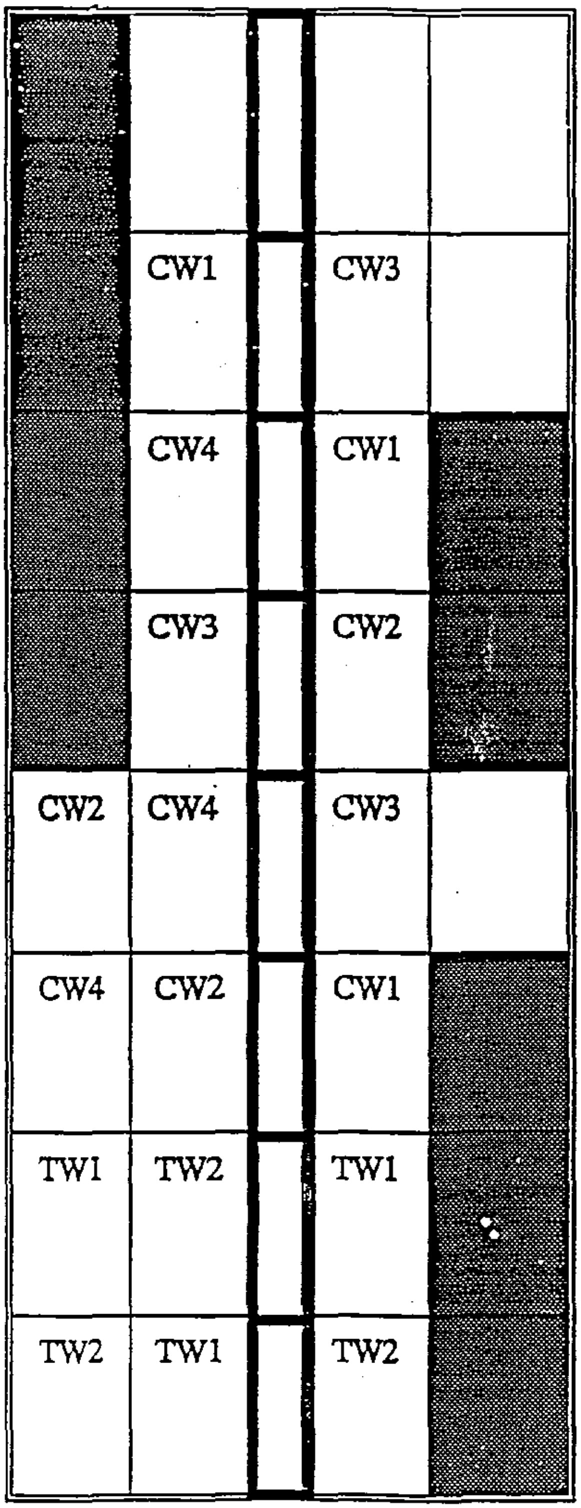


Figure 1. Field Layout. CW* is corn water level. TW* is turf water level.

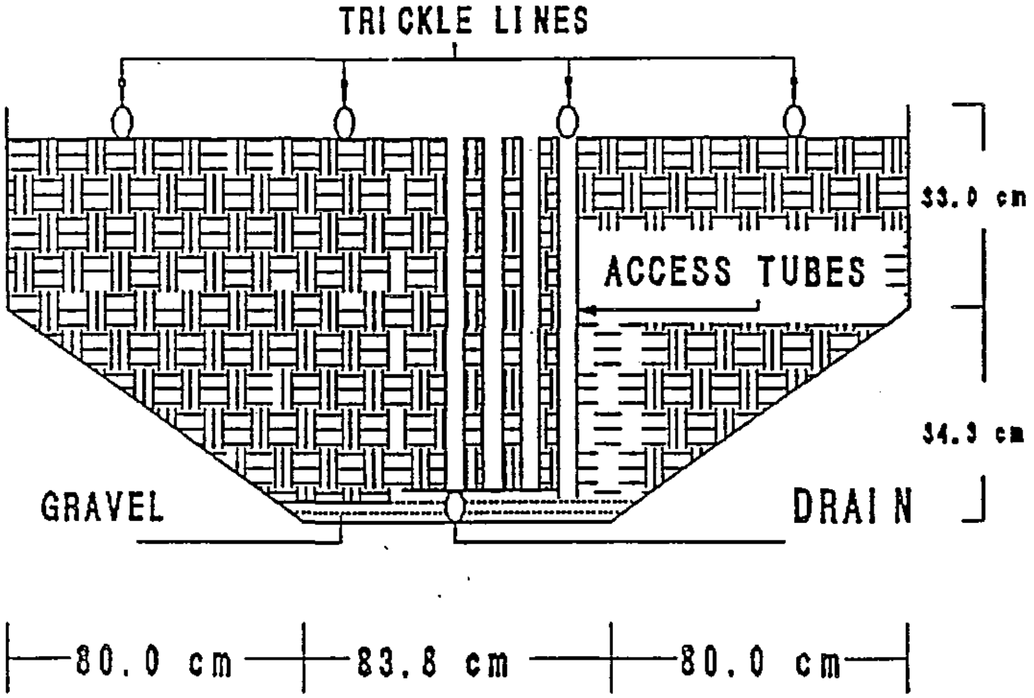


Figure 2. Lysimeter Cross Section.

percent organic matter) were determined using standard methods of soil analysis.

3. CULTURAL PRACTICES.

During the first year (1993), the soil was adequately prepared in all lysimeters before planting the corn or laying the sod. The soil was tilled and leveled. Large soil aggregates were broken down, leaving a smooth surface. Four rows (2 feet apart) were planted with corn in the lysimeter. (Dashed lines in Figure 3 are the rows). For turf, the soil was left leveled. The same soil preparation was done for corn in the second year (1994) after corn was removed from the lysimeters at the end of the first year. After the first year, turf was left in the lysimeters to be used in the next year (summer 1994). No soil preparation was needed for turf.

In summer 1993, soil samples were taken at 3 depths from each of three randomly selected lysimeters (from the 18 lysimeters used in this study), before planting corn or laying sod. The intent was to determine if the soil was deficient in nitrogen, phosphorous, and potassium. It was not necessary to sample all lysimeters upon commencing the first year because all lysimeters had been subjected to the same treatments in previous years.

In summer 1994, soil samples were taken from 3 different depths from each treatment and replicate to determine soil fertility. This was done to determine whether the different water applications in 1993 caused different

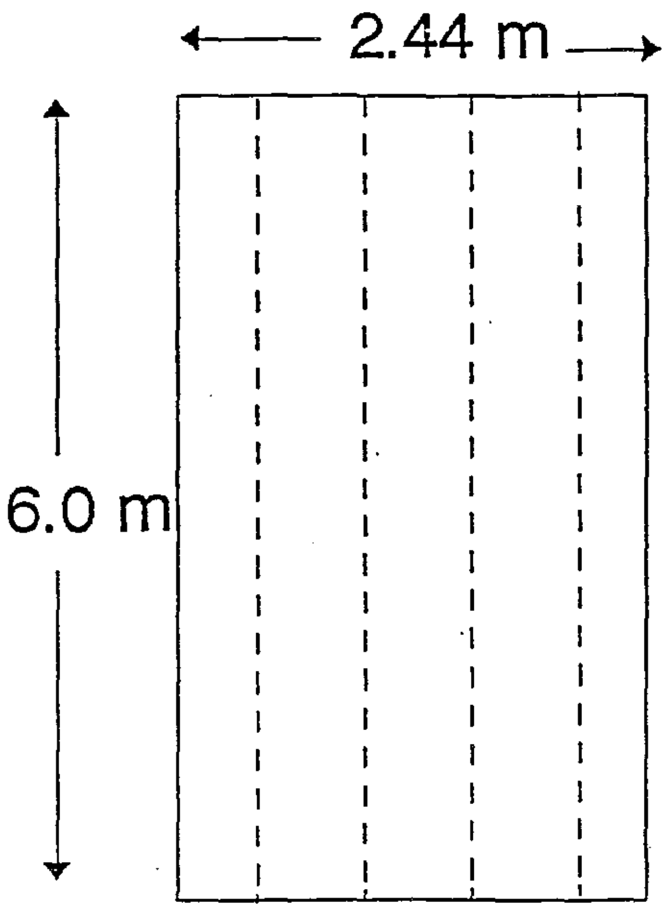


Figure 3. Rows of Corn in a Lysimeter.

ET in/day	ET mm/day	Volume Req. per Lysimeter m^3	Emitters per Lysimeter	Flow per Lysimeter m^3/hr.	Irrigation Duration (min)
0.05	1.27	0.0189	240	0.24	4.7
0.1	2.54	0.0378	240	0.24	9.5
0.2	5.08	0.0755	240	0.24	18.9
0.25	6.35	0.0945	240	0.24	23.6
0.3	7.62	0.113	240	0.24	28.4

Table 3. Irrigation Duration for Different Evapotranspiration Levels.

The moisture content of the soil is determined before and after each irrigation, at different depths (0-15cm, 15-25 cm, 25-35 cm, 35-45 cm, 45-60 cm). A neutron probe is used for this purpose. One access tube is installed in the middle of each lysimeter. In one replicate of each treatment, four additional access tubes are installed symmetrically about the middle one. These access tubes are equidistant from the middle access tube and the respective side of the lysimeter (Figure 4). This allowed us to better estimate the spatial distribution of moisture content in the lysimeter and the error involved in using only readings from a single central access tube.

Samples for pesticide determination were taken at 0-10 cm, 10-20 cm, 20-30cm, and 30-40 cm depths. It was desired that moisture content and pesticide concentration be determined at the same depth. But because neutrons will escape form the soil at shallow depths, the first moisture content reading

5. IRRIGATION AMOUNTS AND EVAPOTRANSPIRATION.

Four irrigation treatments were applied to corn. Irrigation frequency was fixed. Irrigation amount varied as a fixed proportion of crop actual evapotranspiration (ET). Utilized proportions include 0.0 times ET (no irrigation), 0.3 times ET, 0.6 times ET, and 1.2 times ET (where ET is evapotranspiration). Only two water treatments were applied to turf, 0.75 and 1.2 times actual crop ET. Crop actual evapotranspiration was computed on a daily basis from potential evaporation and a crop growth factor. Solar radiation, minimum and maximum temperatures, wet and dry bulb temperature, wind speed, pan evaporation, and precipitation from a weather station (at the river lab) were recorded daily (Appendix A). Although this data was used to calculate potential evapotranspiration via several methods, the Jensen-Haise method guided irrigation in this experiment.

A drip system was used for irrigation. It consists of 0.5 diameter polyethylene laterals 1 foot apart (7 laterals per lysimeter). Emitters, with a flow rate of 1 lph (liter per hour), are spaced 6 inches apart along the lateral. Plants are irrigated twice a week. Data obtained from the weather station was used to determine potential evapotranspiration. Actual evapotranspiration was then determined using a crop factor. Based on actual evapotranspiration, crop water requirement was computed. The duration of irrigation is based on the amount of water required by the plant (amount of actual ET). Table 3 shows irrigation duration for different ET levels.

fertilizer uptake and leaching.

Results of the pre-plant soil fertility tests in both 1993 and 1994 showed that the soil was deficient in nitrogen, but not in phosphorous or potassium. Results indicated that 1.1 pounds of ammonium nitrate were needed in both years for all corn treatments. This amount was broadcast and tilled in before planting in June 1993 and May 1994.

Lysimeters planted with turf received 1.1 pounds of ammonium nitrate in June 1993. In June 1994, each lysimeter received 0.24 pounds of ammonium sulfate. In September 1994, 0.5 pounds of 21-5-0 fertilizer was applied to each lysimeter planted with turf.

4. CROP DATA.

Corn. On June 14, 1993, and May 20, 1994 sweet corn (Incredible variety) was planted in rows 2 feet apart. Two to three seeds were inserted 1.5-2 inches deep in the soil and 12-15 inches apart. Corn emerged on June 18, 1993 in the first season and between June 2-5, 1994 in the second season. Generally more than one plant emerged per location. The corn was thinned after plants were approximately 10 inches tall.

Turf. In the first year, purchased turf was laid on May 27, 1993, to give sufficient time for establishment. Turf was not removed from lysimeters at the end of the first year. It was left for the second year.

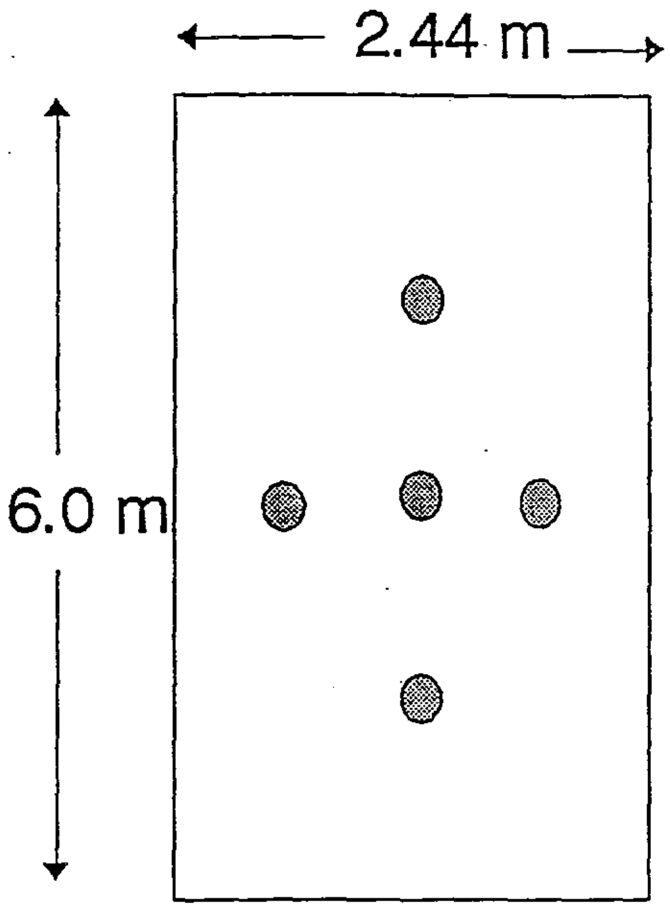


Figure 4. Access Tubes Installed in a Single Lysimeter.

must be taken at the 0-15 cm interval.

6. PESTICIDE APPLICATION

Metolachlor was applied to corn at a rate of 2 pints per acre (3.5 ml per lysimeter) in both years. It was applied on July 19, 1993 and July 17, 1994, (Julian Day 200 and Julian Day 198 respectively) or when the crop was more than 5 inches tall. All corn plots received the same pesticide treatment. Turf received 4 pints (7 ml) per lysimeter of 2,4-D on July 26, 1993, (Julian Day 207) after it was well established in the first year. In the second year, 2,4-D was applied on July 18, 1994, (Julian day 199) at a similar rate of 4 pints per acre (7 ml) per lysimeter. Both metolachlor and 2,4-D were applied according to label instructions.

In the first two months of the 1993 season, 2,4-D was detected in turf lysimeters. By September 1993, Julian Day 270, 2,4-D was no longer detected. This was due partially to the extreme rainfall in July and August that leached the chemical out of the profile.

In 1994, probably because of volatilization due to high temperature 2,4-D was no longer detected in the soil 30 days after application. No rainfall occurred in July and August of 1994 to cause chemical leaching. We reapplied 2,4-D in September 1, 1994 (Julian Day 244) at a higher rate (70 ml per lysimeter). We also collected soil samples twice instead of once per week to verify that adequate chemical was present to better fulfill study objectives.

7. SOIL SAMPLING

Once a week, lysimeters were sampled for metolachlor concentration. In 1993, three different depths (0-10 cm, 10-20 cm, 20-30 cm) were sampled during the first two weeks. Later, after the pesticides were detected at 30 cm, an extra depth was sampled, 30-40 cm. In 1994, we sampled four depths from the beginning of the season because a pre-season analysis for metolachlor indicated that some residues remained from 1993. Samples were: collected using a 0.5 inch auger, placed in a tight plastic bag, and stored at -20° C for subsequent analysis. Drainage water from the lysimeters was also collected, placed in a tight plastic bottle, and analyzed for the respective pesticides.

B. LABORATORY ANALYSIS

The laboratory analysis consisted of two parts. In the first part, soil samples extracted from the field were tested for pesticide concentration and mobility. The second part consisted of laboratory analysis for determining soil water partitioning coefficient.

1. Mobility Analysis.

To determine pesticide concentration in the soil profile, frozen soil samples were brought to room temperature and air dried before large aggregates were broken down to less than 1 cm diameter. Ten grams of the air dry soil were weighed and placed in a 50 ml container. Some 2,4-D, which is highly volatile, may have been volatilized. This could not be avoided when using the

Immuno-Assay Rapid Test Kit to determine pesticide concentration. Thirty milliliters of methanol were added to the soil and the mixture was mixed on a rotary shaker for 24 hours. The extract was then filtered and the supernatant was analyzed by the immunoassay test for the respective pesticide.

2. Adsorption Determination.

To determine adsorption, only two lysimeters were sampled at two different depths. This is considered adequate because all lysimeters contain the same soil type. Pesticide soil water partitioning coefficient for metolachlor is determined according to the procedure described by Talbert and Fletchall (1965) as reported by Bouchard et al., (1982). Air dry soil was ground and sieved in a 0.5 -mm sieve. Half a gram (0.5 g) was weighed and placed in a 50 ml centrifuge tube. Stock solutions of 0.125, 0.25, 0.5, 1, 2, and 4 ppm technical grade metolachlor were prepared. A five milliliter aliquot was added to each tube.

Samples were placed on a rotary shaker for 24 hours to allow the soil-herbicide system to equilibrate. Most kinetic studies reported that 24 hours are sufficient for the soil-pesticide system to reach equilibrium. After 24 hours, the samples were centrifuged at 2000 rpm for 5 minutes. The aliquot was analyzed for the remaining concentration in the solution.

For 2,4-D sorption study, a procedure similar to that described by Hicken (1993) was utilized. Four grams of soil were placed in a centrifuge tube and 40 ml of 2,4-D stock solutions were added to the test tube to insure minimum head space. Minimum head space is desired because 2,4-D is an acid and will volatilize. The soil-solution mixture was then placed on a rotary shaker for 24 hours to equilibrate. Hicken (1993) found through kinetic studies on different soils that equilibrium between the soil and the solution is reached in 24 hours. After shaking, the mixture is centrifuged at 10,000 rpm for 30 minutes. An aliquot was then removed to determine 2,4-D concentration in the solution using the Immuno Assay Test Kit.

CHAPTER IV

RESULTS AND DISCUSSION

A. Metolachlor Distribution in the Soil Profile.

Metolachlor concentrations in the soil profile for the 1993 and 1994 growing seasons are given in Figures 5-16. Figures 5- 8 and Figures 11-14 give metolachlor concentration versus time for each treatment at the sampled depths for both years. Concentrations shown are the average for the three replicates. Figures 9 and 10 and 15 and 16 give metolachlor concentration versus depth for each irrigation treatment and for same sampling days used in Figures 5-8 and 11-14 during the 1993 and 1994 growing seasons respectively.

Irrigation amount did not significantly affect metolachlor mobility and distribution in the soil profile in either year Figures 5-8 and 11-14. Neither the irrigation method nor the irrigation amount caused pesticide leaching. The lysimeters were irrigated using drip irrigation, a very efficient method for applying water. Under a drip system, water is applied near the roots of the plant at a low rate, always less than the infiltration rate of the soil. This results in wet areas along the rows and dry areas away from the rows. Moreover, for treatments 1, 2, and 4 the amount of applied water is less than the crop actual evapotranspiration. With this amount of water no pesticide leaching should occur below the root zone.

Metolachlor was applied at the soil surface after corn reached 5 inches in length. Metolachlor was applied manually and care was taken to insure application uniformity. Samples were extracted 24 hours after application to determine metolachlor concentration in the soil profile. As indicated in Figure 5, no metolachlor was detected in any treatment except for the 0.3

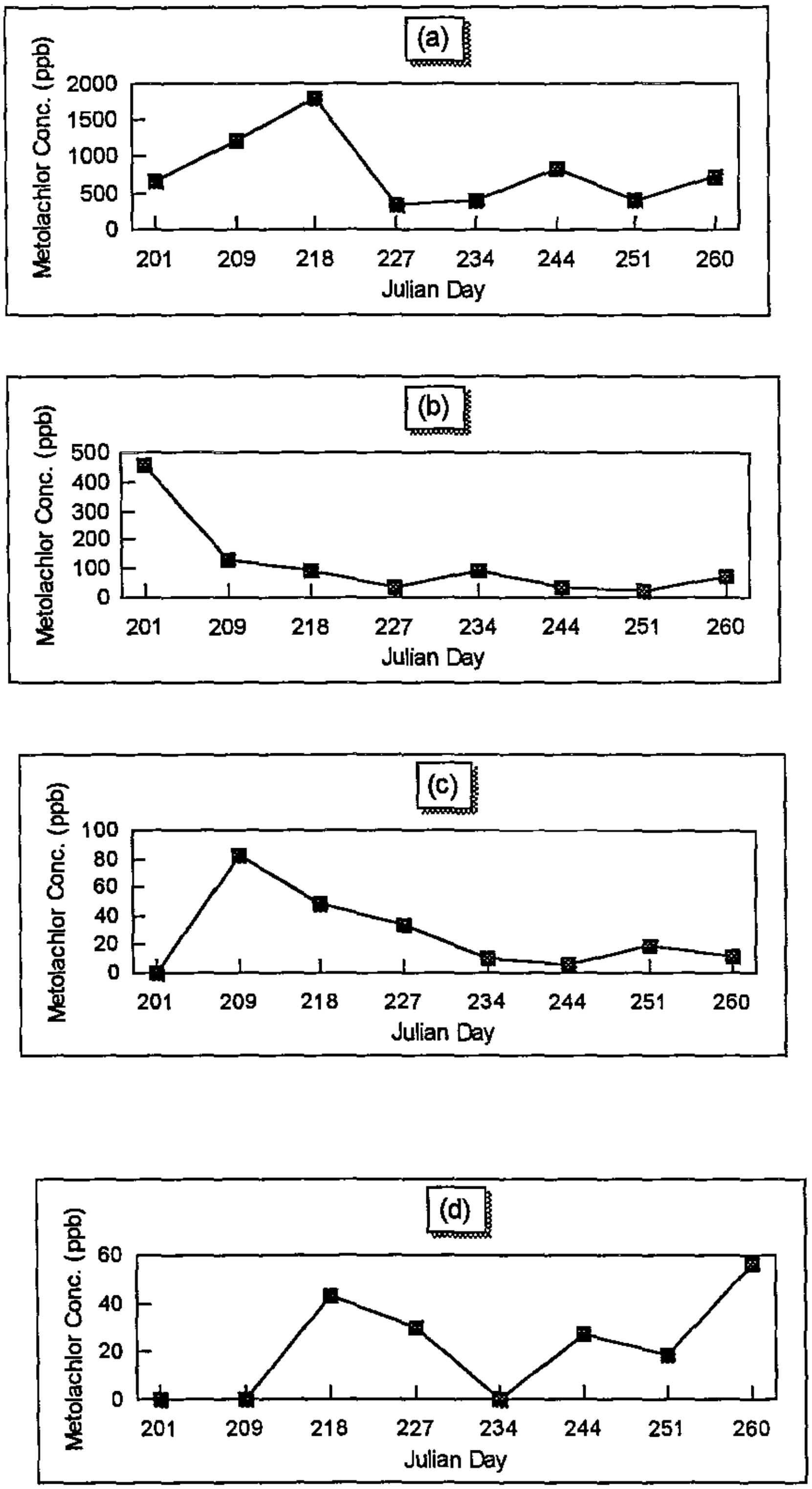


Figure 5. Metolachlor Concentration Versus Time for the 1993 Growing Season and Irrigation Level Equals 0.3 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

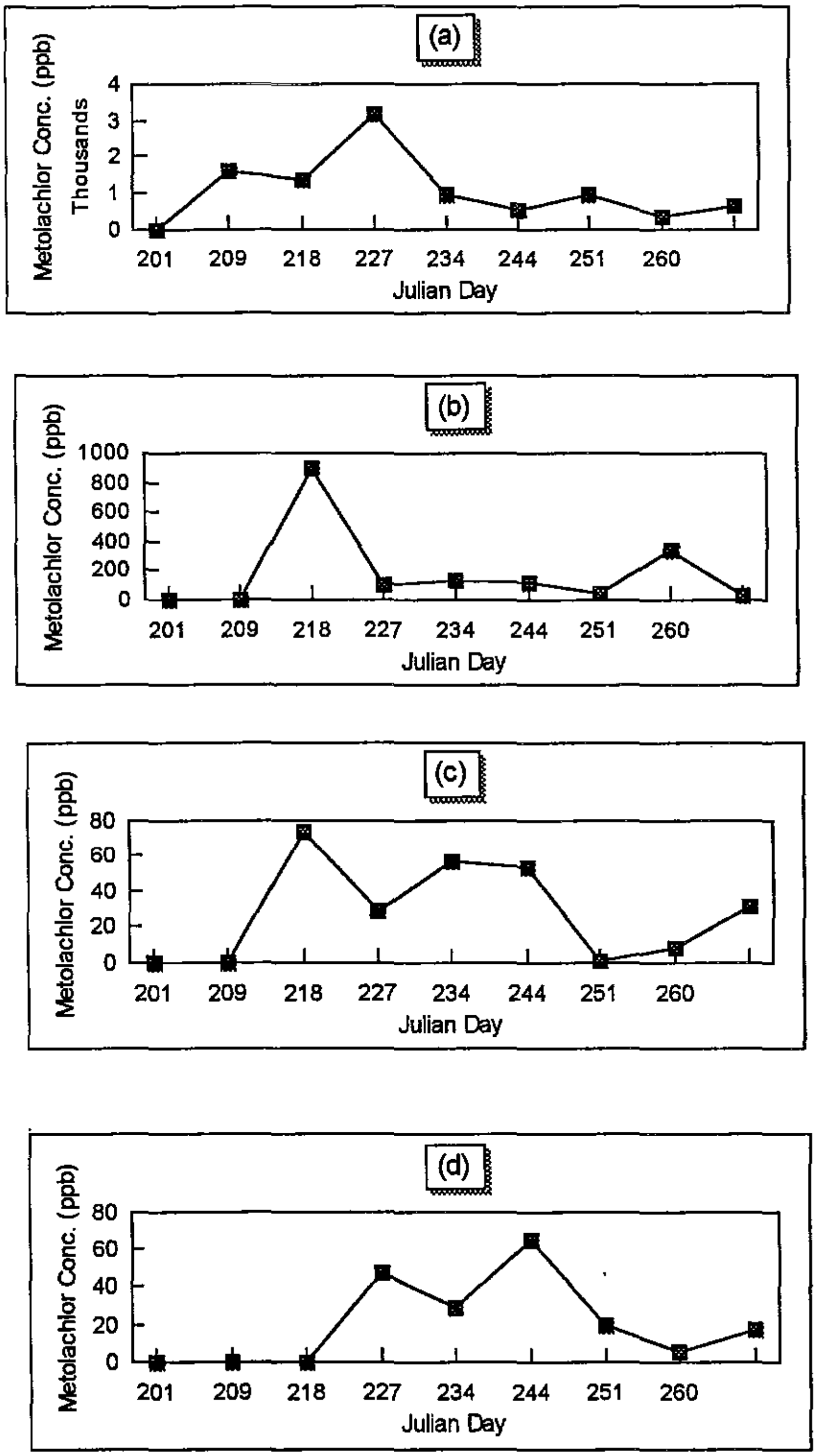


Figure 6. Metolachlor Concentration Versus Time for the 1993 Growing Season and Irrigation Level Equals 0.6 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

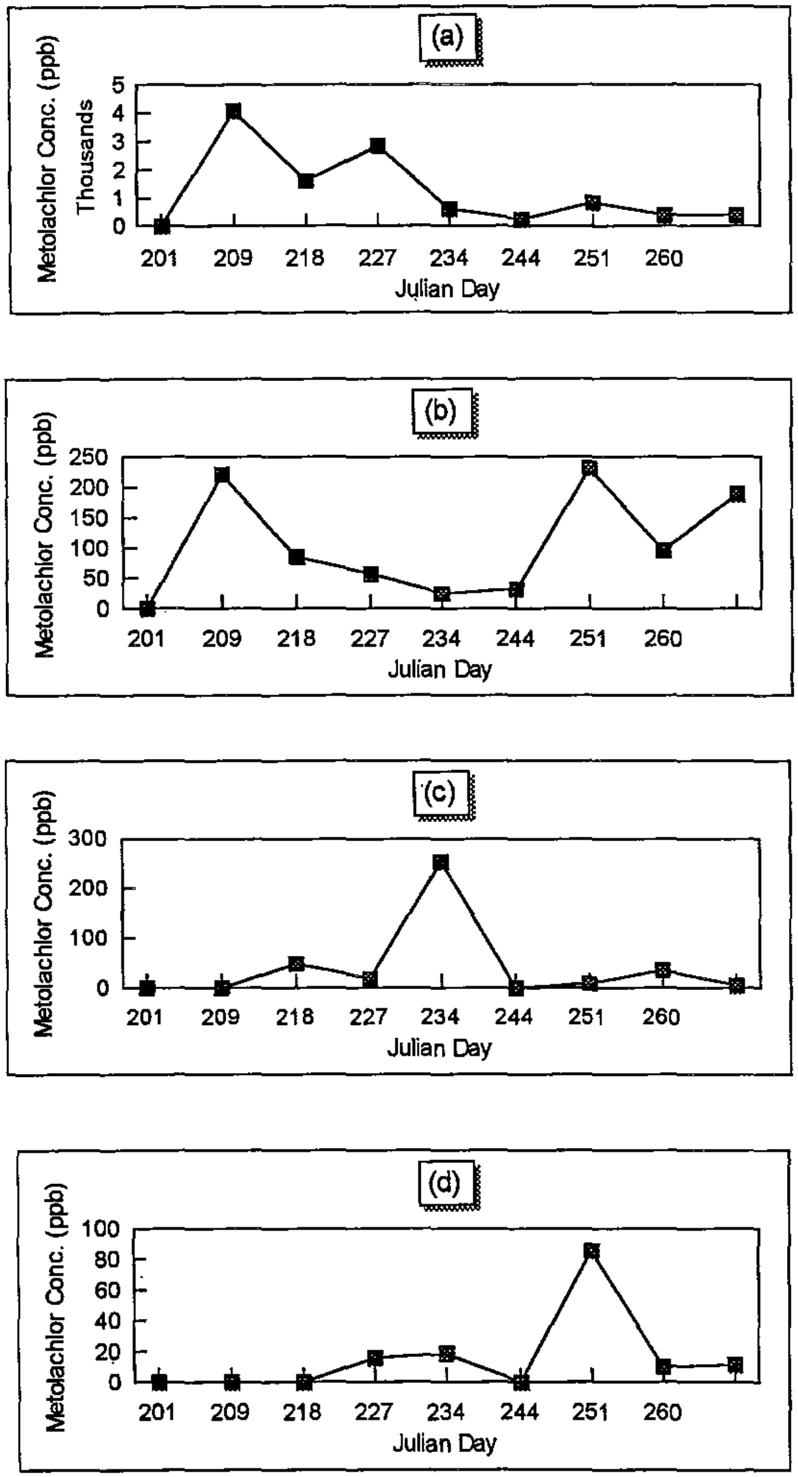


Figure 7. Metolachlor Concentration Versus Time for the 1993 Growing Season and Irrigation Level Equals 1.2 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

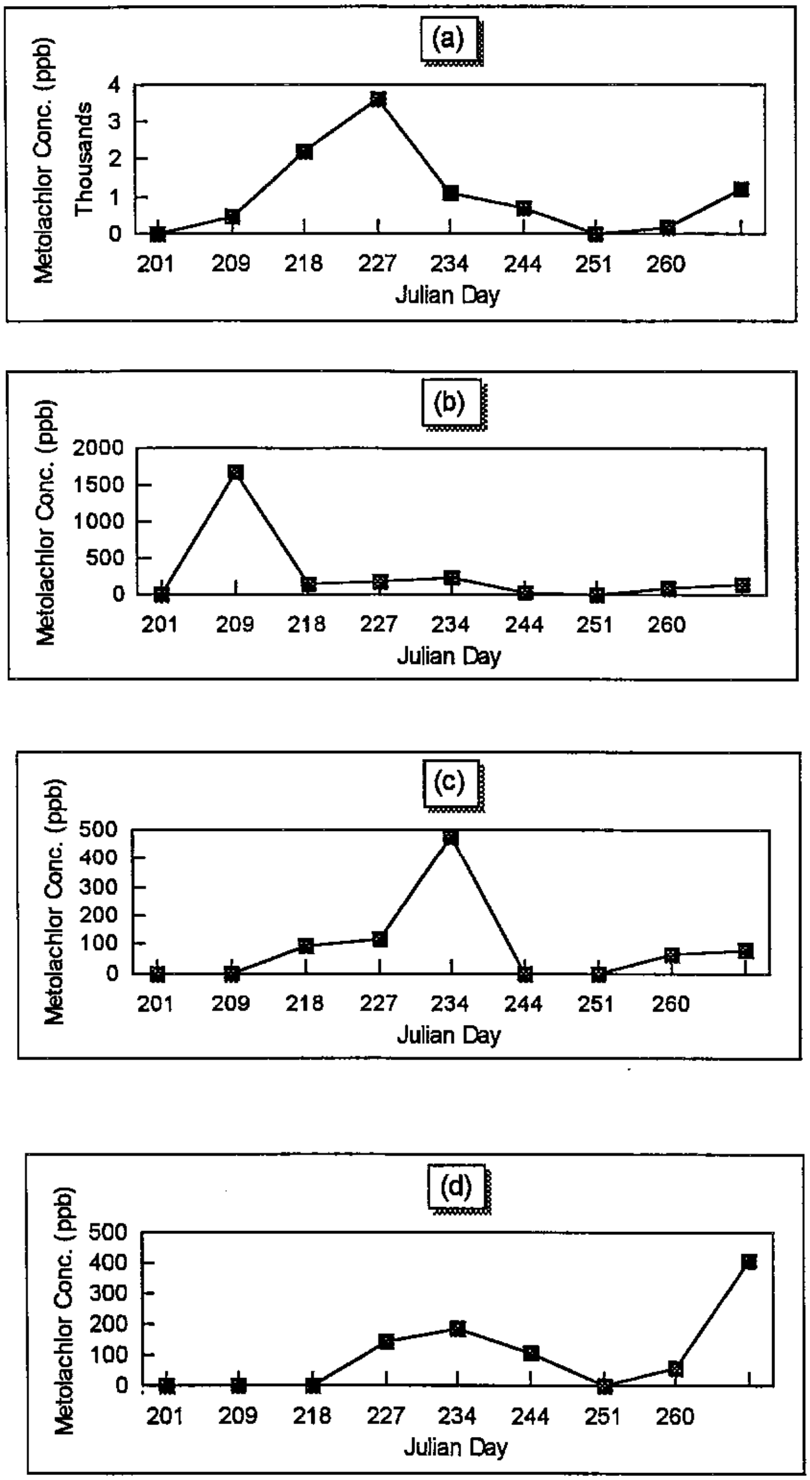
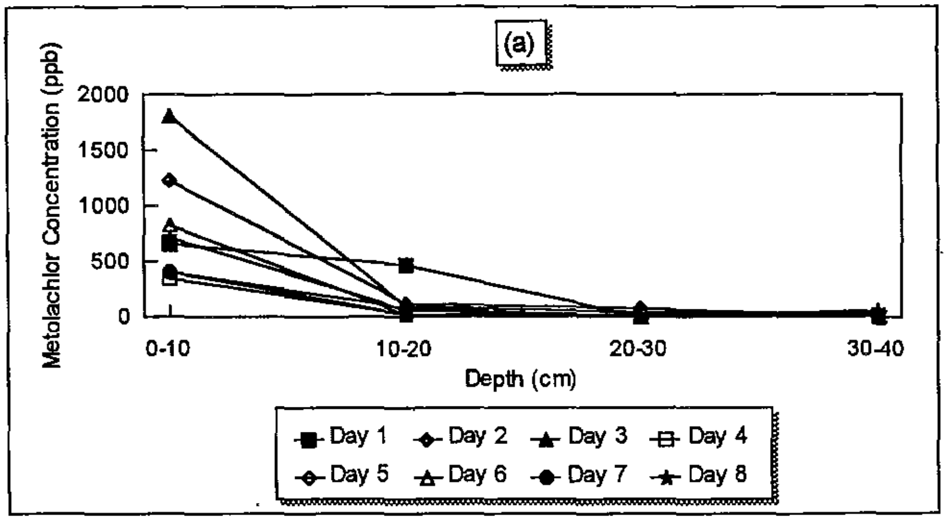


Figure 8. Metolachlor Concentration Versus Time for the 1993 Growing Season and no Irrigation.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.



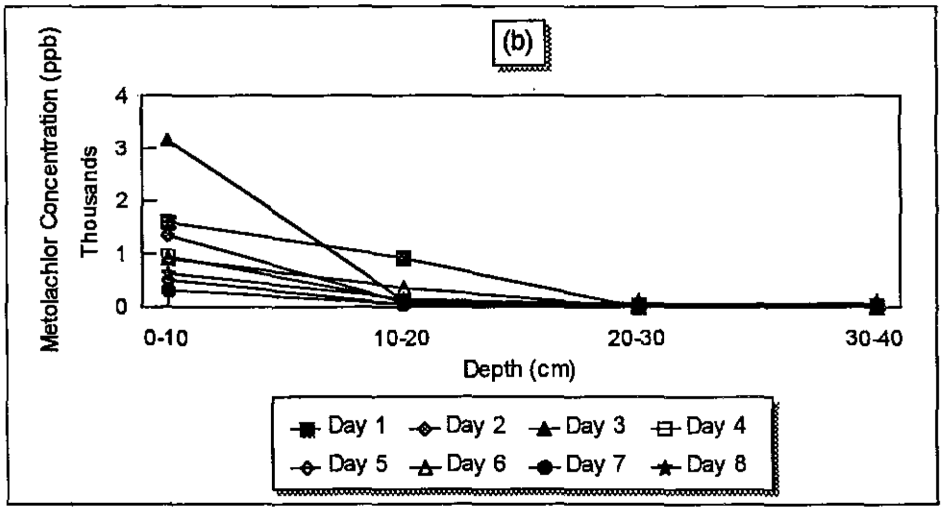


Figure 9. Metolachlor Concentration Versus Depth for the 1993 Growing Season. (a) Irrigation Level Equals 0.3 Times Actual ET; (b) Irrigation Level Equals 0.6 Times Actual ET.

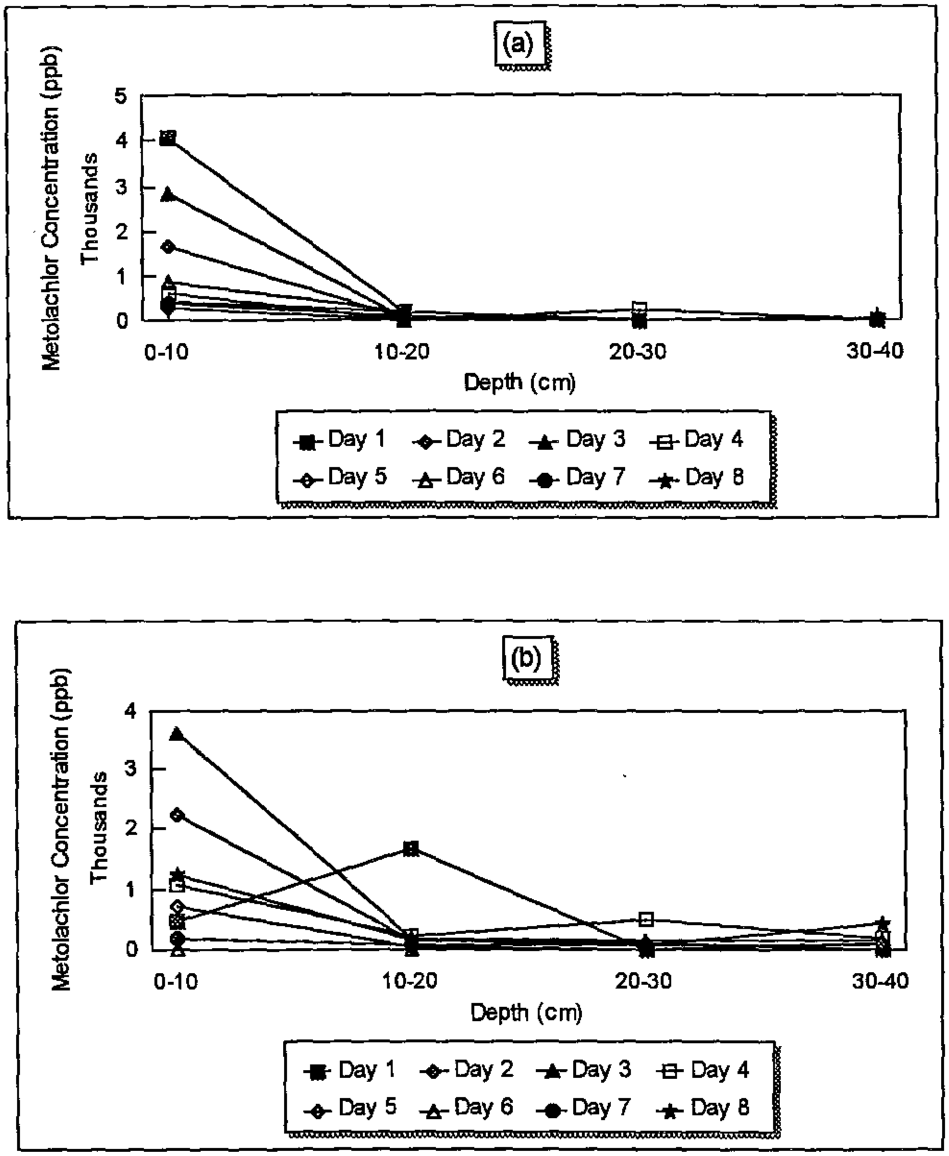


Figure 10. Metolachlor Concentration Versus Depth for the 1993 Growing Season. (a) Irrigation Level Equals 1.2 Times Actual ET; (b) No Irrigation.

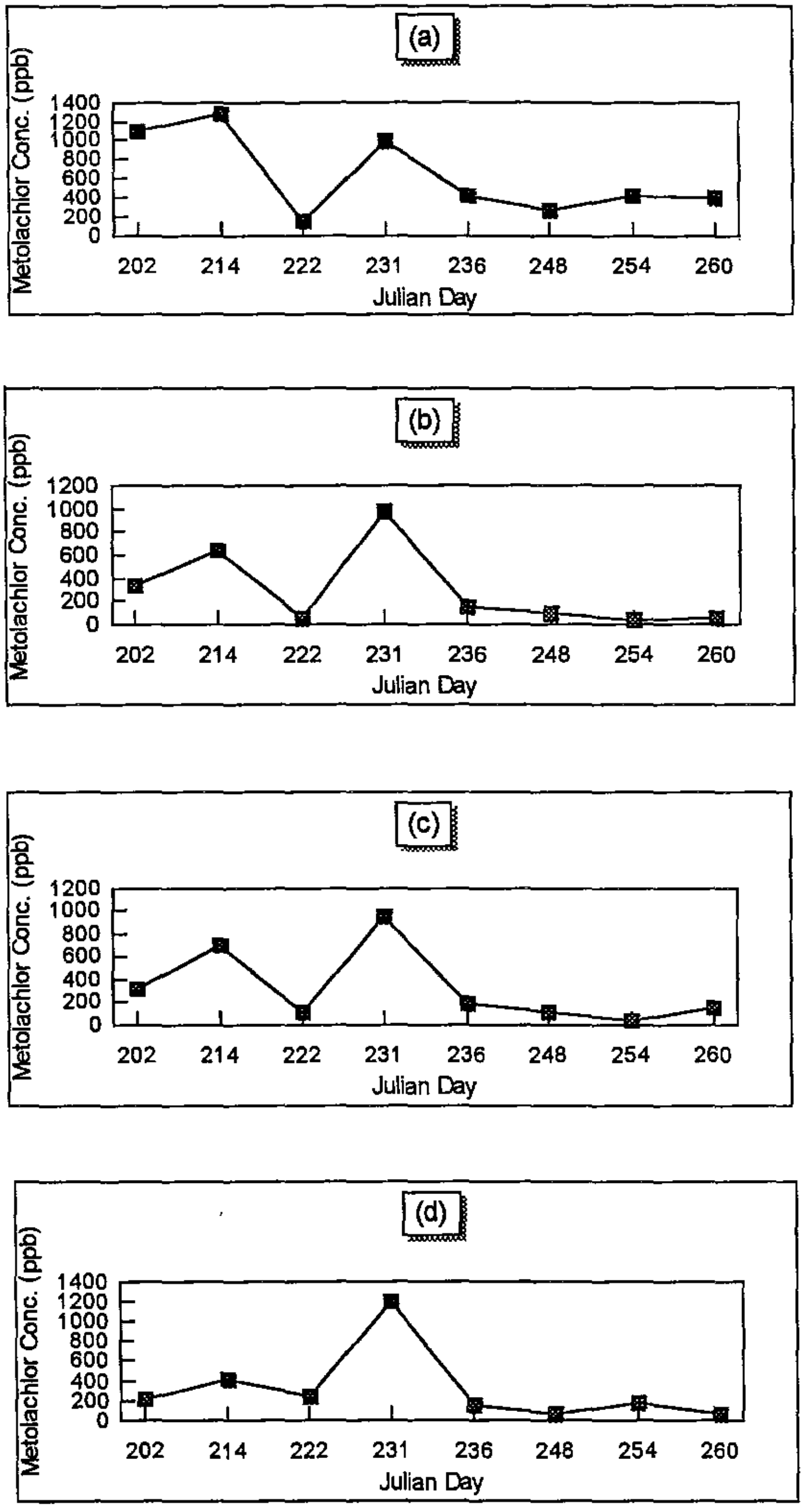


Figure 11. Metolachlor Concentration Versus Time for the 1994 Growing Season and Irrigation Level Equals 0.3 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

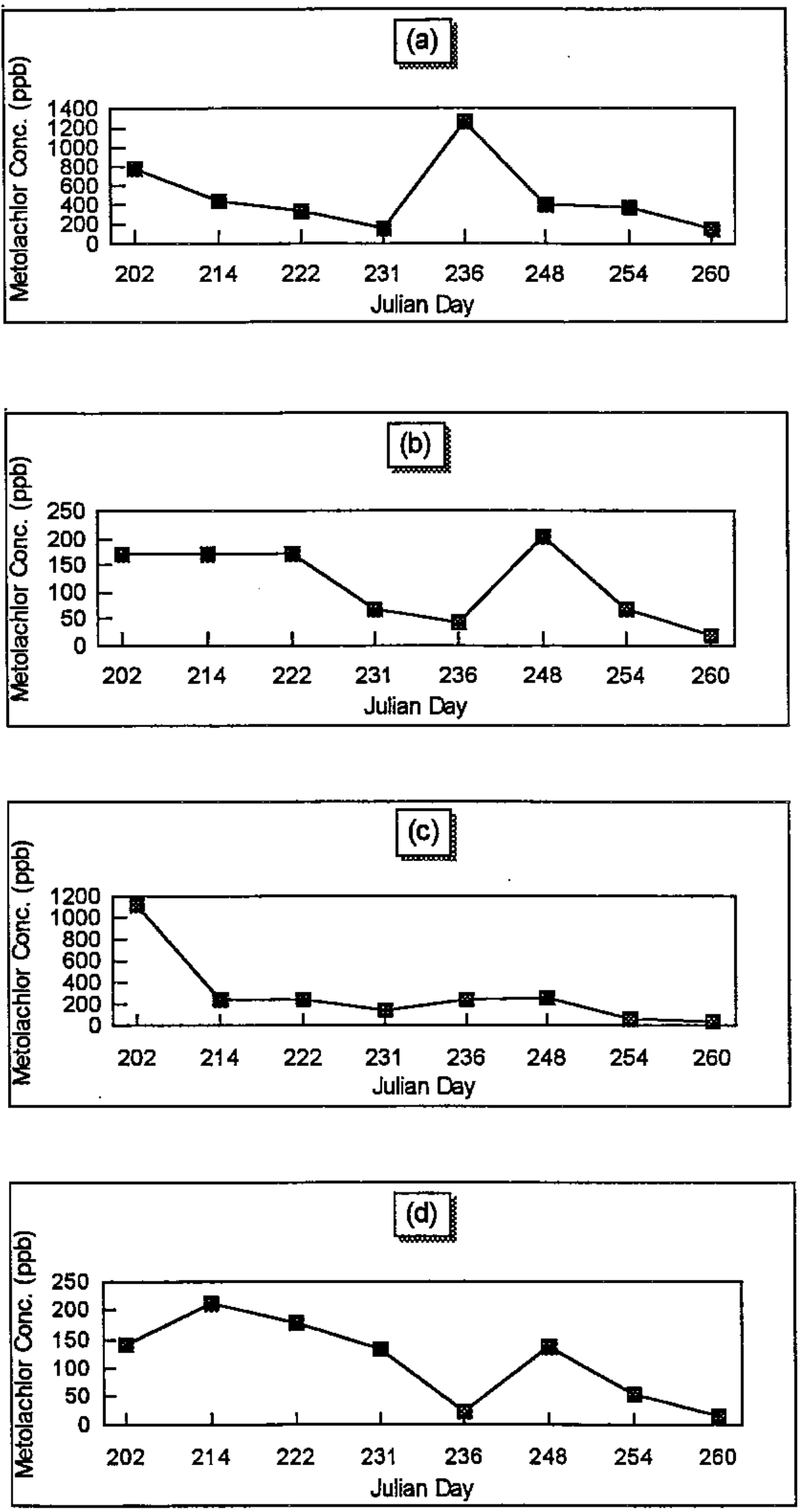


Figure 12. Metolachlor Concentration Versus Time for the 1994 Growing Season and Irrigation Level Equals 0.6 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

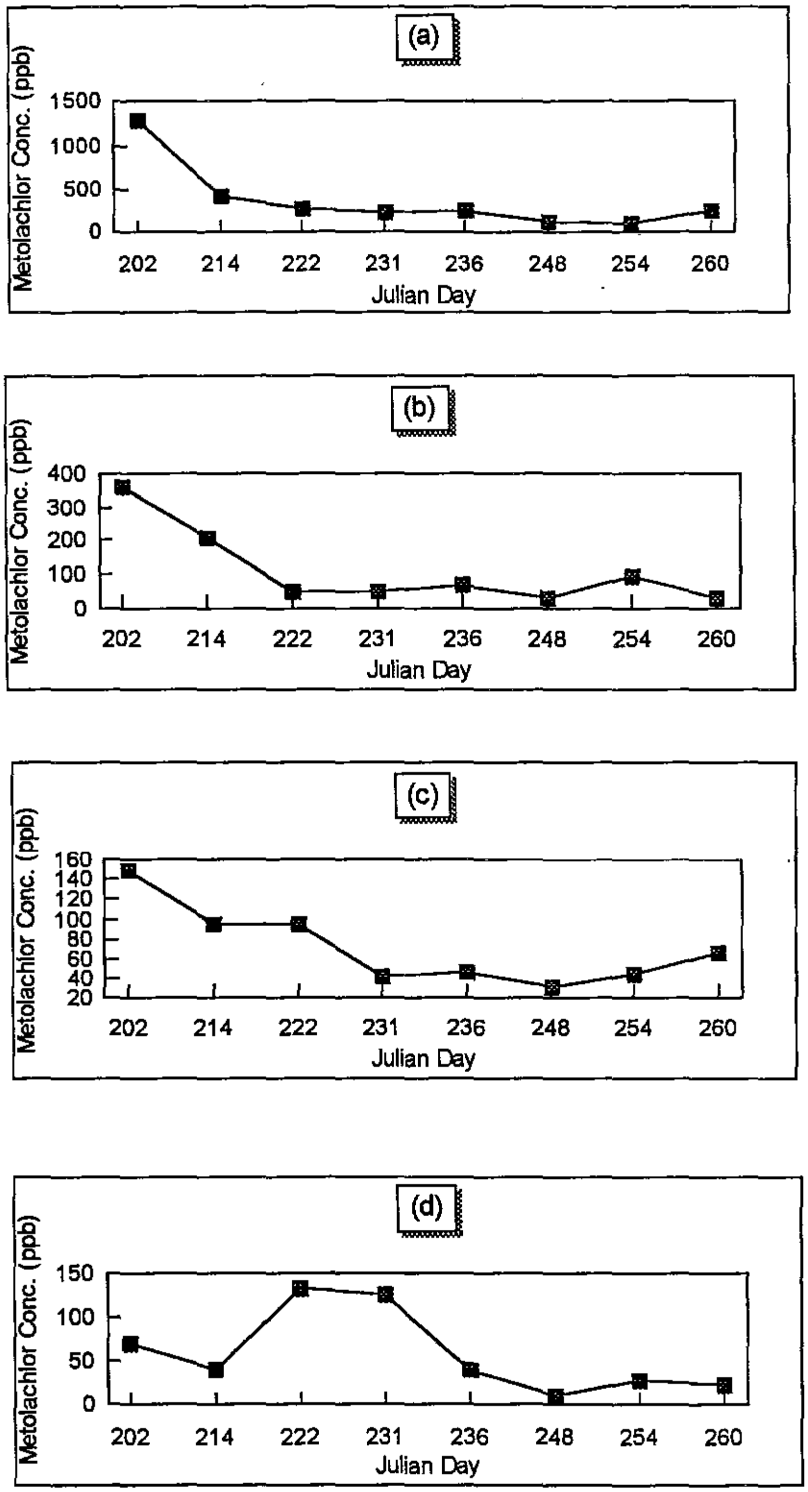


Figure 13.Metolachlor Concentration Versus Time for the 1994 Growing Season and Irrigation Level Equals 1.2 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

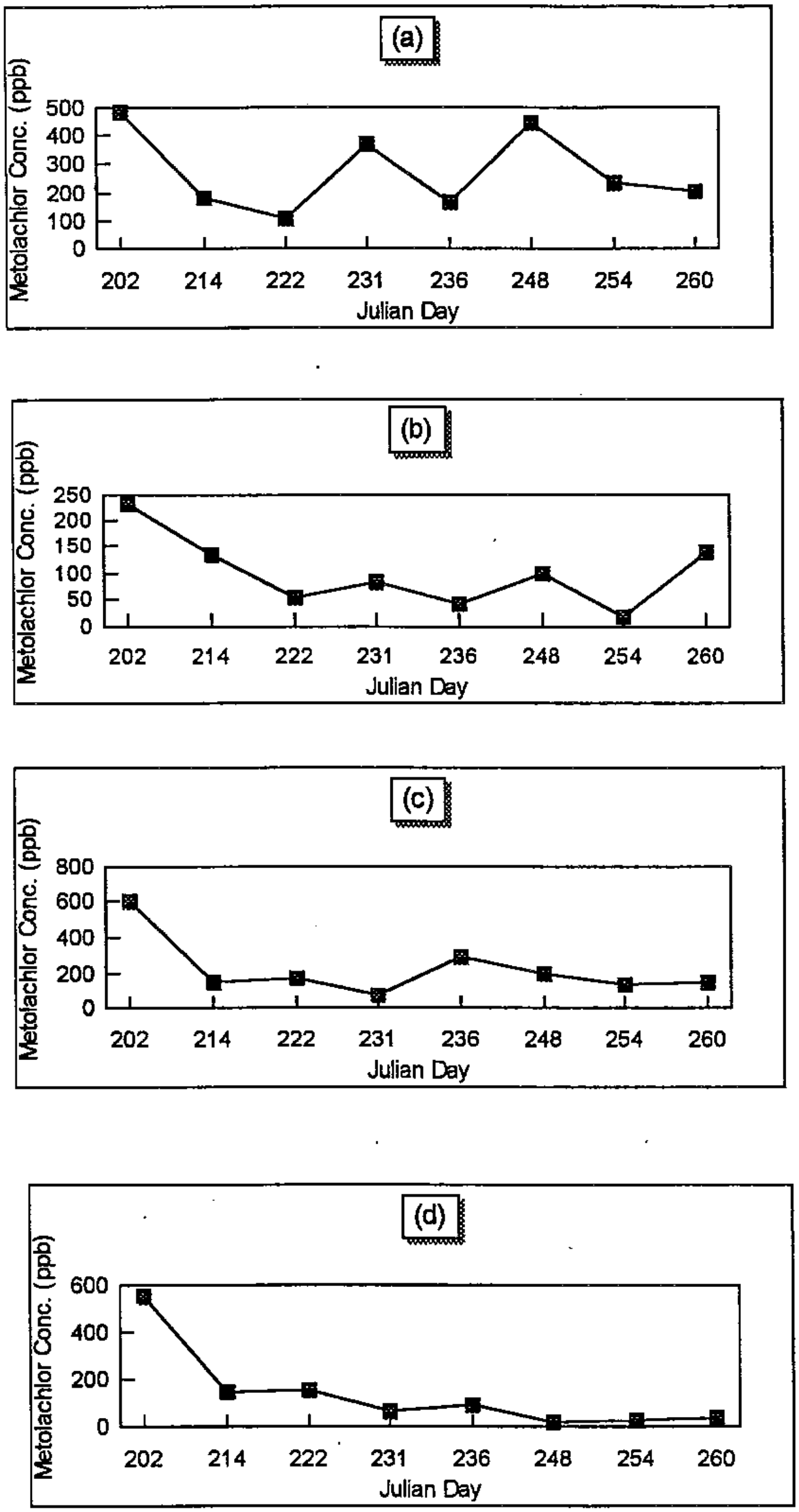


Figure 14. Metolachlor Concentration Versus Time for the 1994 Growing Season and no Irrigation.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

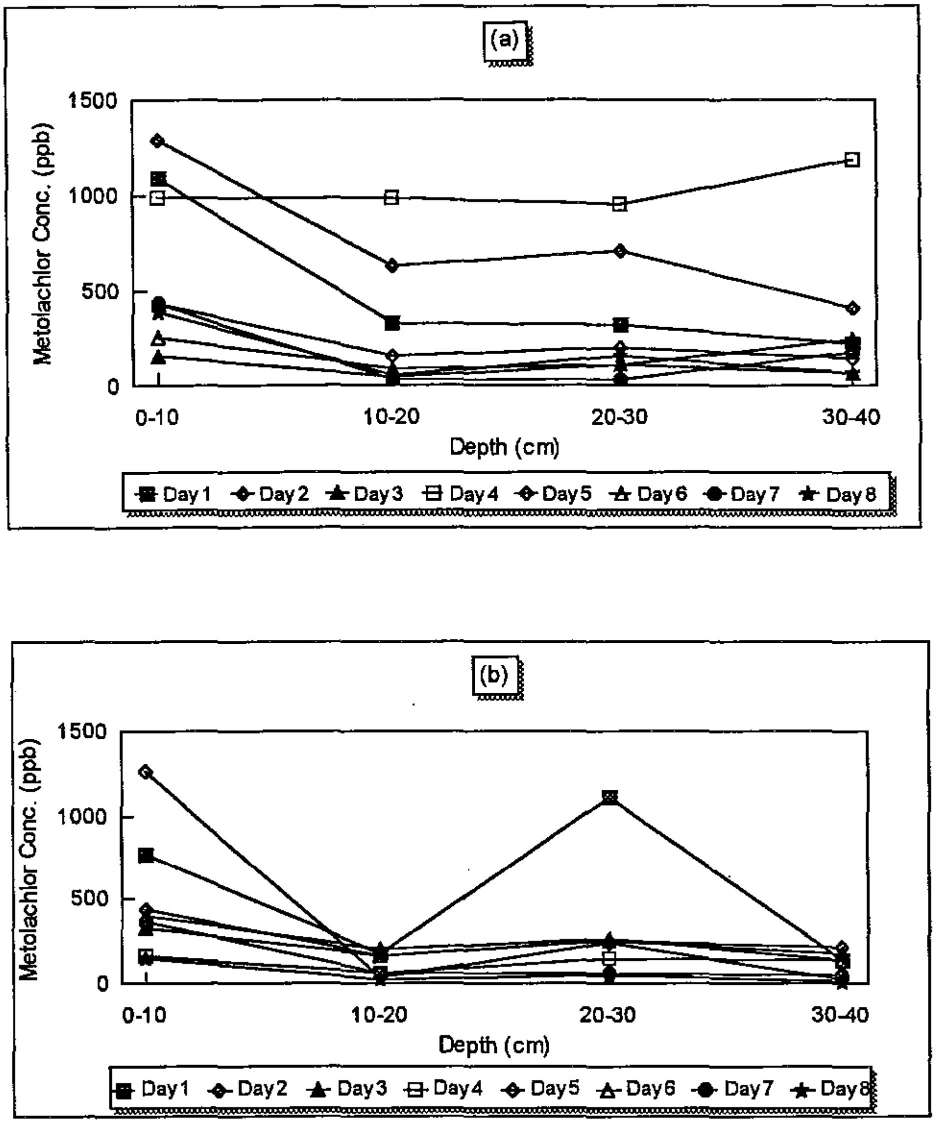


Figure 15. Metolachlor Concentration Versus Depth for the 1994 Growing Season. (a) Irrigation Level Equals 0.3 Times Actual ET; (b) Irrigation Level Equals 0.6 Times Actual ET.

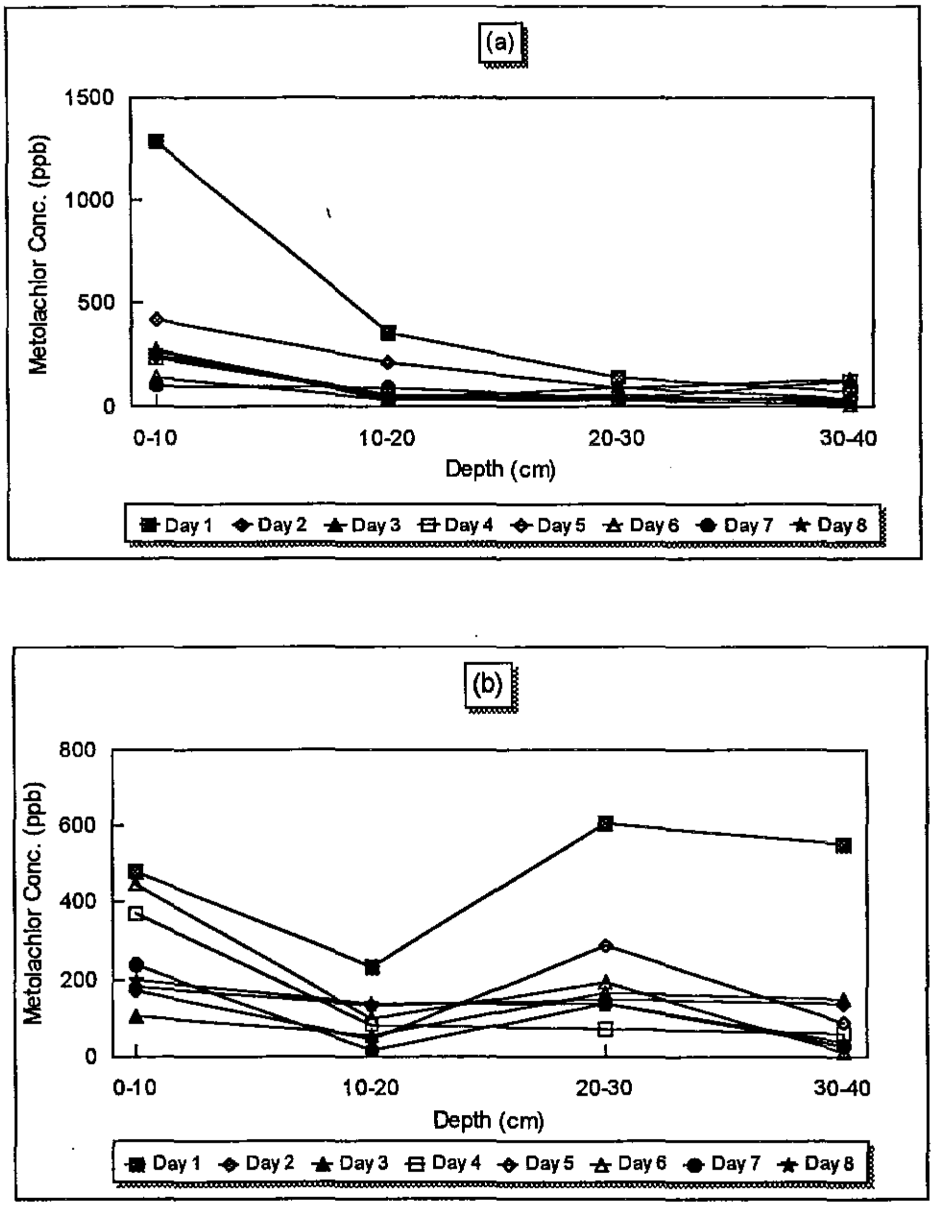


Figure 16. Metolachlor Concentration Versus Depth for the 1994 Growing Season. (a) Irrigation Level Equals 1.2 Times Actual ET; (b) No Irrigation.

times ET irrigation treatment (Figures 5a and 5 b). This detection could be due to a sampling or experimental error. Sampling are collected over an interval and not a specific depth (ex: 0-10 cm). That is what we observe in Figure 5b. Later in the growing season, pesticide concentrations showed a similar trend irrespective of irrigation amount applied.

Leaching of the pesticide was observed in all lysimeters, even in the no irrigation treatment due to rainfall occurring the second week after application in 1993 (Appendix A1). After that, leaching ceased and was not observed even in irrigation treatment 3 (the 1.2 times ET treatment). In this treatment leaching was expected since the amount of applied water exceeds actual evapotranspiration. One possible explanation for this involves the sampling procedure. Each soil sample collected from a lysimeter is a composite sample made from four cores taken randomly from different parts of the lysimeter. In areas closer to the emitters, metolachlor could have leached deeper than in areas more distant from the emitters.

In all irrigated treatments in 1993, metolachlor was leached to deeper depths at the beginning of the season than later in the season. Even in the zero irrigation treatment pesticide leached to below 30 cm in the soil profile. Pesticide leaching was not due to irrigation water, but rather to rainfall occurring shortly after pesticide application and continuing throughout the growing season (Appendix A1). Rainfall leached the pesticide to lower depths and even out of the soil profile. After such rains, metolachlor was detected in the drainage water. Metolachlor was not detected in the drainage water during periods without rainfall.

In the no irrigation treatment, pesticide leached to lower depths after each rainfall event. This is apparent in Figure 8 and Appendix A1. In other treatments, pesticide leaching increased with time with the exception of the 10-20 cm profile in the 1.2 times actual ET treatment. There, metolachlor concentration was high at Julian Day 251. The cause for this could be an error in sampling.

Figures 9 and 10 show pesticide concentration versus depth for the four irrigation treatments in 1993. Again, these figure indicate that irrigation treatments did not affect pesticide leaching although some increase in metolachlor concentration with depth was observed.

At the beginning of the 1994 season, soil analysis indicated that metolachlor was present at all depths in all lysimeters. Metolachlor residues remained in the soil profile from the 1993 season. The amount of metolachlor added to the soil at the beginning of the 1994 season was per label recommendations and did not consider what might be present in the soil at the time of application. This does not interfere with the objectives of the experiment. Pesticide mobility and half-life determination is affected by the total amount of the chemical present in the soil at a particular time rather than the amount added or previously existing in the soil profile. Therefore, the more existing the better.

Metolachlor distribution in the lysimeters in 1994 show the same trend as 1993. Irrigation treatment has no significant effect on pesticide distribution. Rainfall (Appendix A2) in 1994 again affected pesticide mobility as observed in the zero irrigation treatment (Figure 14). Figures 15 and 16 show metolachlor distribution with depth. Metolachlor concentration increased with depth in all irrigation treatments indicating that rainfall is the primary factor in chemical leaching. Also, sampling error and uniformity of application could have caused variation in pesticide concentration at the soil surface.

1. Metolachlor Degradation

a. Metolachlor Half-Life

Table 4 shows computed metolachlor half-life in days for the 1993 and 1994 growing seasons and for the different irrigation treatments. These values are close to those reported in the literature for different soils. Although, the 1994 half-life seem slightly higher than the 1993, in both years, the difference between irrigation treatments is small.

	Growing Season 1993	1994
Irrigation Treatment 1	18.9	21.23
Irrigation Treatment 2	13.87	15.02
Irrigation Treatment 3	14.31	25.25
Irrigation Treatment 4	12.21	20.58

Table 4. Metolachlor Half-Life

Chemical half-life depends not on initial pesticide concentration, but on temperature, soil, and pesticide effects (Bouchard et al, 1982). At higher temperatures, degradation occurs more rapidly. Different soils have different degradable potentials. Microbial activities play an important role in pesticide degradation. For this particular soil and Cache Valley, Utah, climatic conditions, a metolachlor half-life of 12-25 days is appropriate.

b. Adsorption

The adsorption isotherm was used to determine the soil water partitioning coefficients of metolachlor. Linear regression analysis was performed to determine whether this isotherm is linear or nonlinear. It was found that the metolachlor adsorption isotherm is linear when plotted using the logarithmic form of the Freundlich equation $\text{Log}(S) = 1/n\ \text{Log}(C) + \text{Log}(K)$. S is the adsorped concentration and C is the unadsorped, or the solution concentration. The values of C and S were determined in the laboratory as discussed in the material and methods section. The K value was determined by plotting the logarithmic of the adsorped and unadsorped concentrations and determining the Y-intercept.

Average K values from two replicates are presented in Table 5. Adsorptivity did not differ with depth. This was expected because the organic matter content of the soil did not differ with depth. Of all soil properties, organic matter most influences adsorption, followed by cation exchange capacity (Weber and Peter, 1982).

Soil Depth (cm)	Lysimeter 1	Lysimeter 2
0-30 cm	0.57	0.4
30-50 cm	0.21	0.45

Table 5. Partitioning Coefficient for Metolachlor in Lysimeters for 0-30 and 30- 50 cm soil depth.

Soil Depth (cm)	FC	PWP	OC	Bulk Density
0-25	0.168	0.066	1.86	1.65
25-50	0.184	0.072	1.66	1.61

Table 6. Field Capacity (FC), Permanent Wilting Point (PWP), Percent Organic Carbon (OC), and Bulk Density for the Kidman Fine Sandy Loam Soil

B. 2,4 -D Distribution in the Soil Profile.

1. 2,4-D Degradation

2,4-D concentration in the soil profiles for 1993 and 1994 are shown in figures 17 through 22. Again, irrigation treatment did not affect 2,4-D concentration and mobility. For irrigation treatment 1, the amount of applied water is 0.75 times actual evapotranspiration. This amount is insufficient to satisfy crop water requirement and cause chemical leaching. Irrigation treatment 2, or 1.2 times actual evapotranspiration, showed a slightly different trend. More pesticide was detected at lower depths although it is unclear whether irrigation water or rain is the cause.

The turf was irrigated using drip irrigation. If rain did not occur during the growing season, 2,4-D mobility and distribution in the soil profile would have been different than it was.

Figures 17 and 18 show 2,4-D concentration versus time for the 1993 irrigation season. No clear trend in 2,4-D distribution is observed from these figures. The chemical was applied to well established turf. Some 2,4-D might have volatilized and some might have stayed on the soil surface and moved into the soil at a later time. In Figures 19 and 20, 2,4-D concentration in the top 10 cm increased in the second day of sampling indicating a time lag between pesticide application and detection. In the 1994 season the same trend was observed. Irrigation treatments did not affect pesticide leaching. Moreover, there seemed to be a similar time lag as during 1993 between pesticide application and detection in the top 10 cm.

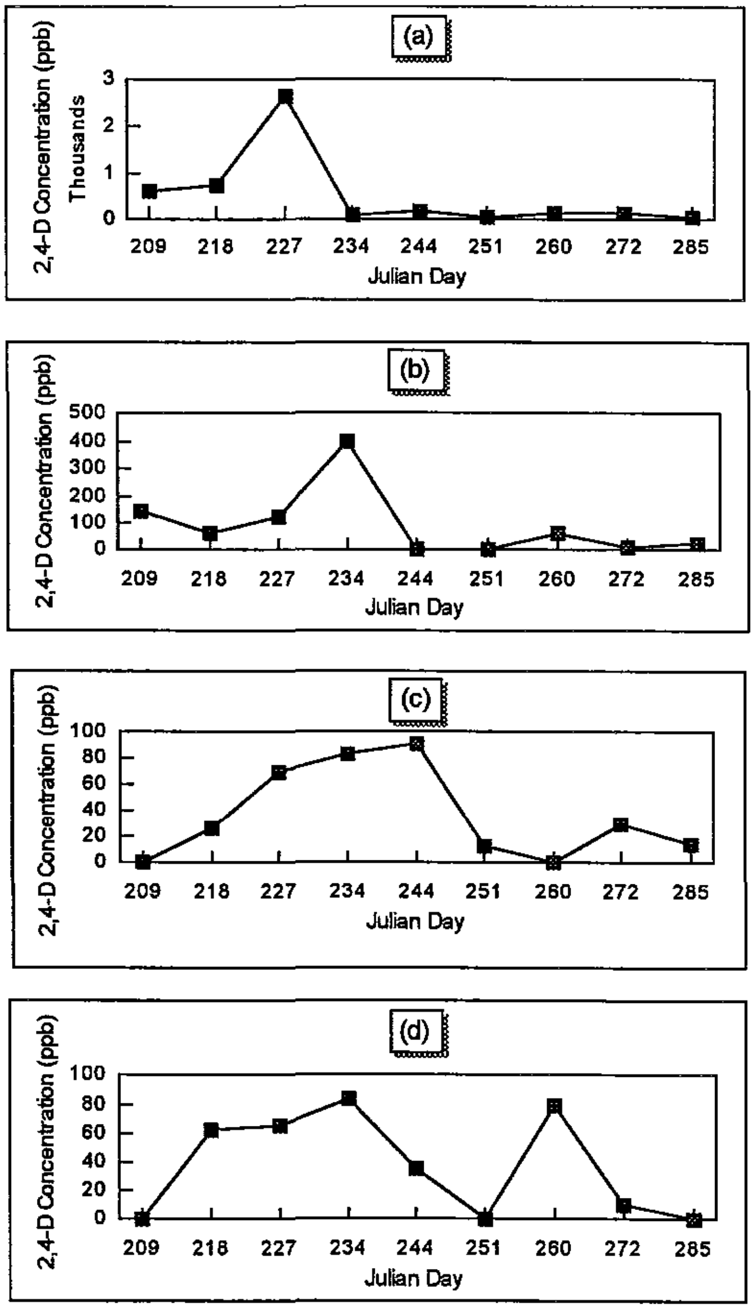


Figure 17. 2,4-D Concentration versus Time for the 1993 Growing Season and Irrigation Level Equals 0.75 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

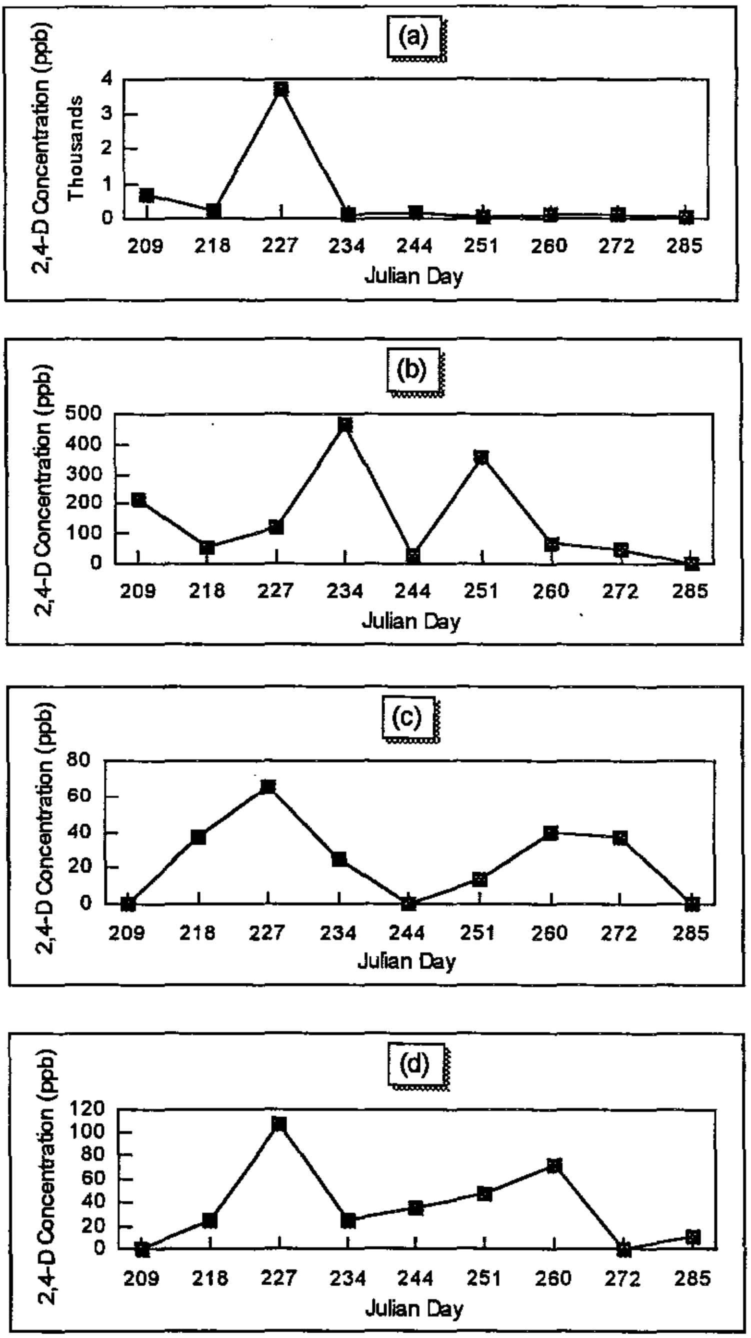


Figure 18. 2,4-D Concentration versus Time for the 1993 Growing Season and Irrigation Level Equals 1.2 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

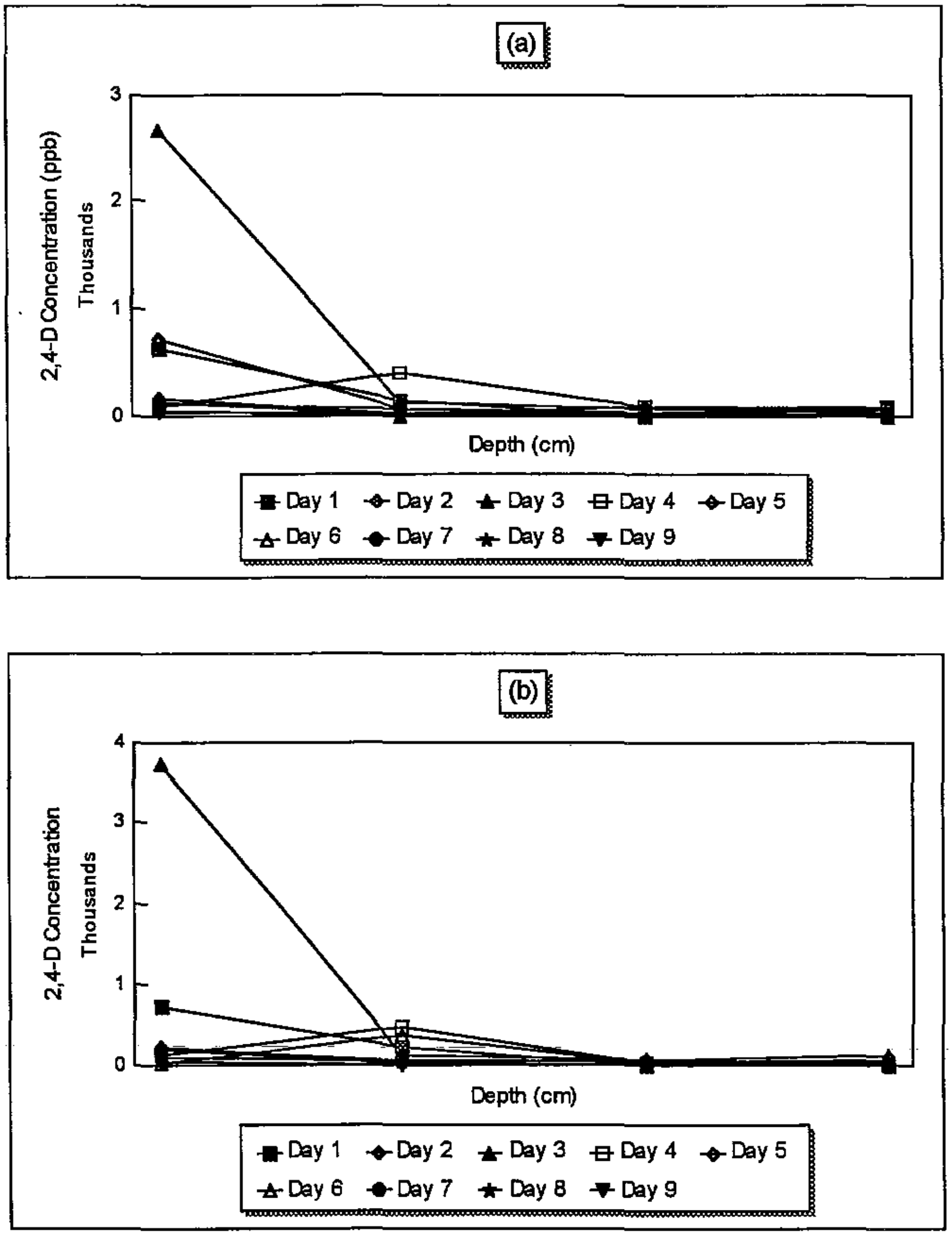


Figure 19. 2,4-D Concentration Versus Depth for the 1993 Growing Season.
(a) Irrigation Level Equals 0.75 Times Actual ET; (b) Irrigation Level Equals 1.2 Times Actual ET.

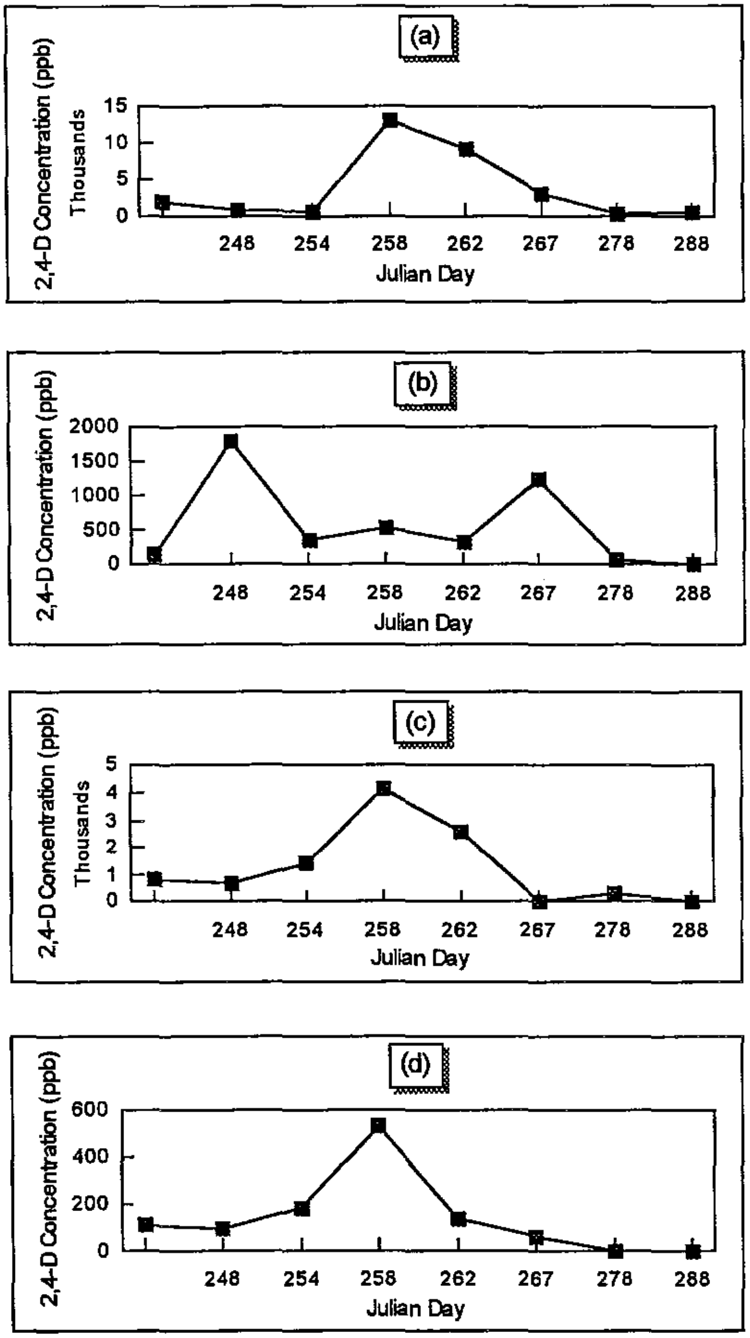


Figure 20. 2,4-D Concentration versus Time for the 1994 Growing Season and Irrigation Level Equals 0.75 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

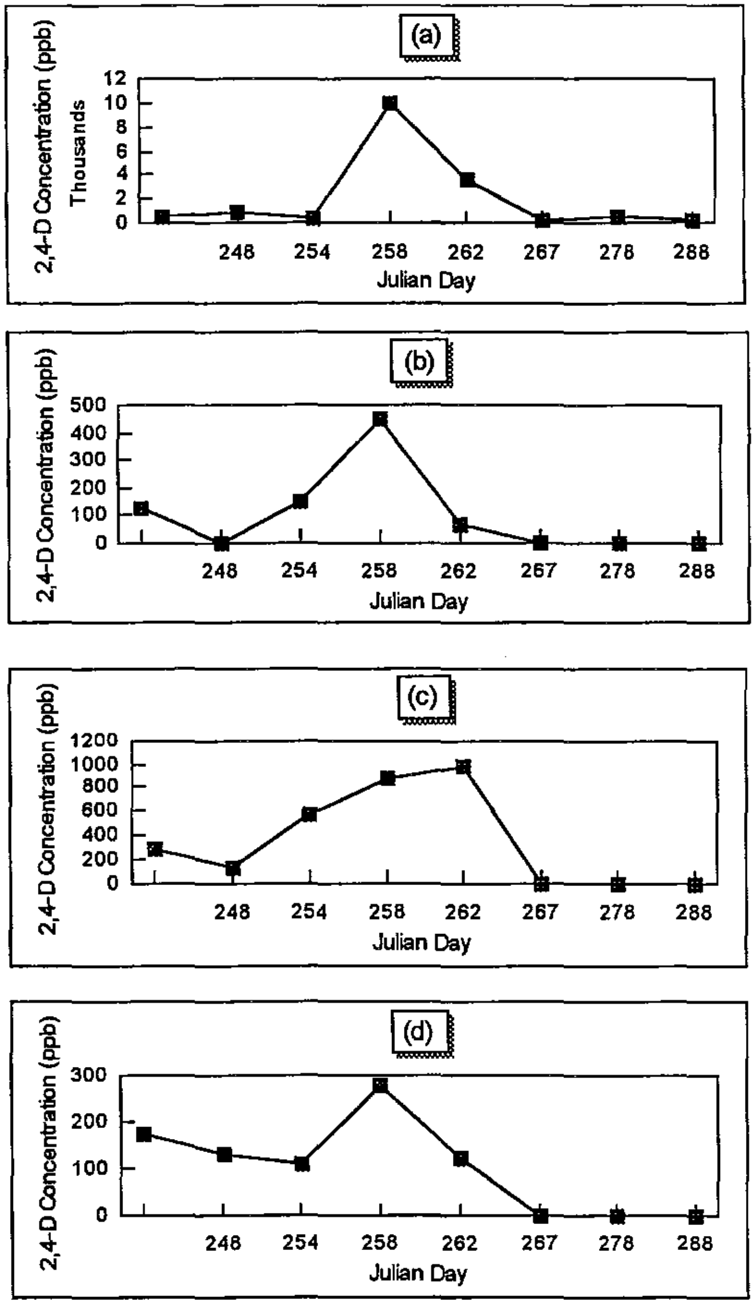


Figure 21. 2,4-D Concentration versus Time for the 1994 Growing Season and Irrigation Level Equals 1.2 Times Actual ET.
(a) 0-10 cm Depth; (b) 10-20 cm Depth; (c) 20-30 cm Depth; (d) 30-40 cm Depth.

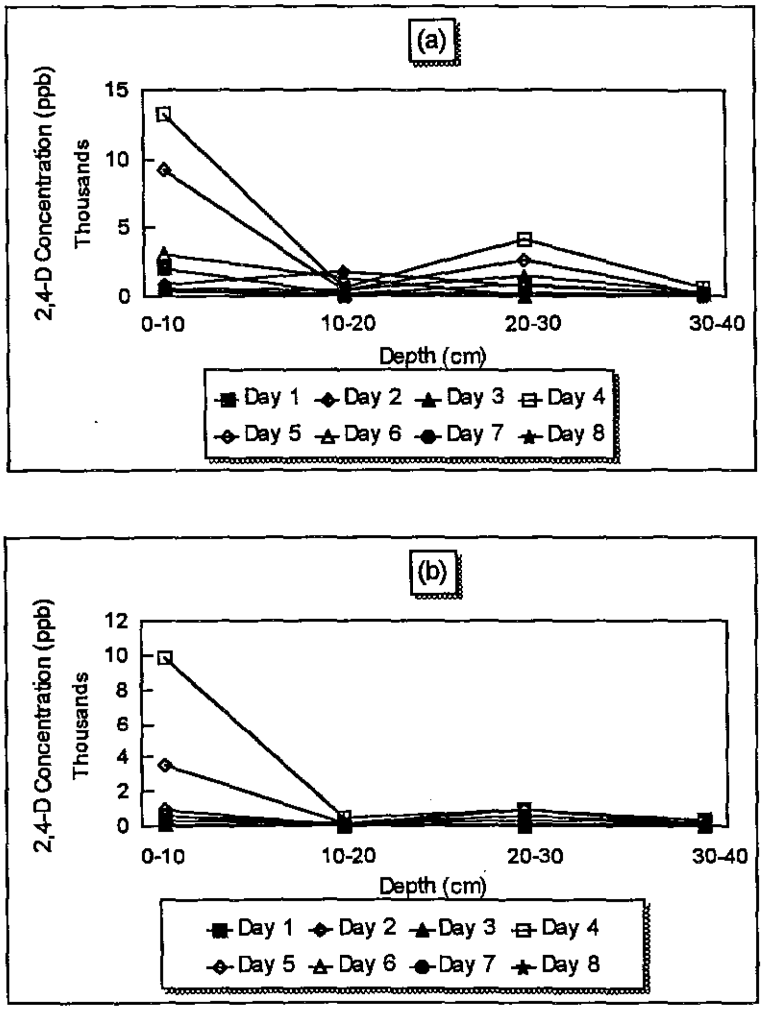


Figure 22. 2,4-D Concentration Versus Depth for the 1994 Growing Season.
(a) Irrigation Level Equals 0.75 Times Actual ET; (b) Irrigation Level Equals 1.2 Times Actual ET.

a. 2,4-D Half-Life

The half-life of 2,4-D was determined using the same procedure as for metolachlor. The half-life of 2,4-D is 18.26 and 18.22 days for irrigation treatments 1 and 2 respectively in 1993. In 1994, the half-life of 2,4-D is 18 and 16 for irrigation treatments 1 and 2 respectively. Water levels have no significant effect on 2,4-D degradation in either year.

b. Adsorption of 2,4-D.

Samples analyzed for 2,4-D adsorption did not reveal any pesticide concentration remaining in the solution even when using a stock solution 100 times more concentrated than those reported in the literature. This could be the result of either the easy volatilization of 2,4-D or the inaccuracy of the test kit used in the analysis. It is recommended that future 2,4-D adsorption studies be made using a different procedure.

C. Statistical Analysis

Statistical analysis was performed using the F-test at the 0.05 confidence level to see the effect of water level, depth, and time of application on metolachlor and 2,4-D concentrations in the soil. Statistical analysis was also used to study the effect of two and three way interactions on pesticide mobility and distribution. Two way interactions involve interactions between time and depth, time and water level, and water level and depth. The three way interaction involve, the effects of depth, time, and irrigation amount on pesticide concentration. Three way interaction is not discussed here because of the complexity in interpreting the results.

Table 7 shows whether irrigation amount, time, and depth have any significant effect on metolachlor and 2,4-D concentrations at the 0.05 confidence level. Irrigation amount did not significantly affect metolachlor concentration in 1994 but did in 1993. Time has a significant effect on metolachlor concentrations in 1993 but not in 1994. Metolachlor concentrations vary significantly with depth in both years.

Irrigation amount did not significantly effect 2,4-D concentration in either year. The concentrations of 2,4-D at each depth are significantly different between replicates for both irrigation treatments in both years. The chemical showed the same trend with time and no significant differences occur between replicates. The interaction between water level and depth was significantly different for metolachlor and 2,4-D in both years.

	Corn		Turf	
	1993	1994	1993	1994
Water Level	SD	NSD	NSD	NSD
Soil Depth	SD	SD	SD	SD
Time	SD	NSD	NSD	NSD
W. LevelxDepth	SD	SD	SD	SD
W. LevelxTime	SD	SD	NSD	SD

Table 7. Statistical Analysis for Corn and Turf.
SD: Significantly Different at 0.05 Level
NSD: Not Significantly Different at 0.05 Level

D. Model Application.

Soil and pesticide parameters determined in this experiment were used in a simulation model to see the effect of irrigation practices on pesticide leaching in Cache Valley, Utah.

Since there is no available data on applied irrigation amounts, a wide range of irrigation amounts were simulated. The crop simulated is corn. No irrigation amounts less than actual evapotranspiration were simulated because it is assumed that actual irrigation practices always apply more water than required to crops to obtain better yield.

The pesticide simulation model used is a regression version of CMLS developed at Utah State University. That simulation/optimization model can maximize crop yield while preventing pesticide leaching using a regression approach. The model was applied in purely simulation mode using the metolachlor parameters determined in the field experiment, the same soil parameters, and the measured rainfall.

The leaching simulations employed a three day irrigation frequency. The simulated irrigation amounts are a function of ET as measured by the weather station. The first simulation run was performed with an irrigation amount equal to potential ET. Subsequent simulations were performed by increasing the amount of applied water 1 mm more than potential ET at every irrigation for each simulation. A total of 50 simulations were performed.

Figure 23 gives the depth the pesticide leached as a function of cumulative irrigation applied. The first irrigation equals crop potential ET (901 mm). According to the model, this irrigation amount plus rainfall would leach the pesticide to 2.47 feet. Considering the two-foot (0.61 m) lysimeter depth, pesticide leaching is expected even in treatments that received water less than potential ET.

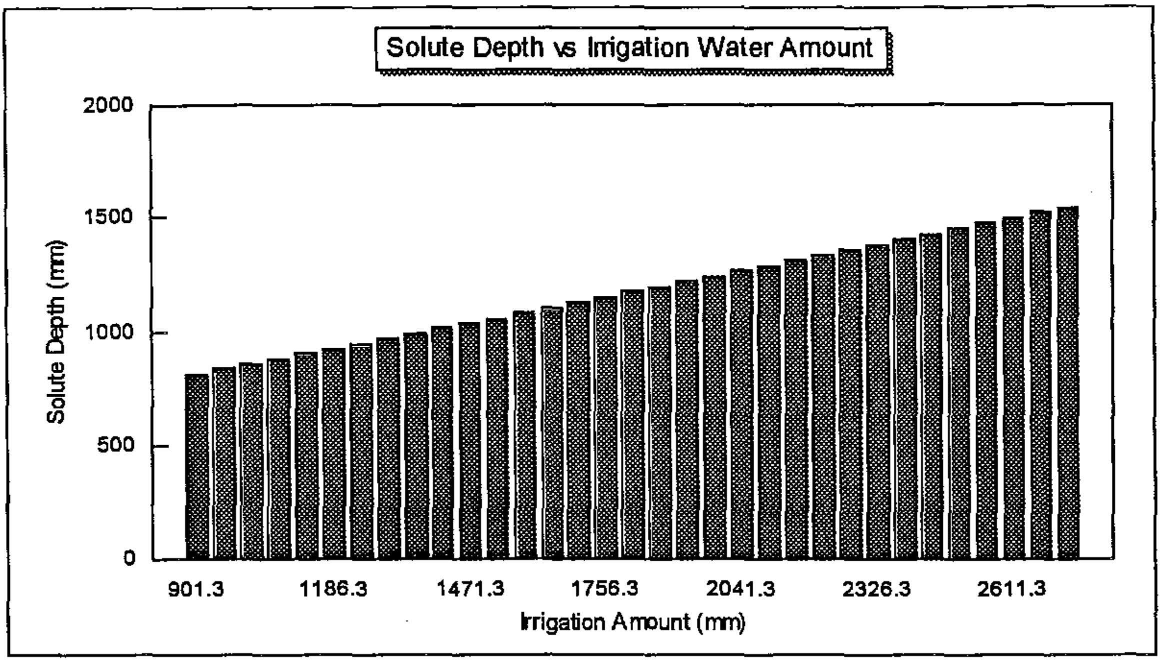


Figure 23. Solute Depth versus Seasonal Irrigation Quantity as Computed by Model

CHAPTER V

VI. SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. Summary and Conclusion

We performed a field lysimeter experiment in the River Laboratory, Logan, Utah during summers of 1993 and 1994 to study the mobility, degradation, and persistence of two commonly applied herbicides under a range of irrigation practices. Metolachlor was applied to sweet corn, 2,4-D was applied to turf. The experimental design consists of four irrigation treatments applied to corn and two irrigation treatments applied to turf. The irrigation amounts applied were based on actual crop evapotranspiration. The irrigation amounts applied to corn for treatments 1-4 are: 0.3, 0.6, 1.2, and 0 times actual evapotranspiration respectively. The irrigation amounts applied to turf are: 0.75 and 1.2 times actual evapotranspiration for treatments 1 and 2 respectively. Each treatment is replicated three times.

Each lysimeter was irrigated two times a week. Soil moisture content was measured at five depths before and after irrigation to monitor soil water fluctuations. Soil samples were collected at four depths once a week after irrigation to determine pesticide concentration in the soil. Drainage water was also analyzed for pesticide concentration.

Analysis of pesticide concentration was performed using Immunoassay Test Kit (RaPID Assay, by Ohmicron). Irrigation amount did not significantly affect pesticide mobility in the soil, because of the amount of applied water. Pesticide distribution in the profile was more affected by rain than by irrigation. Several rainfall events early in the season in the first year leached the pesticide to lower depths.

Half-life for metolachlor was determined to be between 14 and 25 days. Half-life for 2,4-D was determined to be between 18 and 16 days. The adsorption coefficient (K) for metolachlor was between 0.4 and 0.5.

This field experiment indicates that good irrigation management is essential to reduce pesticide leaching to groundwater. If given enough time in the soil, pesticides will degrade and will not reach groundwater in toxic amounts. The trickle irrigation system used in this study was efficient in minimizing pesticide leaching. Had rain not occurred early in the season we might not have not observed pesticide at greater depths.

Efforts to manage nonpoint source pollution require managing chemical application amount, type and frequency as well as water application. Good management practices could minimize if not prevent groundwater pollution. Unmanaged irrigation application increases the potential for groundwater contamination.

B. Recommendations

As a result of this study we recommend the following.

1. An extension program should be implemented to educate water users and homeowners how to more efficiently irrigate crops and lawns to prevent pesticide leaching to groundwater.
2. Extension personnel and state representative could use model predictions in extension programs to educate water users on management strategies that minimize non-point source pollution.

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Appendix A1

	Date	Temperature (C°)		RH(%)		Raim(mm)	Wind 2m (m/s)	SR (ly)	Soil Temp. (C°)
		Max	Min	Max	Min				
RiverLab	2 2893	-2.62	-16.3	84.6	46.23	0	76.8	386.2	1.031
RiverLab	3 193	-1.93	-15.8	84.6	47.47	0	75.5	339.6	.909
RiverLab	3 293	4.638	-13.1	84.2	39.72	0	80.8	309.5	.91
RiverLab	3 393	.327	-10.7	83.4	49.39	0	150.9	339	.729
RiverLab	3 493	1.862	-13.6	83.3	47.27	0	90	351.2	.823
RiverLab	3 593	5.142	-7.43	83.1	45.7	0	82.3	325.1	.87
RiverLab	3 693	8.46	-4.01	82.4	43.56	0	80.1	383.2	.987
RiverLab	3 793	7.24	-4.59	82.5	50.62	0	119.4	361.9	1.173
RiverLab	3 893	4.406	-4.09	82.2	70.8	0	91.4	265.6	1.209
RiverLab	3 993	2.631	-3.78	84.8	76.1	0	78.2	167.2	1.126
RiverLab	3 1093	4.019	-1.35	87.2	75.9	14.73	70.2	126.4	-2.5
RiverLab	3 1193	3.671	-5.33	86.1	51.16	5.08	106.6	344.2	-1.58
RiverLab	3 1293	-.17	-7.51	70.9	37.75	0	191.4	445.1	.957
RiverLab	3 1393	.749	-6.28	75.2	49.36	0	95.7	213.3	1.159
RiverLab	3 1493	5.453	-2.47	81.4	51.14	7.11	82.1	121.6	-.659
RiverLab	3 1593	7.91	.788	80.6	49.69	3.048	141.9	155.4	-1.44
RiverLab	3 1693	8.78	2.746	78.3	49.32	1.016	153.8	105.8	.817
RiverLab	3 1793	10.82	3.209	80.3	67.15	20.57	127.9	117.8	-.646
RiverLab	3 1893	9.26	3.093	80.1	60.4	2.032	80.4	154.6	1.072
RiverLab	3 1993	12.15	2.439	79.9	48.66	0	161.7	310.2	2.849
RiverLab	3 2093	15.31	1.018	80.7	27.05	0	222.6	345.2	2.813
RiverLab	3 2193	10.7	-1.43	81	17.82	0	150.1	499.8	2.49
RiverLab	3 2293	15.18	1.555	44.27	20.02	0	274.2	504.9	4.107
RiverLab	3 2393	19.88	2.823	51.4	14.24	0	343.5	517.6	6.441
RiverLab	3 2493	19.69	7.32	78.9	15.79	4.572	369	281.2	6.487
RiverLab	3 2593	19.37	5.997	79.1	17.85	1.27	276.7	351.8	6.634
RiverLab	3 2693	16.98	6.622	76.9	35.77	1.016	231.4	292	7.84
RiverLab	3 2793	15.64	6.583	78.9	41.98	0	195.7	302.5	8.34
RiverLab	3 2893	11.42	6.192	79.5	54.27	0	119.8	144.8	8.14
RiverLab	3 2993	11.42	4.019	80.4	42.3	5.842	183.9	241	5.759
RiverLab	3 3093	9.85	-.055	81.8	32.73	2.794	156.3	418.5	6.116
RiverLab	3 3193	13.51	.788	63.29	17.34	0	273.3	505.1	7.03
RiverLab	4 193	17.63	1.901	80.5	20.14	13.2	276.2	348.1	6.308
RiverLab	4 293	4.251	.519	80.8	75.6	12.44	86.5	88.8	2.793
RiverLab	4 393	11.38	.212	80.6	40.37	0	258.9	366.5	6.167
RiverLab	4 493	13.88	3.131	80.7	42.39	11.17	264.5	205.4	5.641
RiverLab	4 593	8.35	.212	80.6	43.04	0	152.3	351.3	6.289
RiverLab	4 693	8.07	-1.58	81.3	22.2	0	131.3	384.3	6.759
RiverLab	4 793	11.22	-.323	72.7	21.12	0	243.4	493.8	6.079
RiverLab	4 893	14.21	.711	62.33	20.27	0	303.8	545.5	6.344
RiverLab	4 993	13.34	2.131	80.7	22.5	8.38	168	96.9	4.763
RiverLab	4 1093	12.81	.097	79.8	17.94	0	249.4	509.1	6.572
RiverLab	4 1193	8.94	-1.81	80.7	22.57	0	116.4	426.2	7.28
RiverLab	4 1293	6.7	-1.32	81.6	36.97	15.49	89.1	315.6	4.571
RiverLab	4 1393	8.82	-.323	81.1	28.2	.254	128.8	440	5.728
RiverLab	4 1493	11.34	.021	52.46	20.45	0	312.1	528.7	6.561
RiverLab	4 1593	11.99	.749	78.7	23.51	.762	186.2	364	7.08
RiverLab	4 1693	14.05	3.594	80.2	17.54	2.54	172.3	521.9	7.64
RiverLab	4 1793	17.37	5.53	74.9	18.14	1.524	268.5	453	8.41
RiverLab	4 1893	9.69	.596	80.2	38.05	8.38	195.2	274.6	6.673
RiverLab	4 1993	10.86	1.939	78.3	22.37	.254	165.9	450.7	8.18
RiverLab	4 2093	13.14	1.056	42.52	17.73	0	260.8	559.2	8.55
RiverLab	4 2193	19.78	7.05	44.94	14.45	0	322.3	476.3	8.47
RiverLab	4 2293	18.3	5.219	80.2	17.13	1.778	237.8	326.3	6.729

RiverLab	4	2393	11.26	.212	80.2	20.36	1.778	120.3	463.8	9.02
RiverLab	4	2493	9.14	2.939	80.6	44.39	6.604	136.5	256.3	8.75
RiverLab	4	2593	16.07	4.057	69.71	17.68	.254	268.7	579.1	9.95
RiverLab	4	2693	16.85	1.555	79.7	22.83	4.572	212.2	393.1	10.26
RiverLab	4	2793	13.63	.212	64.84	17.04	0	174.2	671	10.54
RiverLab	4	2893	15.86	2.939	44.67	16.47	0	226.7	673.1	11.33
RiverLab	4	2993	16.11	4.754	80.1	17.74	2.286	218.8	310.5	10.67
RiverLab	4	3093	11.95	2.669	81.4	35.05	.254	133.1	309	10.32
RiverLab	5	193	15.43	2.131	80.9	19.36	0	184.2	665.9	11.25
RiverLab	5	293	17.41	6.504	44.52	20.09	0	265.8	528.1	12.02
RiverLab	5	393	21.85	5.608	80.5	15.07	12.7	278.8	443	11.8
RiverLab	5	493	9.26	1.977	81	53.1	20.32	105.7	263	7.63
RiverLab	5	593	5.725	2.939	80.4	78.3	9.39	72.9	91.7	6.487
RiverLab	5	693	12.64	2.131	80.7	50.63	17.52	160.7	111.2	6.597
RiverLab	5	793	10.86	4.444	78.9	35.8	2.794	115.3	330.7	7.99
RiverLab	5	893	11.18	1.21	80.6	37.71	2.794	154.2	410.5	9.08
RiverLab	5	993	14.84	1.325	80.7	18.46	0	193.3	728	10.61
RiverLab	5	1093	23.02	5.841	44.22	15.79	0	246.1	736	11.16
RiverLab	5	1193	28.04	13.22	25.43	10.94	0	309.8	753	13.7
RiverLab	5	1293	27.64	14.84	16.93	10.97	0	354.2	745	14.48
RiverLab	5	1393	26.54	13.63	34.1	12.13	0	342.8	717	15.42
RiverLab	5	1493	26.16	11.87	39.17	14.89	0	325.2	623.6	15.82
RiverLab	5	1593	24.53	13.18	52.37	16.86	0	221.2	673.5	16.55
RiverLab	5	1693	24.73	10.01	75.3	19.83	.762	214.4	664.3	16.48
RiverLab	5	1793	23.81	9.38	77.2	15.5	0	193.5	713	17.01
RiverLab	5	1893	25.2	10.61	41.47	12.43	0	244.2	708	17.35
RiverLab	5	1993	25.73	12.19	38.32	15.42	0	276	707	16.34
RiverLab	5	2093	27.81	12.97	41.35	13.15	0	327.6	678.8	14.59
RiverLab	5	2193	24.12	13.8	64.75	13.39	0	187.3	632.9	16.67
RiverLab	5	2293	20.11	8.94	76.5	17.23	0	148.2	640.9	16.92
RiverLab	5	2393	21.89	6.856	69.15	13.98	0	205.1	762	17.04
RiverLab	5	2493	25.36	10.61	39.82	14.44	0	247.3	658.4	17.39
RiverLab	5	2593	27.25	14.46	35.46	11.45	0	335.3	723	17.92
RiverLab	5	2693	26.81	14.8	35.48	11.81	0	318.5	689.6	18.1
RiverLab	5	2793	27.7	12.44	31.2	11.1	0	283.4	761	18.23
RiverLab	5	2893	26.92	14.38	27.26	11.65	.508	261.3	687.7	18.51
RiverLab	5	2993	24.12	12.03	48.08	12.61	0	194	722	18.61
RiverLab	5	3093	27.59	10.53	38.62	11.21	0	263.9	727	18.78
RiverLab	5	3193	27.42	14.25	41.91	12.02	0	266.8	483.6	18.38
RiverLab	6	193	21.37	10.33	78.3	17.68	.508	167	632.7	16.76
RiverLab	6	293	20.66	7.28	79.7	18.85	9.39	220.5	328.8	12.89
RiverLab	6	393	11.79	6.348	79.5	66.92	14.22	138.6	226.6	7.95
RiverLab	6	1193	24.48	9.46	78.5	24.87	8.63	257.2	679.2	14.01
RiverLab	6	1293	16.5	3.131	68.64	16.16	0	144.4	797	11.48
RiverLab	6	1393	22.38	4.677	42.72	13.14	0	244.1	797	15.62
RiverLab	6	1493	29.67	9.54	43.42	10.74	0	235.9	768	18.01
RiverLab	6	1593	27.31	14.46	46.48	12.05	0	255.9	632.9	18.49
RiverLab	6	1693	21.27	10.37	62.17	16.94	0	135.3	733	17.02
RiverLab	6	1793	15.14	8.42	73.4	48.84	4.064	163.1	256.1	13.3
RiverLab	6	1893	23.21	11.22	67.1	20.73	.508	165.1	754	14.72
RiverLab	6	1993	26.75	10.94	52.05	13.81	0	268	782	17.47
RiverLab	6	2093	29.91	13.34	44.34	11.44	0	258.2	790	19.25
RiverLab	6	2193	27.36	15.09	54.54	12.48	0	273.1	520.3	19.02
RiverLab	6	2293	21.37	11.42	78.4	13.99	4.064	156.9	660.2	17.66
RiverLab	6	2393	17.54	4.87	78.7	14.82	0	191.1	768	18.48
RiverLab	6	2493	20.38	2.246	78.6	15.7	0	159.9	779	18.15
RiverLab	6	2593	25.41	8.5	42.38	11.89	0	252.9	787	18.79
RiverLab	6	2693	30.83	11.91	36.94	9.76	0	305.6	792	19.65
RiverLab	6	2793	31.7	16.76	33.81	9.67	0	251.8	721	20.59
RiverLab	6	2893	30.03	15.14	38.86	10.57	0	251.1	699.9	21.15
RiverLab	6	2993	22.33	8.98	79.3	11.97	2.286	136.2	767	19.38

RiverLab	6	3093	24.37	8.35	35.68	12.14	0	269.2	773	17.72
RiverLab	7	193	26.75	10.82	29.11	11.89	0	289.6	780	19.2
RiverLab	7	293	29.31	9.57	78.3	11.58	5.08	254.5	566.2	19.26
RiverLab	7	393	18.07	8.82	78.7	24.65	3.048	155.1	431.4	14.82
RiverLab	7	493	17.5	7.56	78.8	35.66	5.08	230.8	398.3	14.33
RiverLab	7	593	22.43	7.99	72.3	15.67	0	253.1	703	16.56
RiverLab	7	693	24.12	7.95	51.73	12.66	0	236.8	777	18.1
RiverLab	7	793	27.03	8.98	61.37	11.23	0	250.1	785	17.07
RiverLab	7	893	24.07	6.778	52.47	12.41	0	205.9	782	18.07
RiverLab	7	993	28.9	10.9	35.97	10.57	0	312	777	17.17
RiverLab	7	1093	28.96	12.72	40.93	10.74	0	217.3	768	18.55
RiverLab	7	1193	28.79	11.06	31.76	10.44	0	278.2	786	16.77
RiverLab	7	1293	26.21	9.97	42.7	11.97	0	205.7	718	16.85
RiverLab	7	1393	25.73	9.5	26.24	11.99	0	248.1	693	17.89
RiverLab	7	1493	28.21	12.81	37.55	10.99	0	217.7	740	18.41
RiverLab	7	1593	26.97	11.75	40.51	12.11	0	181.5	737	17.55
RiverLab	7	1693	23.46	8.9	52.26	15.03	0	180.6	749	18.33
RiverLab	7	1793	26.59	11.26	40.51	11.65	0	241.2	752	18.2
RiverLab	7	1893	26.48	11.06	40.91	11.61	0	213.7	750	19.29
RiverLab	7	1993	30.46	13.47	26.58	10.26	0	303.9	740	19.83
RiverLab	7	2093	29.31	14.55	36.02	10.24	0	269.1	745	19.99
RiverLab	7	2193	22.38	12.32	53.39	16.99	0	191.2	477.5	17.56
RiverLab	7	2293	21.8	10.98	76.5	24.07	1.27	230.4	314	12.72
RiverLab	7	2393	13.76	10.25	79.2	70	30.73	149.5	66.67	-8.34
RiverLab	7	2493	19.83	10.78	78.9	37.91	4.064	147	342.8	10.45
RiverLab	7	2593	24.78	10.17	72	19.04	.762	265.2	502.3	11.78
RiverLab	7	2693	20.48	9.81	78.1	28.84	31.49	151.1	631.9	13.8
RiverLab	7	2793	24.63	9.26	64.6	18.24	0	247.8	739	14.29
RiverLab	7	2893	31.96	12.72	47.35	14.01	0	290.8	713	17.37
RiverLab	7	2993	31.26	18.74	36.98	11.49	0	265.7	482.7	18.61
RiverLab	7	3093	31.45	17.59	33.51	10.37	0	244.1	719	17.93
RiverLab	7	3193	29.67	14.34	44.8	10.94	0	190.9	723	19.7
RiverLab	8	193	30.27	12.93	38.96	9.9	0	255.6	737	18.83
RiverLab	8	293	29.02	13.26	35.28	11.01	.254	245.9	727	19.56
RiverLab	8	393	30.21	16.03	33.53	10.92	0	319.6	711	20.3
RiverLab	8	493	24.94	13.96	75.6	21.65	5.334	282.1	381.8	14.13
RiverLab	8	593	27.53	15.26	67.94	12.94	0	266.8	557.3	17.39
RiverLab	8	693	29.37	14.51	44.44	12.01	0	222.1	632.7	20.31
RiverLab	8	793	27.75	15.05	69.21	18.6	2.794	285.8	324	17.92
RiverLab	8	893	28.73	14.51	62.84	14.61	.254	325.1	681.5	18.19
RiverLab	8	993	30.52	16.5	40.68	12.88	0	303.5	538.5	18.6
RiverLab	8	1093	29.67	17.15	45.08	13	0	245.9	661.9	20
RiverLab	8	1193	28.79	13.22	77.2	16.12	1.524	196.2	653.7	19.07
RiverLab	8	1293	30.39	12.44	76.1	10.06	0	200.9	670.7	20.47
RiverLab	8	1393	27.47	12.36	49.33	12.18	0	233	672.9	20.64
RiverLab	8	1493	29.43	13.84	30.09	10.67	0	287	680.8	20.45
RiverLab	8	1593	29.85	16.5	19.45	10.52	0	284.4	615.2	20.18
RiverLab	8	1693	23.46	10.17	49.97	14.96	0	152.8	640.4	19.9
RiverLab	8	1793	25.89	9.89	49.33	12.68	0	213.4	642.9	19.85
RiverLab	8	1893	29.91	11.38	34.31	10.2	0	244.4	633.8	20.19
RiverLab	8	1993	31.7	12.81	43.92	9.6	0	286	577.6	20.51
RiverLab	8	2093	28.84	15.35	62.91	14.02	1.524	313.9	430.6	18.71
RiverLab	8	2193	23.66	11.79	78.4	23.52	6.604	160.4	601.3	15.94
RiverLab	8	2293	24.12	11.91	77	25.49	3.81	212.3	567	14.46
RiverLab	8	2393	29.97	12.19	55.13	11.03	0	314.4	640.3	17.57
RiverLab	8	2493	30.89	14.46	40.58	9.9	0	241.7	628.7	19.99
RiverLab	8	2593	24.99	9.02	71.9	15.4	0	114.1	585.3	19.89
RiverLab	8	2693	24.12	6.504	76.8	12.14	0	145.8	629.3	19.58
RiverLab	8	2793	27.42	8.58	30.55	10.79	0	269.7	627	19.48
RiverLab	8	2893	27.98	10.9	35.99	11.1	0	289.2	618.4	19.83
RiverLab	8	2993	21.94	10.13	37.17	13.15	0	205.8	608.2	19.69

RiverLab	8	3093	23.71	5.841	44.93	12.92	0	228.1	603.8	19.27
RiverLab	8	3193	26.64	10.37	32.08	11.69	0	269.1	594.3	19.62
RiverLab	9	193	26.16	11.99	31.76	12.96	0	228.3	390.8	19.61
RiverLab	9	293	25.68	8.23	51.97	11.83	0	170.5	595.6	18.5
RiverLab	9	393	28.44	10.66	28.44	11.38	0	273.5	579.1	16.54
RiverLab	9	493	28.96	14.67	36.88	11.6	0	292.1	418.3	18.12
RiverLab	9	593	28.55	12.64	33.45	11.32	0	281.6	538.7	18.75
RiverLab	9	693	28.61	13.92	29.92	11.7	0	289.6	504.5	18.98
RiverLab	9	793	27.81	13.88	29.42	11.16	0	231.1	528.3	17.79
RiverLab	9	893	27.08	11.83	33.91	11.89	0	249.3	554.5	18.1
RiverLab	9	993	28.67	11.38	27.36	10.79	.508	255.8	554.1	18.48
RiverLab	9	1093	28.32	10.53	37.87	10.66	0	244.6	557.7	18.01
RiverLab	9	1193	29.67	12.6	40.12	10.44	0	260.3	451.6	16.19
RiverLab	9	1293	18.56	6.153	44.72	14.35	0	137.2	494	16.71
RiverLab	9	1393	15.94	1.67	75.4	15.53	0	135	533.3	16.07
RiverLab	9	1493	19.65	3.71	35.55	14.02	0	271.8	489	15.62
RiverLab	9	1593	23.36	8.03	19.7	12.56	0	279.2	462.1	15.65
RiverLab	9	1693	20.8	7.05	76	16.15	.508	239.6	273.8	13.52
RiverLab	9	1793	14.3	7.48	79	59.32	3.302	104.7	184.1	11.08
RiverLab	9	1893	14.13	7.13	78.8	63.14	8.12	75.6	197.6	10.47
RiverLab	9	1993	19.37	6.817	78	19.59	0	211.2	397.7	11.55
RiverLab	9	2293	21.09	3.903	57.29	14.87	0	106.9	436.4	14.51
RiverLab	9	2393	23.16	5.686	61.62	14.37	0	166.9	439.4	15.1
RiverLab	9	2493	20.57	7.17	50.93	14.02	0	219	477.2	15.47
RiverLab	9	2593	21.99	6.426	46.36	13.22	0	238.1	479.5	15.23
RiverLab	9	2693	23.06	6.856	27.83	12.42	0	263.4	481.3	15.14
RiverLab	9	2793	24.99	7.09	29.23	11.95	0	260.1	473.8	15.22
RiverLab	9	2893	26.1	9.93	22.75	11.37	0	286.7	446.8	15.36
RiverLab	9	2993	26.43	10.05	22.95	11.29	0	272	442.8	14.82
RiverLab	9	3093	25.68	7.79	39.63	11.83	0	208.4	366.7	14.73
RiverLab	10	193	24.68	9.42	42.47	12.37	0	164.3	418.5	14.76
RiverLab	10	293	24.78	10.21	31.56	12.07	0	264.6	438.7	14.96
RiverLab	10	393	26.05	8.66	27.07	11.75	0	273.8	436.6	15.19
RiverLab	10	493	27.19	11.54	23.23	10.94	0	315.8	393.4	15.04
RiverLab	10	593	27.14	8.66	73.8	11.62	0	217.3	301.9	13.29
RiverLab	10	693	19.28	9.77	77.2	33.36	0	107.5	184.4	13.51
RiverLab	10	793	14.09	3.903	78.2	46.27	22.86	99.5	59.12	9.17
RiverLab	10	893	10.78	2.785	79.1	55.28	7.36	117.1	225.3	8.17
RiverLab	10	993	10.37	2.862	79	49.94	.508	178.5	213.2	9.51
RiverLab	10	1093	15.86	.097	79.4	24.17	0	140	373.4	8.71
RiverLab	10	1193	15.47	4.793	78.5	37.39	10.16	179.9	155.3	7.79
RiverLab	10	1293	14.21	8.19	79.7	58.68	2.54	98.9	160.2	9.98
RiverLab	10	1393	15.22	6.465	75	51.8	3.556	277.4	214	10.06
RiverLab	10	1493	13.42	6.153	76	50.44	1.016	153.4	138.5	10.61
RiverLab	10	1593	8.5	5.414	77.1	72.8	22.6	221.8	55.2	8.85
RiverLab	10	1693	11.42	5.103	77.6	60.83	.254	135.4	158.7	9.97
RiverLab	10	1793	12.72	1.862	77.6	46.18	1.524	116.6	219.4	9.49
RiverLab	10	2193	15.35	2.516	62.25	22.51	0	242.9	301.1	10.46
RiverLab	10	2293	18.07	5.025	56.45	18.65	0	234.3	306.9	10.97
RiverLab	10	2393	18.61	3.401	52.29	15.81	0	278	334.8	11.09
RiverLab	10	2493	18.25	4.522	50.1	17.63	0	225.8	304.3	11.25
RiverLab	10	2593	15.64	.941	72.8	15.72	0	151.7	323	10.89
RiverLab	10	2693	12.64	-.17	42.66	19.45	0	226.1	317.2	10.13
RiverLab	10	2793	10.94	-1.51	69.02	21.81	0	138.6	219.5	9.78
RiverLab	10	2893	10.25	-.592	67.47	23.8	.508	111.3	86.5	8.67
RiverLab	10	2993	7.01	-3.32	66.19	18.31	0	118.3	316.5	8.02
RiverLab	10	3093	9.73	-5.65	48.7	17.61	0	196.2	309.5	7.96
RiverLab	10	3193	13.05	-3.93	41.33	16.64	0	138.9	263.2	7.93
RiverLab	11	193	9.61	-2.2	57.73	17.61	0	118.3	275.2	7.99
RiverLab	11	293	8.78	-4.05	44.52	19.54	0	206	225	7.45
RiverLab	11	393	11.62	.557	45.48	17.76	0	142.8	67.08	7.37

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RiverLab  11 493      7.99  -2.7 60.96 20.17      0 103.1 265.2   7.7
RiverLab  11 893      9.34 -5.76  48.2 17.97      0 182.1   239  6.01
RiverLab  11 993     10.41 -6.71 45.49 17.14      0 185.5 243.1  5.92
RiverLab 11 1093      8.39 -2.47  39.6 19.34      0 184.4 125.7 6.268
RiverLab 11 1193     10.17 -3.62 45.29 18.16      0 150.1 198.4 6.303
RiverLab 11 1293      7.05 -2.12  44.4 19.35      0 107.5 186.1 6.454
RiverLab 11 1393     4.793 -6.28 61.07 20.38      0  91.5 185.5 5.782
RiverLab 11 1493     6.426 -4.28 62.09 19.69      0   104 240.4  5.87
RiverLab 11 1593     6.114 -6.87 45.15 19.41      0 201.5 230.7 5.092
RiverLab 11 1693      9.02 -4.71  28.9 17.99      0 218.1 235.9 4.908
RiverLab 11 1793     10.49 -5.61 45.07 17.89      0 173.4 191.2 5.113
RiverLab 11 1893      7.87 -7.39 53.29 20.21      0   100 56.39 5.079
RiverLab 11 1993     3.131 -9.29 43.46 20.26      0 247.6   228 3.855
RiverLab 11 2093     5.336 -8.68 44.99 19.76      0 223.8 225.6 3.611
RiverLab 11 2193      8.07 -7.83 42.87 18.31      0 164.2 202.6 3.917
RiverLab 11 2293      8.54 -1.16    66 20.72  10.16 147.8 56.29 3.857
RiverLab 11 2393     -.438 -8.23 64.44 21.16  1.778 110.6  99.5 3.853
RiverLab 11 2493     -7.11 -14.7 65.15 50.44      0    93 30.07 4.138
RiverLab 11 2593     -8.72 -18.2 65.68  26.6   .254 148.1  54.1 3.255
RiverLab 11 2693     -4.67 -17.9 63.38 33.05      0 160.4 150.4 2.701
RiverLab 11 2793     -3.74 -16.9 64.43  34.5      0 136.7 218.7 2.802
RiverLab 11 2893     -2.05 -12.5 64.28 31.28   .254 104.1 139.3 2.924
RiverLab 11 2993     4.173 -9.09 65.05 34.32  5.334  88.9 197.5 2.909
RiverLab 11 3093     4.289 -4.44 69.66  37.5   1.27 104.8 48.33 2.928
RiverLab  12 193     3.633 -6.55 69.83 48.58   .254  86.5 68.03 3.048
RiverLab  12 293     4.483 -3.74  70.2 43.23      0 121.1 104.4  2.91
RiverLab  12 393     -.208 -7.27  71.3 49.65      0 125.8  77.5 2.969
RiverLab  12 493     2.746  -2.7  72.1 42.39  1.016 151.6 47.36 2.953
RiverLab  12 593     1.401 -8.07  73.3 29.51   .254 128.8   159 3.062
RiverLab  12 693     1.056 -7.39  72.3  41.8      0  88.2 101.8 2.838
RiverLab  12 793     1.517 -6.63  72.2 45.71      0 173.7   124 2.661
RiverLab  12 893      9.73  -2.2 69.86 18.96      0 120.5  71.1 2.763
RiverLab  12 993       9.1  .749 68.73 26.65  5.334 116.3 103.1 2.381
RiverLab 12 1093      9.77 -1.16  71.6 32.29      0   279 181.8 2.321
RiverLab 12 1193     14.21 -1.43 56.89 18.06      0 249.3 160.8 1.529
RiverLab 12 1293       7.6 -8.19 69.29 46.15  4.826 108.4 30.61 2.363
RiverLab 12 1393      .979 -9.09  70.2 33.56   .254   187 181.7 3.396
RiverLab 12 1493     3.209 -9.25  71.2 25.55  1.016 100.2 158.9 2.976
RiverLab 12 1593     2.131 -6.63 69.97 33.18  1.016   107 121.7 2.914
RiverLab 12 1693      .404 -4.63 67.31 61.09   1.27 68.45    50 3.017
RiverLab 12 1793      .941 -7.79 66.38 35.72  3.048 109.8 145.3  3.15
RiverLab 12 1893     -4.94 -10.7 64.57 55.61      0 144.4 108.6 3.085
RiverLab 12 1993     -1.85 -9.58 64.32 32.71   .254 143.2   124 2.747
RiverLab 12 2093     -3.35 -13.3 64.37  24.3   .508 141.6 172.5  2.35
RiverLab 12 2193     -1.97 -12.4 64.06 26.39   .254 131.7 120.1  1.97
RiverLab 12 2293     -5.37 -13.4 62.53 25.22      0 186.6   112 1.775
RiverLab 12 2393     -2.54 -11.1 63.41 22.39   .508 125.6 175.9 1.857
RiverLab 12 2493     -2.05 -13.9 63.16 21.57   .508  85.6 172.3  1.76
RiverLab 12 2593     -1.97 -14.3 64.03 22.14   .508 62.86 158.1 1.484
RiverLab 12 2693      .059 -11.8 63.53 21.56      0 57.39 150.7 1.356
RiverLab 12 2793      .366 -7.51 63.62 26.51      0  61.1  81.6 1.591
RiverLab 12 2893     1.171 -6.39 65.95 41.99  1.524  88.3 67.76 1.946
RiverLab 12 2993     -2.28 -8.27 59.31 31.44      0 235.4  83.3 1.962
RiverLab 12 3093     -1.74 -8.07 63.93 28.71      0   153 152.6  1.91
RiverLab 12 3193     1.862 -5.22 62.22 33.81      0  81.5  87.9 1.874
```

APPENDIX A2

		TEMP(C)		RH(%)		Rain	Wind	SR	Soil T	
PLACE	MO/DAY	Max	Min	Max	Min	(mm)	(km/d)	(ly)	(10cm)	(30cm)
RIVLAB94	5 28	25.09	0	44.32	0	.254	82.8	578.2	19.77	17.35
RIVLAB94	5 29	27.36	9.94	40.5	11.37	0	174.2	686.1	18.13	17.33
RIVLAB94	5 30	31.22	10.02	29.67	10.3	0	136.5	761	19.21	17.92
RIVLAB94	5 31	22.79	11.78	51.57	13.22	2.794	177.8	289.7	17.78	17.74
RIVLAB94	6 1	22.62	10.93	58.23	14.13	2.032	101.4	565.9	18.01	17.38
RIVLAB94	6 2	27.15	9.77	43.72	11.73	0	168.1	753	18.8	17.77
RIVLAB94	6 3	30.93	13.44	20.21	10.08	0	162.7	706	17.33	24.77
RIVLAB94	6 4	27.68	13.71	19.78	11.24	0	148.5	759	15.21	29.77
RIVLAB94	6 5	30.16	12.9	19.01	10.38	0	155.9	786	18.98	17.88
RIVLAB94	6 6	27.43	10.18	20.45	11.3	0	224.3	622.3	17.63	26.71
RIVLAB94	6 7	19.93	5.82	49.22	14.08	.254	100.8	764	17.3	16.05
RIVLAB94	6 8	19.25	5.596	42.64	14.25	0	110.2	763	16.43	11.91
RIVLAB94	6 9	24.6	7.74	19.02	12.32	0	174.6	768	17.76	16.34
RIVLAB94	6 10	28.52	9.55	18.21	11	0	188.8	781	18.86	17.34
RIVLAB94	6 11	31.37	12.89	17.06	9.93	0	204	749	20.05	18.31
RIVLAB94	6 12	29.79	13.63	18.49	10.46	0	162	643.9	20.61	18.96
RIVLAB94	6 13	32	15.45	16.82	9.83	0	188.7	471.9	19.8	-6999
RIVLAB94	6 14	21.23	11.11	20.07	13.5	0	106.2	615.8	15.53	-6999
RIVLAB94	6 15	21.45	8.68	20.69	13.59	.254	173.8	349.2	13.72	-6999
RIVLAB94	6 16	24.07	8.62	21.76	12.55	0	108	778	16.92	14.54
RIVLAB94	6 17	28.84	8.76	18.94	10.73	0	149.6	784	18.26	16.38
RIVLAB94	6 18	32.22	13.74	16.67	9.65	0	178.6	810	19.88	17.75
RIVLAB94	6 19	32.79	16.47	15.48	9.3	0	174.8	793	21.04	19.01
RIVLAB94	6 20	34.25	16.18	15.42	8.75	0	197	730	21.44	19.93
RIVLAB94	6 21	28.24	19.28	18.75	10.93	0	183.7	317.3	18.8	12.85
RIVLAB94	6 22	30.34	15.91	24.47	10.38	0	164.5	713	20.53	17.42
RIVLAB94	6 23	33.02	16	16.06	9.26	.508	202.9	739	21.22	19.65
RIVLAB94	6 24	32.48	15.61	15.43	9.36	.254	209.9	653.7	21.06	19.97
RIVLAB94	6 25	35.81	16.06	15.29	8.33	0	205.4	793	21.61	20.69
RIVLAB94	6 26	29.68	10.72	17.85	10.55	0	173.2	779	21.86	21.15
RIVLAB94	6 27	29.43	9.42	18.57	10.67	0	154.9	795	20.97	20.57
RIVLAB94	6 28	33.42	14.64	15.79	9.17	0	210.7	743	19.93	-6999
RIVLAB94	6 29	33.81	18.48	14.88	9.07	0	214.5	774	16.99	-6999
RIVLAB94	6 30	34.6	16.51	15.16	8.75	0	200.1	785	20.32	19.88
RIVLAB94	7 1	33.27	18.49	14.43	9.24	0	188.3	746	21.38	20.76
RIVLAB94	7 2	31.07	16.2	16.62	10.05	0	172.4	726	21.7	21.58
RIVLAB94	7 3	29.59	13.5	17.25	10.57	0	142	768	21.82	21.8
RIVLAB94	7 4	25.68	13.02	16.84	12	0	162.5	441.5	20.43	21.24
RIVLAB94	7 5	33.02	12.98	16.92	9.36	0	223.2	641.1	20.6	20.75
RIVLAB94	7 6	19.93	7.1	33.11	14.44	0	77.5	451.7	19.06	20.11
RIVLAB94	7 7	28.36	7.74	43.51	11.34	.254	123	736	19.7	18.97
RIVLAB94	7 8	31.52	12.66	18.95	9.85	0	181.7	744	16.01	11.81
RIVLAB94	7 9	34.5	15.46	15.75	8.78	0	217.3	726	19.51	25.67
RIVLAB94	7 10	34.84	16.12	15.77	8.7	0	189	725	21.01	20.67
RIVLAB94	7 11	33.39	16.11	15.71	9.33	0	156.6	742	19.72	20.17
RIVLAB94	7 12	31.98	13.38	16.09	9.69	0	186.8	760	19.79	22.67
RIVLAB94	7 13	32.31	14.09	15.95	9.83	0	185.9	752	17.23	21.34
RIVLAB94	7 14	32.53	16.28	15.4	9.51	0	198.9	746	19.92	22.93
RIVLAB94	7 15	35.54	15.64	15.43	9.05	1.016	161.9	741	21.11	22.56
RIVLAB94	7 16	35.37	18.98	14.41	8.62	0	172.7	686.2	21.93	22.96
RIVLAB94	7 17	35.06	17.7	14.75	8.46	0	175.5	691.3	22.13	23.22
RIVLAB94	7 18	35.06	18.3	14.53	8.52	0	180	714	19.44	23.04
RIVLAB94	7 19	31.69	16.16	15.39	9.75	0	158	737	21.66	22.35
RIVLAB94	7 20	34.06	16.37	15.34	9.07	0	160.9	734	22.1	22.8
RIVLAB94	7 21	35.27	19.75	13.95	8.64	0	196	741	22.58	23.32
RIVLAB94	7 22	34.85	19.39	14.25	8.59	0	178.6	557.6	22.49	23.34
RIVLAB94	7 23	34.34	19.46	16.62	8.79	1.27	141.6	626.5	23.23	23.99
RIVLAB94	7 24	34.55	17.57	21.73	8.76	0	119.1	688.2	23.67	24.12
RIVLAB94	7 25	35.87	18.44	17.94	8.18	0	184.6	577.1	23.4	23.79
RIVLAB94	7 26	37.58	19.74	14.93	7.62	0	160.7	702	23.75	23.78
RIVLAB94	7 27	36.86	20.76	14.27	7.7	0	152.8	643.6	23.64	25.73
RIVLAB94	7 28	34.68	19.26	14.38	8.47	0	156.8	559.2	16.54	-6999
RIVLAB94	7 29	35.32	18.35	15.73	8.38	0	126.9	597.5	16.36	-6999

RIVLAB94	7	30	35.76	21.39	19.42	8.31	0	155.5	573.3	17.79	20.85
RIVLAB94	7	31	33.88	18.39	29.45	9.37	0	149.6	671.2	21.06	19.92
RIVLAB94	8	1	33.85	17.74	29.14	9.03	4.826	142.2	633.4	18.8	20
RIVLAB94	8	2	34.57	17.99	18.03	8.95	0	132.9	679.7	18.32	18.6
RIVLAB94	8	3	36.49	17.62	15.3	8.21	0	145.3	706	20.91	23.31
RIVLAB94	8	4	37.25	21.8	13.6	7.78	0	227.6	676.9	17.97	29.06
RIVLAB94	8	5	36.3	17.88	14.47	8.04	0	194.3	717	19.06	21.06
RIVLAB94	8	6	34.79	18.32	14.46	8.71	0	170.6	690.5	17.66	19.68
RIVLAB94	8	7	33.99	16.74	14.89	8.91	0	181.6	591.7	18.49	22.74
RIVLAB94	8	8	33.75	20.43	16.92	8.98	0	214.9	405.8	16.88	22.33
RIVLAB94	8	9	29.13	18.4	25.57	11.01	6.858	177.1	461.1	19.67	20.55
RIVLAB94	8	10	31.72	17.09	24.97	9.61	0	185.4	622.7	18.77	20.84
RIVLAB94	8	11	31.33	14.76	51.76	10.13	0	112.5	639.3	17.89	20.14
RIVLAB94	8	12	31.91	15.66	31.72	10	0	133.1	592.7	19.87	21.85
RIVLAB94	8	13	33.72	14.09	41.02	9.18	0	109.3	656	21.34	22.08
RIVLAB94	8	14	35.28	20.52	13.92	8.48	0	165	655.2	22.17	23.61
RIVLAB94	8	15	34.45	19.15	16.09	8.79	0	185.7	651.2	22.55	23.71
RIVLAB94	8	16	34.32	15.96	15.87	8.82	0	163.2	547.5	21.98	22.94
RIVLAB94	8	17	34.03	16.24	15.22	8.87	0	186.3	654.9	19.35	30.94
RIVLAB94	8	18	34.01	17.61	14.69	9.11	0	157.5	537.8	20.63	23.09
RIVLAB94	8	19	32.08	15.43	26.24	9.87	0	120.5	578.3	21.91	23.51
RIVLAB94	8	20	33.64	17.28	15.75	9.05	0	179.9	589.2	21.96	23.39
RIVLAB94	8	21	32.43	17.86	29.9	9.56	1.27	155.7	601.1	22.22	23.42
RIVLAB94	8	22	30.39	14.33	45.72	10.29	4.826	191.4	619.6	21.37	22.87
RIVLAB94	8	23	31.14	12.42	25.48	9.99	0	158.7	630.8	17.66	20.62
RIVLAB94	8	24	33.91	16.13	15.3	9.26	0	205.4	637.2	19.91	21.15
RIVLAB94	8	25	32.8	16.33	15.35	9.42	0	151.7	627.2	20.81	22.13
RIVLAB94	8	26	33.33	17.25	14.82	9.22	0	204	624	19.13	23.01
RIVLAB94	8	27	26.28	14.98	23.75	11.98	0	127.6	178.5	18.54	20.39
RIVLAB94	8	28	31.55	15.91	21.59	10.24	1.016	159.3	592.4	18.03	27.08
RIVLAB94	8	29	30.71	12.14	18.02	10.19	0	126.7	591.6	17.36	27.58
RIVLAB94	8	30	31.88	11.22	17.04	10.63	0	163.1	603.2	18.45	20.1
RIVLAB94	8	31	30.96	12.97	16.41	10.09	0	188.9	564.8	18.83	20.79
RIVLAB94	9	1	30.98	13.81	16.14	9.99	0	209.3	398.3	18.89	20.99
RIVLAB94	9	2	30.95	16.2	15.42	9.98	0	228	438.4	17.25	20.25
RIVLAB94	9	3	28.29	13.51	16.9	11.02	0	115.9	572.2	18.46	21.15
RIVLAB94	9	4	26.03	11.47	17.13	11.78	0	129.8	559.6	17.61	20.93
RIVLAB94	9	5	29.95	10.51	17.33	10.53	0	166	568.4	17.96	21.05
RIVLAB94	9	6	29.58	11.32	17.3	10.67	0	190	385.7	17.99	21.3
RIVLAB94	9	7	31.69	14.17	16.25	9.93	0	209.6	528.3	18.66	21.75
RIVLAB94	9	8	31.96	18.68	14.32	9.63	0	209.9	535.5	19.22	22.13
RIVLAB94	9	9	30.34	15.31	15.51	10.26	0	159.2	509.4	19.54	22.04
RIVLAB94	9	10	27.02	10.55	17.46	11.36	0	107.4	375.8	18.58	21.2
RIVLAB94	9	11	28.37	10.79	27.96	11.12	0	155.3	526.2	18.68	21.08
RIVLAB94	9	12	27.39	15.72	15.53	11.4	0	203.8	369.4	18.45	21.06
RIVLAB94	9	13	26	13.48	18.79	11.79	0	233	475.9	17.78	20.74
RIVLAB94	9	14	17.23	6.435	48.23	16.34	.254	89.6	136.1	15.94	19.05
RIVLAB94	9	15	22.44	5.517	47.03	13.25	0	138.3	510.7	15.17	19.79
RIVLAB94	9	16	25.95	8.74	20.05	12.07	0	186.7	513.1	14.42	19.38
RIVLAB94	9	17	28.17	11.33	17.66	11.17	0	207.5	508.6	16.13	18.14
RIVLAB94	9	18	29.62	12.15	16.83	10.65	0	196	497	16.63	19.02
RIVLAB94	9	19	28.81	10.13	19.16	10.87	0	156.2	479.7	17.23	19.69
RIVLAB94	9	20	26.8	12.43	17.73	11.73	0	175.1	404.4	16.33	19.36
RIVLAB94	9	21	25.69	7.89	41.97	11.99	0	147	474.4	13.68	17.91
RIVLAB94	9	22	26.57	8.35	18.38	11.75	0	167.2	494.1	13.32	20.63
RIVLAB94	9	23	30.64	9.53	17.36	10.65	0	177.2	492	14.61	19.89
RIVLAB94	9	24	29.96	9.49	18.31	10.37	0	185.2	482.6	14.92	18.21
RIVLAB94	9	25	30.07	15.81	15.31	10.33	1.27	187.5	480.1	13.34	19.54
RIVLAB94	9	26	29.19	0	15.7	0	0	60.14	420.4	14.9	18.6
RIVLAB94	9	27	29.31	12.1	16.62	10.76	0	184.1	450.4	14.66	16.7
RIVLAB94	9	28	30.08	8.48	17.74	10.24	0	177	440.1	14.97	17.04
RIVLAB94	9	29	22.34	11.23	64	13.6	20.07	90.5	225	15.74	21.69
RIVLAB94	9	30	15.8	8.34	65.64	26.71	3.81	61.75	201.4	15.5	19.23
RIVLAB94	10	1	18.28	6.393	62	20.62	0	74	322.6	15.1	18.32
RIVLAB94	10	2	17.16	10.12	50.36	16.04	0	123.2	182.6	14.94	18.31
RIVLAB94	10	3	11.42	3.378	48.35	18.01	0	114	199.9	13.54	16.83
RIVLAB94	10	4	15.78	4.11	48.1	20.06	1.27	226.3	157.9	12.69	15.45
RIVLAB94	10	5	16.7	6.723	63.68	18.51	18.8	138.2	130.6	12.7	15.8
RIVLAB94	10	6	12.29	6.918	65.47	38.77	4.318	60.16	101.4	12.71	15.35

RIVLAB94	10	7	17.47	4.76	54.49	17.33	0	130.6	320.9	12.96	15.51
RIVLAB94	10	8	19.06	5.371	33.41	14.45	0	194.4	408.4	12.86	15.57
RIVLAB94	10	9	21.46	4.742	40.96	13.73	0	181.6	412	12.99	15.72
RIVLAB94	10	10	24.25	4.061	29.81	12.87	0	199.3	377.1	13.04	15.88
RIVLAB94	10	11	17.39	7.75	21.8	15.4	0	185.4	249.1	12.93	15.72
RIVLAB94	10	12	16.33	5.186	41.56	15.86	0	132.9	296.4	12.62	15.1
RIVLAB94	10	13	22.2	10.35	23.53	13.07	0	169.1	322.9	13.31	15.57
RIVLAB94	10	14	17.43	.321	64	16.47	34.8	125.9	153.2	12.63	16.79
RIVLAB94	10	15	5.955	.144	68.65	38.95	6.35	67.08	113.1	10.69	14.16
RIVLAB94	10	16	5.961	1.102	62.71	43.27	2.794	65.61	84.9	10.66	13.29
RIVLAB94	10	17	7.86	3.674	62.99	45.17	3.302	48.83	51.12	10.66	13.22
RIVLAB94	10	18	11.56	4.626	63.32	30.67	2.032	69.73	109.4	11.05	13.32
RIVLAB94	10	19	16.57	3.673	44.48	16.19	0	181.1	351.5	10.87	13.12
RIVLAB94	10	22	14.64	0	22.72	0	0	60.03	144.9	12.05	13.83
RIVLAB94	10	23	18.59	.806	52	14.87	0	155.7	336.7	10.79	13.12
RIVLAB94	10	24	19.89	1.201	42.79	14.19	0	184.6	331.5	10.92	13.18
RIVLAB94	10	25	19.01	2.155	35.76	14.56	0	168.8	327.5	10.88	13.15
RIVLAB94	10	26	17.79	1.597	38.39	14.8	0	131.8	181.6	10.64	12.94
RIVLAB94	10	27	19.68	5.305	44.97	13.99	0	93.2	240	11.29	13.45
RIVLAB94	10	28	17.45	-1.199	35.6	15.09	0	99.7	61.52	10.37	13.16
RIVLAB94	10	29	10.13	-2.532	33.82	17.56	0	126.6	316.3	8.72	11.6
RIVLAB94	10	30	10.68	-3.882	26.26	17.61	0	124.9	308.1	8.09	10.83
RIVLAB94	10	31	11.75	-2.565	24.37	16.85	0	103.9	132.3	7.69	10.41
RIVLAB94	11	1	16.82	.316	62.01	15.13	.254	106.4	50.98	8.4	10.74
RIVLAB94	11	2	3.76	-2.079	63.23	37.93	.254	44.1	14.66	7.81	10.55
RIVLAB94	11	3	1.295	-5.225	61.24	29.16	2.032	80.2	130.6	7.41	10.14
RIVLAB94	11	4	1.581	-8.19	36.46	23.46	1.778	186.3	186.7	6.024	9.49
RIVLAB94	11	5	3.523	-1.345	63.46	25.91	8.38	54.57	76.3	6.7	9.52
RIVLAB94	11	6	10.23	1.051	65.61	23.55	.508	65.79	148.6	7.82	10.14
RIVLAB94	11	7	7.37	.079	66.77	43.82	6.35	61.88	34.5	7.9	10.62
RIVLAB94	11	8	3.831	-2.117	67.72	32.99	4.318	62.96	59.63	6.985	9.96
RIVLAB94	11	9	8.95	-1.815	50.75	27.9	3.556	135.3	159.4	6.717	9.3
RIVLAB94	11	10	13.29	4.256	41.16	16.6	0	153.2	150.5	7.71	9.93
RIVLAB94	11	11	15.86	4.609	26.68	16.32	0	153.2	250.4	8.2	10.36
RIVLAB94	11	12	6.599	.252	63.1	26.98	14.48	55.16	28.72	7.56	10.13
RIVLAB94	11	13	.733	-3.92	62.94	32.25	.508	65.83	52.61	6.715	9.19
RIVLAB94	11	14	2.418	-6.127	52.42	22.49	.254	122.6	213.9	6.164	8.79
RIVLAB94	11	15	1.629	-6.962	47.84	24.63	1.016	142	184.9	4.968	8.05
RIVLAB94	11	16	6.948	-3.171	59.26	19.81	4.318	109.2	45.58	5.616	8.16
RIVLAB94	11	17	.645	-4.688	59.47	24.38	1.524	79.5	74.3	5.734	8.14
RIVLAB94	11	18	-.739	-8.83	56.81	38.27	.762	62.68	56.87	5.727	8.13
RIVLAB94	11	19	-3.048	-12.9	53.78	24.75	0	78.7	212.5	5.324	7.9
RIVLAB94	11	20	-1.693	-10.88	56.24	35.78	0	80.8	106.3	5.014	7.61
RIVLAB94	11	21	.874	-10.79	59.18	32.78	.254	63.45	170.4	5.277	7.72