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SIMAZINE RESIDUES IN CANAL WATER AND CROPS RESULTING FROM EXPERIMENTAL APPLICATION FOR DITCHBANK WEED CONTROL

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16. ABSTRACT

Field studies determined the quantities of simazine (2-chloro-4,6-bis-(ethylamino)-s-triazine) found in irrigation water after experimental ditchbank treatment for weed control. Simazine applications to watered and dewatered canal banks were made at 2.25 and 4.5 kg/ha to provide selective control of annual weeds. Simazine levels in flowing canal water immediately following herbicide application did not exceed 60 μg/L. First flow water samples taken in the spring from treated canals, when dewatered the previous fall, showed a peak concentration of 250 μg/L within the treated reach which was diluted to $<$ 5 μg/L immediately downstream. To determine residues that might accumulate in crops from canal waters containing low levels of simazine, a field study was initiated in which six crops representing nine commodity groupings were sprinkler and furrow irrigated with water containing 0.01 and 0.1 mg/L simazine. Crops harvested at 7 and 30 days' posttreatment revealed no detectable simazine residue in corn grain, pinto bean pods and foliage, and cucumbers. Trace amounts ranging from 0.5 to 2.9 μg/L were found in sugar beets, corn foliage, and tomatoes. Sugar beet foliage sprinkler irrigated with both rates of simazine contained 5 μg/L at 7 days' posttreatment. Alfalfa sprinkler irrigated with 0.1 mg/L simazine contained 6.4 μg/L, which was the largest residue found in crop samples. Included is a literature review that suggests water residue levels resulting from experimental application of simazine to inside slopes of canals were within established tolerances for potable water and probably would not impact adversely on crops and nontarget aquatic organisms.

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Joint report with
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INTRODUCTION

Simazine (2-chloro-4,6-bis-(ethylamino)-s-triazine) is a widely used soil-applied herbicide in both crop and noncrop situations. The selective rate application of soil-applied herbicides for the management of annual grasses and broad-leaved weeds on irrigation canal banks is not a common practice in the Western United States. Care must be taken when applying herbicides with soil residual activity to avoid removing all ditchbank vegetation including desirable perennial grass species necessary for soil stabilization. Triazine herbicides, such as simazine, are particularly desirable in this respect in that they exhibit a mode of action which allows many perennial grasses to metabolize the herbicide to nonharmful products [1].[1] For example, Houston and Van Der Sluijs [2] found that a 3.4-kg/ha (3-lb/acre) application of atrazine increased the vigor of short grass range herbage, but effectively controlled annual species.

It has been demonstrated that annual ditchbank vegetation growing on the inside slopes of canals can be managed with low-rate applications of simazine [3]. The application rates of 4.5 to 6.7 kg/ha (4 to 6 lb/acre) are similar to rates being used in crops irrigated with these canal waters. Perennial ditchbank weeds are not normally controlled at low rates, but are managed by spot applications of other herbicides. There are several advantages to using simazine in arid areas (150- to 250-mm annual precipitation). One application of simazine is equal to 4 to 5 foliar herbicide applications per year, allows a more flexible timing of herbicide application, and reduces herbicide drift to nearby crops which can be sensitive to foliar applied herbicides.

When a herbicide is applied to the bank of either a flowing or dewatered canal, some residue in the irrigation water might be anticipated. The amount of herbicide residue is of concern in determining safe use patterns and in establishing tolerances. A potable water tolerance of 0.01 mg/L (0.01 p/m, parts per million) has been established for simazine and its metabolites 2-amino-4-chloro-6-ethylamino-s-triazine and 2,4-diamino-6-chloro-s-triazine when present as a result of herbicide application for aquatic weed control [4]. A food tolerance of 12 mg/L of simazine and its metabolites in or on raw agricultural commodity fish also has been established [5]. Several crop commodity tolerances have been established for simazine and are used in support of the many crop use labels for this herbicide.

The use of simazine for aquatic weed control has led to a number of studies designed to determine the effects of the herbicide on the aquatic habitat. Ellis, et al. [6], found that applications of 0.25 to 0.5 mg/L for algae control in lakes resulted in little or no injury to invertebrate animals. Mayer and Sanders [7] studied the influence of simazine exposure on nontarget aquatic organisms and found differing responses. However, a number of the tests showed no adverse effects when the herbicide was applied according to the normal use pattern. The influence of simazine on the aquatic habitat and its organisms is reviewed in greater detail in appendix B.

Studies leading to the establishment of water, crop, and fish food additive tolerances, as well as studies on the effect of simazine on the aquatic habitat, suggest that applications on the inside slopes of canal banks present no significant environmental hazards. However, most of the previous work was not conducted following normal ditchbank use patterns. The purpose of this study was to determine canal water residue levels resulting from the application of simazine to the inside slopes of irrigation canal banks. Treatments were made either when the canals were delivering irrigation water or when dewatered during the nonirrigation season in a manner approximating expected use. The canal water residue data were collected from three different geographical areas of the Western United States following application of herbicide at two rates. The efficacy of the treatments is discussed in appendix A. Irrigation water with levels of simazine added, comparable to residues resulting from ditchbank applications, was used to furrow and sprinkler irrigate six crops representing nine commodity groupings. Treated crops were analyzed for simazine residue and observed for symptoms of injury.

[1] Numbers in brackets refer to items in the bibliography.

SUMMARY

A field study was initiated during 1976 to determine the amount of simazine (2-chloro-4,6-bis-(ethylamino)-s-triazine) likely to be found in irrigation water following ditchbank treatment for weed control. Canals were selected in California, Colorado, and Washington State for the application of simazine to both watered and dewatered sites at rates of 2.25 kg/ha (2 lb/acre) and 4.5 kg/ha (4 lb/acre). Immediately following herbicide application simazine levels detected in flowing canal water did not exceed 60 µg/L (60 p/b, parts per billion). First flow samples collected in the spring of 1977, from the dry application sites, peaked at 250 µg/L (250 p/b) within the treated section but dropped rapidly to less than 5 µg/L (5 p/b).

In a correlated study, six crops representing nine commodity groupings were irrigated with water containing 0.01 and 0.1 mg/L (0.01 and 0.1 p/m) simazine. Herbicide was applied through both sprinkler and furrow irrigation and crops were harvested at intervals of 7 and 30 days following treatment. Simazine residue was not found in corn grain, pinto bean pods and foliage, and cucumbers. Trace amounts ranging from 0.5 to 2.9 µg/L (0.5 to 2.9 p/b) were found in sugar beets, corn foliage, and tomatoes. Larger amounts of herbicide residue occurred in sugar beet foliage in which 5 µg/L (5 p/b) were detected in the 7-day samples collected from plots sprinkler irrigated with water containing 0.01 and 0.10 mg/L simazine. Alfalfa, which contained the largest amounts of residue of the crops tested, contained 6.4 µg/L (6.4 p/b) in samples collected from plots sprinkler irrigated with water containing 0.1 mg/L simazine. A review of available literature indicates that the crop and canal water residue levels which resulted from the experimental application of simazine to inside slopes of canal banks were within established tolerances for potable water and would produce no significant impact on crops and nontarget aquatic organisms. The effectiveness of these treatments for weed control was possibly limited by the drought conditions prevalent throughout the West during the winter of 1976.

APPLICATIONS

This study provides data which can be used in support of a petition for potential registration of simazine for weed control when applied to ditchbanks of both watered and dewatered canals. Simazine is a soil-applied herbicide which, when applied at selective rates for the control of annual ditchbank weed species, produces sufficient weed control to reduce significantly operation and maintenance costs and minimizes the chances of herbicidal hazards to irrigation system habitats and waters. Supporting studies show that one fall application of simazine in arid areas could replace four or five foliar treatments per year with systemic herbicides. Monetary savings and more flexible timing of treatment during nonirrigation seasons can be achieved.

MATERIALS AND METHODS

CANAL WATER RESIDUES

Herbicide Application

Simazine, in an 80-percent wettable powder formulation, was applied to canal banks located within the CBT (Colorado-Big Thompson) Project, Loveland, Colorado; CBP (Columbia Basin Project), Ephrata, Washington; and CVP (Central Valley Project), Fresno, California. Applications were made during the 1976 growing season both to canals carrying water at the time of herbicide treatment and to other canals after dewatering in the fall. The inside slopes of the canal banks were sprayed using a boom-type rig calibrated to provide a specific [kilogram per hectare (lb/acre)] application rate of active ingredient for a given spray rig speed. Applications were made while the spray rig traveled in an upstream direction and allowed for a 0.3-m (1-ft) overlap onto the water's edge or the corresponding wetted perimeter of dewatered canals. This method was designed to represent a typical ditchbank herbicide application. Table 1 shows herbicide application data, including the rate of application, size of the

Table 1.—*Herbicide application data from simazine treatments made on canal banks in California, Colorado, and Washington to determine canal water residues*

Canal identity and location	Date treated	Date sampled	Treated plot size, m	Treated plot size, ft	Simazine rate, kg/ha	Simazine rate, lb/acre	Total spray discharge, L/ha	Total spray discharge, gal/acre	Canal flow at time of treatment or sampling, Velocity m/s	Velocity ft/s	Volume m^3/s	Volume ft^3/s
Water in canals												
	1976	*1976*										
Friant-Kern Canal, CVP, concrete-lined 3.97 km	Aug. 11 treated in p.m.	Aug. 11	610 x 3	2000 x 10	2.25	2	190	20	0.45	1.5	48	1700
Friant-Kern Canal, CVP, concrete lined 15.44 km	Aug. 11 treated in a.m.	Aug. 11	610 x 3	2000 x 10	4.50	4	190	20	0.45	1.5	48	1700
Greeley-Loveland Canal, CBT, unlined earth, 17.2 km	Aug. 24	Aug. 24	610 x 3	2000 x 10	2.25	2	190	20	0.36	1.2	6.79	240
Greeley-Loveland Canal, CBT, unlined earth, 17.92 km	Aug. 25	Aug. 25	610 x 3	2000 x 10	4.50	4	190	20	0.36	1.2	6.79	240
Lateral PE 38.9B CBP, unlined earth	Sept. 2	Sept. 2	804 x 2.4	2640 x 8	2.25	2	475	50	0.36	1.2	2.15	76
Lateral PE 38.9	Sept. 2	Sept. 2	644 x 2.4	2112 x 8	4.50	4	475	50	0.36	1.2	2.15	76
Dry ditch—first water sampled												
	1976	*1977*										
Farmer's Ditch, CBT unlined earth, 7.2 km	Nov. 10	May 11	610 x 3	2000 x 10	2.90	2.58	190	20	0.36	1.2	0.28	10
Greeley-Loveland Canal, CBT, 19.2 km	Nov. 10	May 18	610 x 3	2000 x 10	7.43	6.6	190	20	0.36	1.2	5.66	200
Lateral, WB 10, CBP, unlined earth	Nov. 12	Mar. 16	804 x 2.4	2640 x 8	2.25	2	475	50	0.36	1.2	1.13	40
Lateral, WB 5, CBP, unlined earth	Nov. 12	Mar. 23	644 x 2.4	2112 x 8	4.5	4	475	50	0.36	1.2	0.16	5.5

CBT (Colorado—Big Thompson), CBP (Columbia Basin Project), and CVP (Central Valley Project) treated plot, flow volume, and additional pertinent data. Figure 1 is a view showing simazine application to the Friant-Kern Canal. Note the 0.3-m overlap of spray onto the concrete lining. This is not a normal practice; however, it was done to simulate the maximum amount of herbicide which could enter the water during spray operations. Experimental plot sites selected had no additions of water or turnouts within the sampled area.

Sample Collection Procedure

Water in canals.–The procedure for sampling canals having water in them at the time of treatment required establishing five sampling stations located: upstream, midway through, immediately below, and 1.6 km (1 mi) and 8.0 km (5 mi) below the application site. The only variation from established procedure occurred with the 4.5-kg/ha (4-lb/acre) treatment of the Friant-Kern Canal, where a sampling station was established 0.8 km rather than 1.6 km downstream from the starting point. One-liter samples were collected, in duplicate, from the edge and midpoint of the canal at intervals of 5, 10, and 15 minutes after the start of spraying. This procedure was followed at each station for a total of 6 samples per station and 30 samples for the entire treatment.

Dry ditch application.–In the spring of 1977, samples were collected from the first water to flow through the sections of canal dry-treated the previous fall. Three 1-liter untreated check water samples, plus additional sets of three samples at locations within the upper, middle, and lower portions of the treated segment, were taken. Also, the first, second, and fourth volumes of water were sampled as the flow passed over a drop or check dam at the downstream end of the treated segment. Figure 2 represents the drop structure. In instances where it was not possible to use concrete drop structures already in place, it was necessary to construct temporary dams of earth and plastic sheeting. When the water arrived at the stations within the 610-m (2000-ft) plots, approximately 5 minutes elapsed from the time the leading edge appeared until samples were taken. The leading and terminal ends of the water segment were marked with Rhodamine B dye. Dye markers enabled estimation of the time required for a measured volume to pass the simazine-treated area. The canal water samples were frozen immediately and stored for analysis.

Analytical Methods

A summary of the procedure used for the extraction of simazine from canal water is shown

Figure 1.–Experimental application of simazine on the Friant-Kern Canal, CVP, California, 1976. Photo P801-D-78397

on figure 3. The field-collected water samples were thawed, stabilized at room temperature, and thoroughly shaken before transfer of a 200-mL aliquot to a 500-mL separatory funnel. Chloroform, in which simazine is soluble to the extent of 900 mg/L was used as the solvent. Samples were extracted three times, and the chloroform extracts were filtered through sodium sulfate prior to collection in a 125-mL Erlenmeyer flask. The chloroform was heated to 30 °C and evaporated under a stream of dry air. The eluates remaining were transferred to a 15-mL centrifuge tube with aliquots of 5, 4, and 3 mL of nano-grade ethyl ether. The ethyl ether was evaporated and the sample was redissolved in 2 mL of nano-grade benzene.

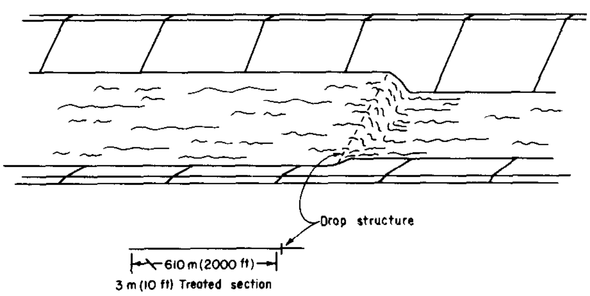

Figure 2.–Sampling site layout for the collection of first flow water samples.

Samples were analyzed on a Hewlett-Packard Model 5730 A gas chromatograph equipped with a nitrogen and phosphorus specific detector. This detection system involved the replacement of the normal flame collector assembly with one which contained an alumina cylinder coated with rubidium bromide. The nature of the detector response to compounds containing nitrogen and phosphorus is beyond the scope of this discussion but appears to involve a so-called low temperature plasma layer surrounding the alkali pellet [8].

The detector, once in operation, was capable of providing excellent sensitivity to simazine in the range of 0.2 µg/L in the final benzene extract and a degree of selectivity which required no cleanup procedures with water samples and only minimal cleanup with crops. However, the lifespan of the Hewlett-Packard collector units containing a rubidium pellet was unexpectedly short, possibly a result of contaminants in the extracts. A 1.2-m by 2-mm glass column, packed with 150 to 125 µm (U.S. standard No. 100 to 200) sieve chromosorb W coated with 2 percent OV-101, was used throughout the analysis. Nitrogen flow through the column was maintained at 30 mL/min. Regulation of hydrogen and air flow through the detector was optimized for each unit following installation, but remained stable once established. The column temperature was 200 °C with injection port and detector temperatures of 250 and 300 °C, respectively.

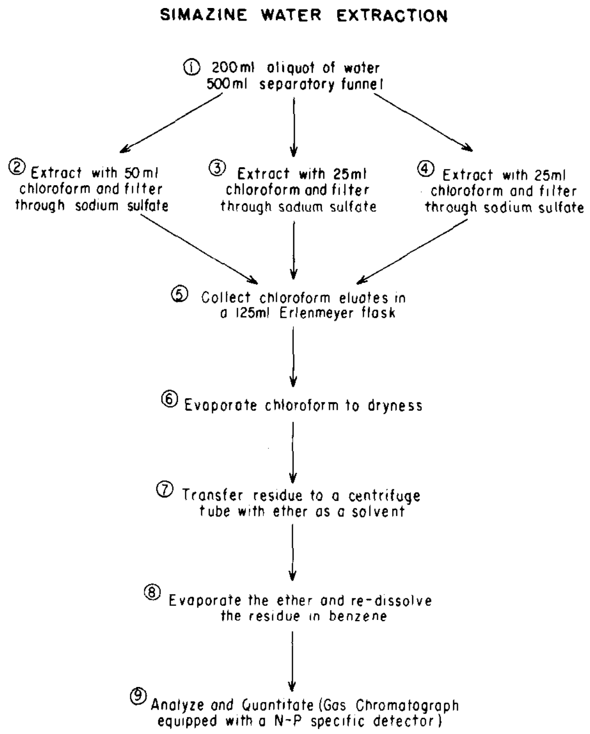

Figure 3.–Extraction procedure used in the determination of simazine residues in canal water.

CROP RESIDUES

Study site

The simazine crop residue study was conducted on plots located within the Denver Federal Center, Denver, Colorado, at an elevation of 1680 m (5600 ft). The total land area devoted to these studies was 0.76 ha (1.9 acres), where 0.2 ha (0.5 acre) was used for the furrow treatments, and 0.56 ha (1.4 acres) for sprinkler treatments. The area allowed for potential rotation of use from year to year, thus avoiding the possibility of soil residue carryover and buildup. The land was fenced and posted with signs to indicate the experimental nature of the study. Individual plots were arranged as shown on figures 4 and 5. The twelve 4.5- by 9-m (15- by 30-ft) furrow irrigation plots were divided into six 1.5- by 4.5-m (5- by 15-ft) subplots. Six circular sprinkler irrigation plots, each with a radius of 9 m (30 ft), were divided into six 3- by 4.5-m (10- by 15-ft) radially arranged subplots. Subplots were divided into two 1.5- by 4.5-m (5- by 15-ft) planting areas containing one crop per area. The soil was a sandy clay loam containing 1.8 to 2.6 percent organic matter. The arrangement of the plots and the apparatus for the application of herbicide were patterned after procedures developed by Bruns and Kelley [9].

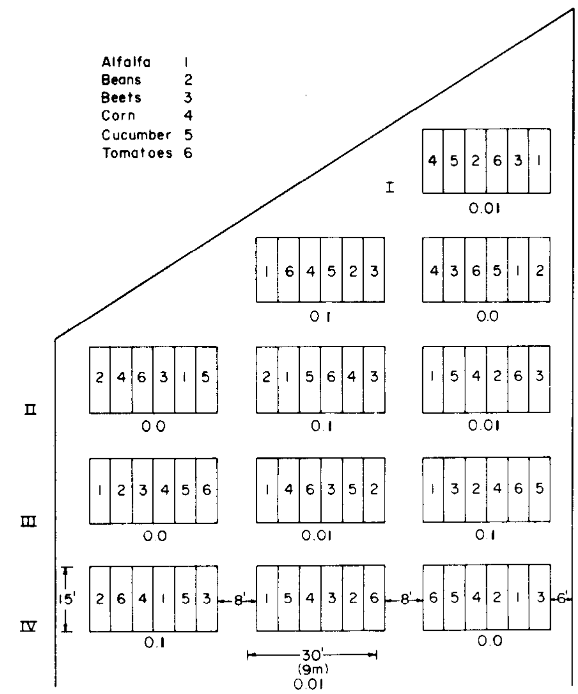

Figure 4.–Furrow irrigation plot layout for simazine treatments.

Irrigation Techniques

Six crops, representing nine commodity groupings, were furrow and sprinkler irrigated with water to which simazine was added at rates of 0.0, 0.01, and 0.10 mg/L with the twofold purpose of obtaining residue data and observing injury to sensitive crops. The crops treated and commodity groups represented were: tomatoes–fruiting vegetable, cucumbers–cucurbit, alfalfa–forage (legume), sugar beets–root crop and leafy vegetable, corn–grain crop and grass forage, and pinto beans–seed pod vegetable and stored grain.

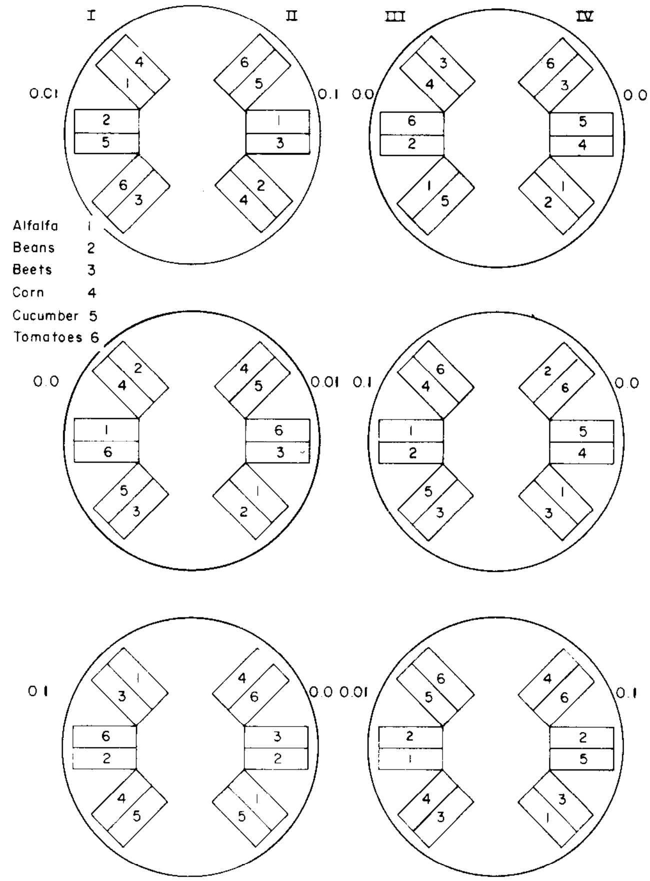

Figure 5.–Sprinkler irrigation plot layout for simazine treatments.

To accomplish furrow irrigation treatments, simazine was mixed with water in 1100-L (300-gal) stock-watering tanks and distributed to the individual furrows by way of a manifold device providing equal volumes to each replicate plot. The sprinkler treatments employed a pressurized tank and metering device to deliver a concentrated solution to the individual lines for final dilution. A controlled heating unit, installed in the bottom of the herbicide solution tank, maintained a water temperature between 50 and 60 °C (122 and 140 °F). At this temperature, simazine was sufficiently soluble to eliminate the need for an agitation system to keep the herbicide in solution. Following dilution, simazine was applied to the crops by pulsating-type sprinklers. Herbicide was applied in 50 mm (2 in) of water for both sprinkler and furrow treatments. Figures 6, 7, and 8 show the crop residue study plots and a typical furrow irrigation.

Figure 6.–Sprinkler plots used to apply simazine for crop residue study. Photo P801-D-78398

Figure 7.–View of furrow irrigated plots for simazine treatment of crops. Photo P801-D-78399

Figure 8.–Facilities for furrow irrigation treatment with simazine for crop residue studies. Photo P801-D-78400

Crop Sample Collection and Analysis

Crop samples were collected from the untreated control and the 0.01 and 0.10 mg/L treated plots at intervals of 7 and 30 days following treatment. The sampled plant material was placed in plastic bags and frozen until analysis. The extraction procedures, as outlined in figure 9, were based on methods supplied by the CIBA-Geigy Corp., with modifications to suit the individual crops and the detection system used [10]. Seventy-five grams of plant material were chopped and ground in a kitchen blender with 150 mL of distilled water. The slurry was transferred to a 1.0-L glass jar with a Teflon-lined cap and mixed with 160 mL of chloroform for one-half hour on a mechanical shaker. The mixture was decanted through a glass-wool-lined Buchner funnel into a 500-mL separatory funnel. The glass jar was rinsed with aliquots of 20 and 10 mL of chloroform which also were decanted through the Buchner funnel. The glass wool mat was compressed to remove as much liquid as possible prior to a final rinse with 10 mL chloroform. Following separation of the chloroform-water-plant material mixture in the separatory funnel, the chloroform was drained through a fritted glass funnel containing 20 g of

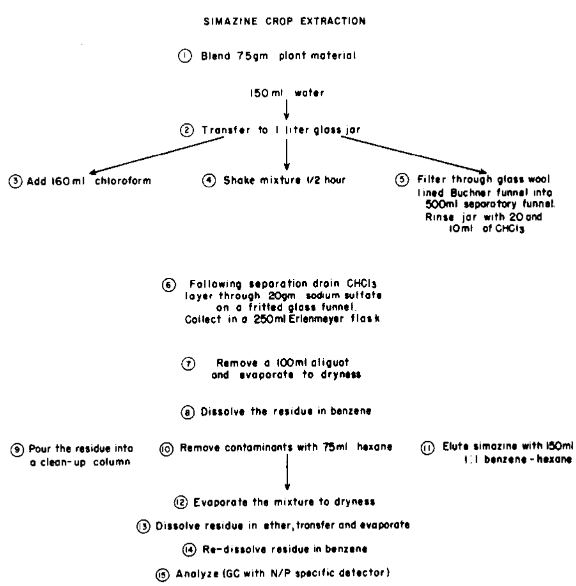

Figure 9.–Extraction procedure used in determination of simazine residues in crop samples.

sodium sulfate. The sodium sulfate was rinsed with 10 mL chloroform and the entire extract was collected in a 250-mL Erlenmeyer flask. The chloroform extract was diluted to a standard volume of 200 mL and a 100-mL aliquot was removed. A stream of hot dry air at 30 °C was used to evaporate the sample to dryness, after which the residue was dissolved in benzene and poured into a clean-up column containing 24 g of activity grade V aluminum oxide. The various contaminants, including heavy pigmentation from some crops, were removed with a rinse of 75 mL nano-grade hexane. Simazine was eluted from the column with 150 mL 1:1 nano-grade benzene-hexane mixture. The solvent was evaporated to dryness with a stream of air and the remaining residue was transferred to a graduated 15-mL centrifuge tube with aliquots of 5, 4, and 3 mL nano-grade ethyl ether. Following evaporation of the ethyl ether, the residue was dissolved in benzene ready for analysis. Samples were analyzed, as described, for water residues.

RESULTS AND DISCUSSION

CANAL WATER RESIDUES

Watered Canals

The recovery levels from fortified irrigation canal water are summarized in table 2. Simazine residue levels from wet canal applications are shown in table 3. The values obtained from the 2.25-kg/ha (2-lb/acre) application on the Friant-Kern Canal are shown on figure 10. The three sets of samples taken within the treated section produced low residue levels at the beginning of the treatment, higher levels at the midpoint, and lower levels at the end of ditchbank plot spraying. The highest values were found at the 1.6-km (1-mi) station, but within 8.0 km, the level had dropped by two-thirds. The phenomenon of a higher herbicide concentration at the 1.6-km sampling point compared to the sampling station immediately below the treated area could be the result of either incomplete mixing of the simazine residue in the canal water or errors in field sampling. It is clear from figure 11 that the dissipation pattern for the 4.5-kg/ha (4 lb/acre) Friant-Kern treatment differed from that of the 2.25-kg/ha rate in that the highest simazine level occurred at the end of the treatment (upstream sampling site). One explanation for this is the possibility that the herbicide solution remaining in the tank at the end of the application was discharged at this point. With this exception, all levels are low and drop gradually to less than 0.2 μg/L (0.2 p/b) at the 8.0-km (5-mi) downstream sampling station.

Table 2.—*Simazine recovery levels from fortified irrigation canal water*

Level added, mg/L	Recovery, percent	Average recovery, percent
0.05	83	83
	82	
0.10	91	92
	93	
0.50	97	94
	91	
1.0	90	92
	94	
	Overall mean	90

Simazine residue in flowing water resulting from 2.25 and 4.5 kg/ha applications on the Greeley-Loveland Canal are shown on figures 12 and 13. A point of comparison between the two treatments is the steady decline in residue from the downstream end of the treated swath to the 8-km downstream sampling station. The highest level for the 2.25-kg/ha treatment was detected at the station located just below the start of spraying, with the midpoint-station values being very close. The highest herbicide concentration for the 4.5-kg/ha treatment was found at the midpoint station.

Examination of figures 14 and 15 shows a nearly identical pattern of simazine dissipation following the application of 2.25- and 4.5-kg/ha rates on the PE 38.9 lateral. The residue levels reach a maximum within the treated segment, but drop rapidly at the 1.6 km station and continue to decline gradually to the final sampling point.

Table 3.—*Simazine concentration in mg/L in irrigation water following bank treatment of wet canals*

*Sampling station	Friant-Kern Canal, (2 lb/acre) 2.25 kg/ha	Friant-Kern Canal, (4 lb/acre) 4.5 kg/ha	Greeley-Loveland Canal, (2 lb/acre) 2.25 kg/ha	Greeley-Loveland Canal, (4 lb/acre) 4.5 kg/ha	PE 38.9B Lateral, (2 lb/acre) 2.25 kg/ha	PE 38.9 Lateral, (4 lb/acre) 4.5 kg/ha
Upstream	0.9	14.9	0.1	5.4	0	0
Midway	1.6	0.5	2.4	33.3	10.4	58.8
Below	0.3	1.3	2.4	5.4	14.5	35.2
0.8 km (0.5 mi) downstream		0.8				
1.6 km (1.0 mi) downstream	2.3		2.0	4.1	4.9	16.2
5.6 km (3.5 mi) downstream					3.7	
7.68 km (4.8 mi) downstream						10.9
8.0 km (5.0 mi) downstream	0.8	0.2	1.4	1.9		

* Sampling station refers to locations immediately upstream, midway through, immediately below 0.5, 1.0 kilometer, etc., below the point at which simazine was applied.

Dry Canals

Simazine residue levels obtained from first spring flow samples from dry ditch applications are summarized in table 4. Samples collected from the Farmer's Ditch and Greeley-Loveland Canal on the CBT Project showed a similar pattern of gradual increase in simazine residue levels as water passed through the treated section, followed by a gradual decline of levels found after the first, second, and fourth volumes of water passed over the drop at the downstream end. This buildup and decline is shown on figures 16 and 17.

The first flow samples collected from dry ditch treatments at 2.25 and 4.5 kg/ha on the WB 10 and WB 5 laterals show a pattern of herbicide buildup and dissipation similar to that observed on CBT canals. As shown on figures 18 and 19, there was a rapid increase in residue as water passed through the treated section, with a peak being reached at the downstream end. From this point, the levels dropped sharply as the first, second, and fourth volumes of water passed over the drop structure.

In summary, simazine levels found in flowing canal water immediately following herbicide application did not exceed 60 μg/L. First flow samples collected in the spring of 1977 from the dry application sites peaked at 250 μg/L within the treated section, but dropped rapidly to less than 5 μg/L.

CROP RESIDUES

The crop recovery levels, which are shown in table 5, were determined for each crop prior to the extraction and analysis of samples. Recoveries ranged from 79 percent for alfalfa to 93 percent for both pinto bean pods and foliage. The residue levels detected in each of the test crops are shown in table 6. All values reported are corrected for percent recovery and represent the mean of four replicate treatments. Tomatoes, Super Sioux variety, were analyzed with minimal GC interference (gas liquid chromatography). Recovery levels from check samples to which known quantities of simazine were added, averaged 92 percent. Samples taken from the untreated control plots at 7 and 30 days showed no trace of simazine, indicating the effectiveness of control measures to prevent drift from the sprinkler plots. Samples taken from plots treated with 0.01 and 0.10 mg/L (0.01 and 0.10 p/m) simazine contained no residue from either sprinkler or furrow irrigation after 7 days. At 30 days following treatment, however, as shown on

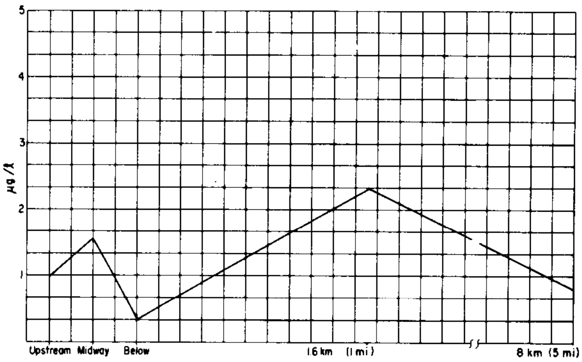

Figure 10.–Residue levels resulting from the application of simazine to the banks of the Friant-Kern Canal 2.25 kg/ha (2 lb/acre) applied Aug. 11, 1976.

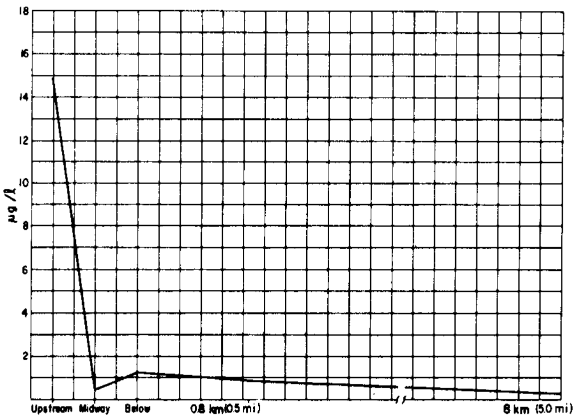

Figure 11.–Residue levels resulting from the application of simazine to the banks of the Friant-Kern Canal 4.5 kg/ha (4 lb/acre). Applied Aug. 11, 1976.

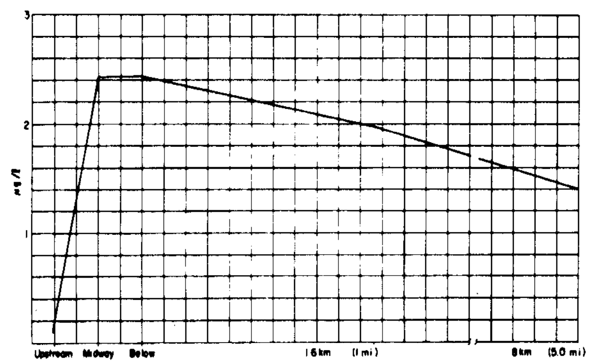

Figure 12.–Residue levels resulting from the application of simazine to the banks of the Greeley-Loveland Canal 2.25 kg/ha (2 lb/acre). Applied Aug. 4, 1976.

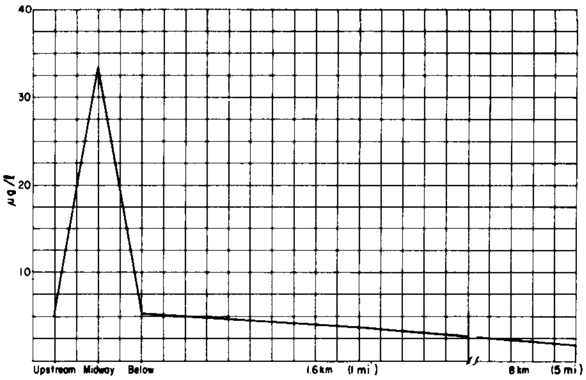

Figure 13.–Residue levels resulting from the application of simazine to the banks of the Greeley-Loveland Canal 4.5 kg/ha (4 lb/acre) applied Aug. 25, 1976.

Figure 14.–Residue levels resulting from the application of simazine to the PE 38.9B lateral CBP 2.25 kg/ha (2 lb/acre) applied Sept. 2, 1976.

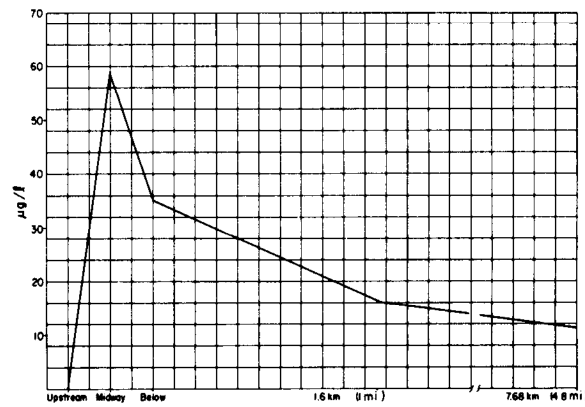

Figure 15.–Residue levels resulting from the application of simazine to the PE 38.9 lateral CBP 4.5 kg/ha (4 lb/acre) applied Aug. 24, 1976.

Table 4.—*Simazine concentration in mg/L in first flow irrigation water following bank treatment of dry canals*

Sampling station	Farmer's Ditch, (2 lb/acre) 2.25 kg/ha	Greeley-Loveland, Canal (4 lb/acre) 4.5 kg/ha	WB 10 Lateral, (2 lb/acre) 2.25 kg/ha	WB 5K Lateral, (4 lb/acre) 4.5 kg/ha
Upper 1/3	0.3	1.1	2.0	3.6
Middle 1/3	.4	0.7	6.7	28.4
Lower 1/3	.9	2.8	8.7	249.5
1st volume	.8	3.1	2.0	64.4
2nd volume	.4	2.5	0.6	3.7
4th volume	.2	1.8	1.1	2.4

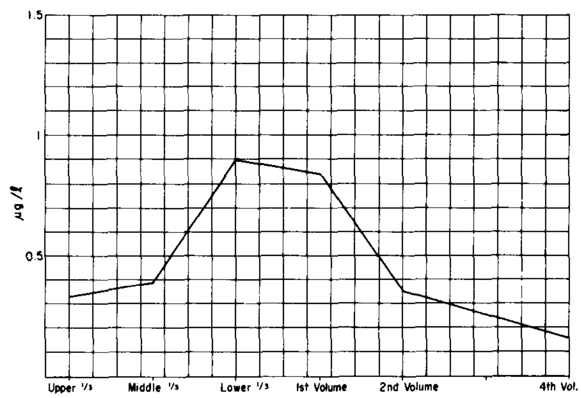

Figure 16.–First flow residue levels resulting from the fall application of simazine to the Farmer's Ditch 2.25 kg/ha (2 lb/acre) applied Nov. 10, 1976, sampled May 11, 1977.

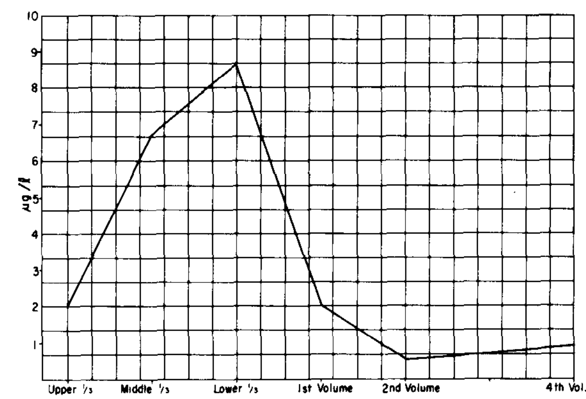

Figure 18.–First flow residue levels resulting from the fall application of simazine to the WB 10 lateral-CBP 2.25 kg/ha (2 lb/acre) applied Nov. 16, 1976, sampled Mar. 16, 1977.

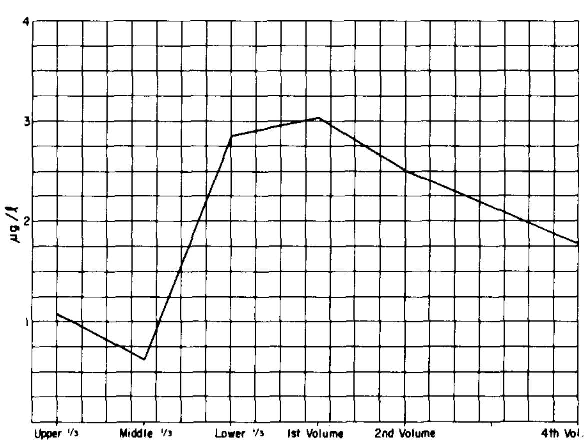

Figure 17.–First flow residue levels resulting from the fall application of simazine to the Greeley-Loveland Canal 4.5 kg/ha (4 lb/acre) applied Nov. 10, 1976, sampled May 18, 1977.

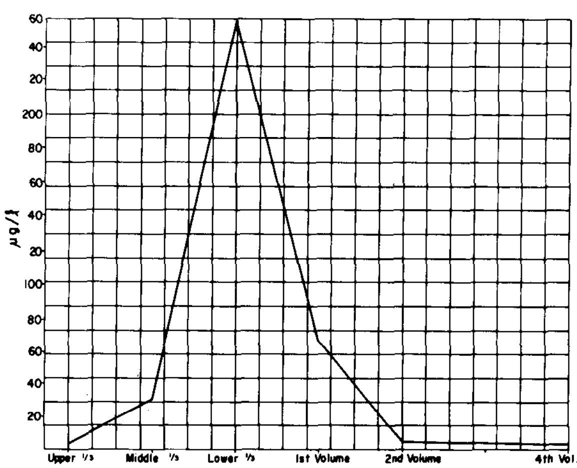

Figure 19.–First flow residue levels resulting from the fall application of simazine to the WB 5K lateral-CBP 4.5 kg/ha (4 lb/acre) applied Nov. 12, 1976, sampled Mar. 16, 1977.

figure 20, the 0.01-mg/L sprinkler samples contained 0.9 μg/L (0.9 p/b) and the 0.10-mg/L sprinkler and furrow application samples contained 1.7 and 2.9 μg/L, respectively.

Table 5.—*Simazine recovery levels from fortified crop samples*

Crop	Level added, mg/L	Recovery, percent	Average recovery for each crop, percent
Tomato	0.1	96	
	0.5	83	92
	1.0	97	
Cucumber	0.1	89	
	0.5	89	88
	1.0	87	
Alfalfa	0.05	88	
	0.1	78	79
	0.5	75	
	1.0	75	
Sugar beets	0.05	80	
	0.1	90	88
	0.5	89	
	1.0	93	
Sugar beet foliage	0.05	84	
	0.10	89	89
	0.50	91	
	1.0	91	
Corn	0.05	86	
	0.10	88	89
	0.50	88	
	1.0	92	
Corn foliage	0.05	86	
	0.10	86	89
	0.50	93	
	1.0	90	
Pinto beans and pods	0.05	93	
	0.10	90	93
	0.50	93	
	1.0	94	
Pinto bean foliage	0.05	84	
	0.10	96	93
	0.50	95	
	1.0	95	

The extraction of simazine from cucumber samples, which were weighed and liquified–including the peel–was complicated by the formation of heavy emulsions prior to filtration. The 88-percent recovery level reflected this difficulty. The samples, however, were analyzed with no interference and the only simazine residue found was 0.3 μg/L (0.3 p/b) detected in the 30-day sprinkler applied 0.01 mg/L samples. This is graphically represented on figure 21.

Alfalfa was one of the more difficult crops to analyze for residues. The fibrous nature complicated homogenation and the dense pigmentation of the extract made filtration through an aluminum oxide-packed column a necessity. Also, it is suspected that the high nitrogen content resulted in some extraneous GC peaks, an apparent result of the specificity of the detector to nitrogen. Examination of table 6 indicates that some of the alfalfa check samples contained small amounts of simazine or apparent simazine. These samples were reextracted and analyzed. In most instances, the new values confirmed the originals. However, at this level of sensitivity, peak heights ranged from 1 to 9 mm and small variations resulted in dramatic differences in calculated concentrations (μg/L). Simazine was present at both the 0.01- and 0.10-mg/L treatment rates and, in most instances, the amounts detected declined with time from 7 to 30 days. The largest amounts of herbicide were found in alfalfa collected 7 days after sprinkler treatment (3.8 and 6.4 μg/L for the 0.01- and 0.1-mg/L rates, respectively). This fact, coupled with the decline in residue levels with time, might indicate that the 7-day sprinkler treated alfalfa samples had simazine on the foliar surface which was removed with repeated irrigations. The maximum levels detected were 3.8 μg/L from sprinkler irrigated 0.01-mg/L, 7-day samples and 6.4 μg/L from sprinkler irrigated 0.1-mg/L, 7-day samples. Figure 22 shows these findings.

Sugar beets were treated as two separate commodities representing both a root crop and a leafy vegetable. The recovery level for sugar beets was 88 percent. No simazine was detected in the root portion in any of the controls. Residue levels of 0.6 μg/L and 0.7 μg/L were found in 30-day sprinkler and furrow samples irrigated with water containing 0.01 mg/L as shown on

Table 6.—*Simazine residues in µg/L in field and vegetable crops after irrigation with water containing simazine*

Treatment rate, mg/L	Tomatoes	Cucumbers	Alfalfa	Sugar beets, Roots	Sugar beets, Foliage	Corn, Kernels	Corn, Foliage	Pinto beans, Bean + pods	Pinto beans, Foliage
				7 days after treatment					
0.0 —Sprinkler	0	0	0.2 SE 0.08	0	0	0	0	0	0.7 SE 0.34
.01—Sprinkler	0	0	3.8 SE 0.07	0	5.1 SE 0.73	0	0.6 SE 0.17	0	0
.10—Sprinkler	0	0	6.4 SE 0.17	1.3 SE 0.25	5.0 SE 0.51	0	2.5 SE 0.33	0	0
.0 —Furrow	0	0	1.3 SE 0.24	0	0	0	0	0	0.6 SE 0.29
.01—Furrow	0	0	0.1 SE 0.04	0	0.2 SE 0.11	0	0	0	0
.10—Furrow	0	0	5.1 SE 0.63	0.7 SE 0.21	2.6 SE 0.50	0	0.8 SE 0.06	0	0
				At harvest *30 days after treatment*					
0.0 —Sprinkler	0	0	0	0	0	0	0	0	0
.01—Sprinkler	0.9 SE 0.37	0.3 SE 0.09	1.0 SE 0.22	0.6 SE 0.19	2.8 SE 0.28	0	0	0	0
.10—Sprinkler	1.7 SE 0.40	0	2.1 SE 0.24	0	1.5 SE 0.15	0	0.7 SE 0.10	0	0
.0 —Furrow	0	0	1.6 SE 0.22	0	0.8 SE 0.39	0	0	0	4.5 SE 2.25
.01—Furrow	0	0	0.6 SE 0.11	0.7 SE 0.21	0.8 SE 0.16	0	0	0	0
.10—Furrow	2.9 SE 0.22	0	0.6 SE 0.11	0	0.9 SE 0.15	0	0	0	0

figure 23. Simazine levels of 1.3 and 0.7 µg/L were detected in sprinkler and furrow samples collected 7 days after treatment with 0.10 mg/L. No simazine was found in 7-day samples from 0.01 mg/L treatments or in 30-day samples from 0.10 mg/L treatments.

The recovery levels determined for sugar beet foliage samples averaged 89 percent. Figure 24 shows sugar beet foliage contained more simazine than did samples of the root portion (fig. 23), particularly with sprinkler irrigation. At both the 0.01- and 0.10-mg/L treatment rate, 7-day sprinkler samples contained nearly identical amounts of simazine with 5.1 and 5.0 µg/L, respectively. After 30 days, herbicide levels had declined in the sprinkler irrigated plants to 2.8 µg/L (2.8 p/b) in the 0.01-mg/L (0.01-p/m) exposure and 1.5 µg/L in the 0.10-mg/L exposure. The largest amount of simazine found in furrow irrigated plants was 2.6 µg/L in 7-day samples from a plot treated with 0.10 mg/L. The untreated control plants, with the exception of the 30-day samples from furrow irrigation plots, were free of simazine residue. In this instance, only one sample of four replicated plots contained simazine.

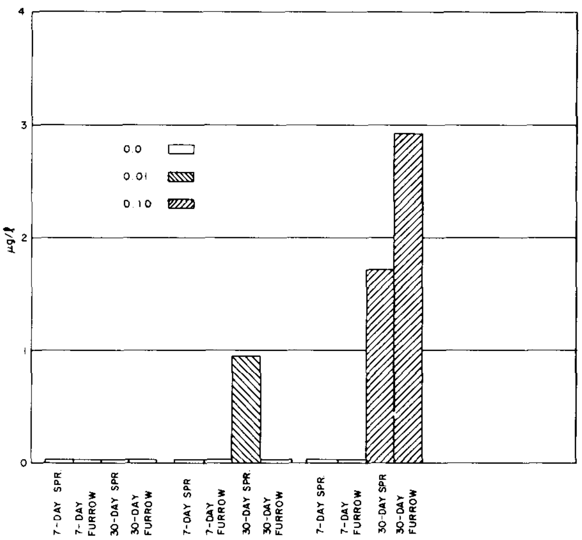

Figure 20.–Simazine residue levels in tomatoes.

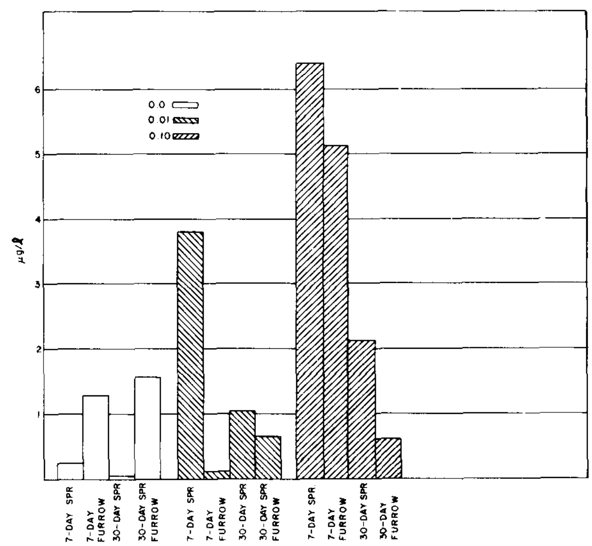

Figure 22.–Simazine residue levels in alfalfa.

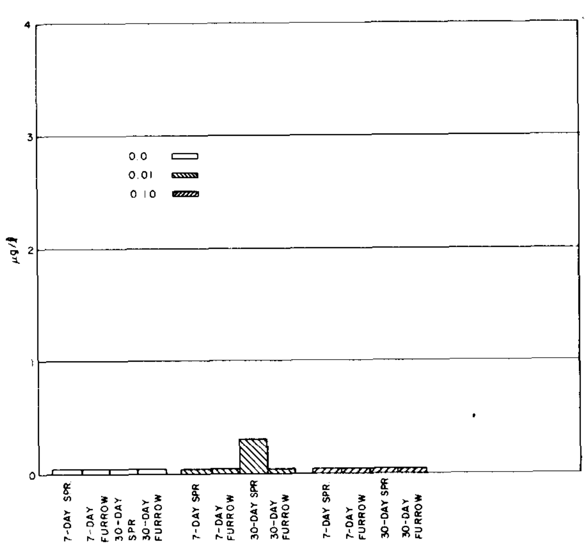

Figure 21.–Simazine residue levels in cucumbers.

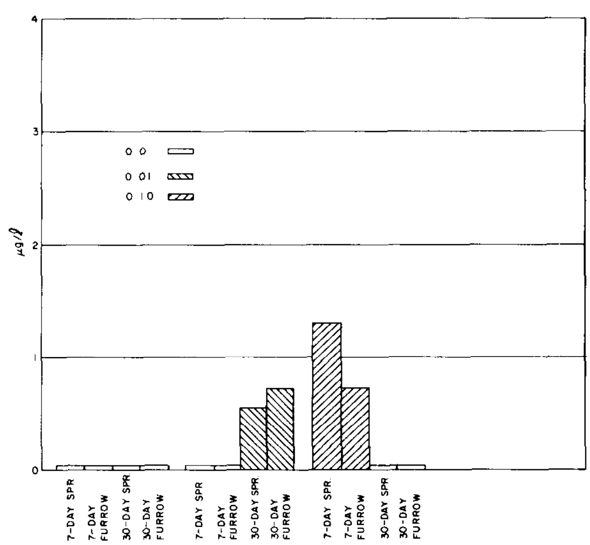

Figure 23.–Simazine residue levels in sugar beet roots.

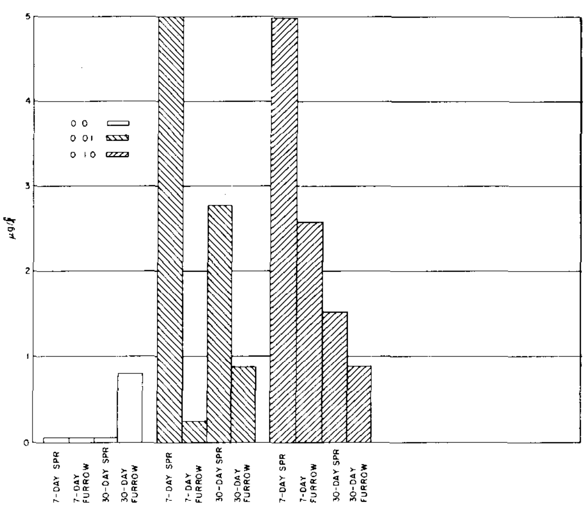

Figure 24.–Simazine residue levels in sugar beet foliage.

The recovery levels determined for corn grain and corn foliage were both 89 percent. Corn grain was the most difficult of the crops to extract. Portions of the cob were included with the grain to simulate its possible usage as cattle feed. Heavy emulsions formed following shaking and separated only with gentle agitation of the separatory funnel over a period of 20 to 30 minutes. Following column filtration (aluminum-oxide packed), however, the extract appeared clear and no interference in GC analysis resulted. No simazine was detected in any of of the corn (plus cob with husk removed) samples, as shown on figure 25.

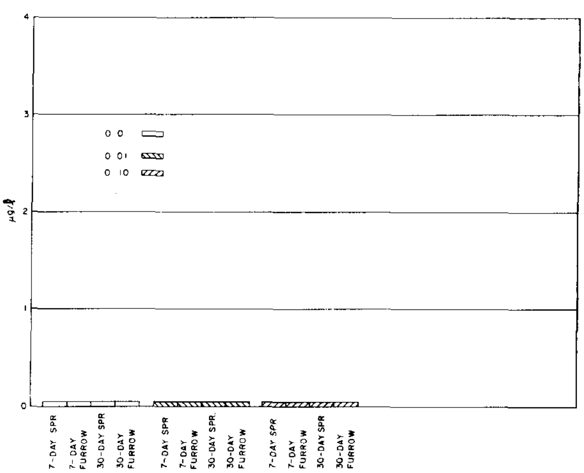

Figure 25.–Simazine residue levels in corn grain.

Corn foliage contained some simazine residue. The pattern of herbicide accumulation and dissipation was similar to that noted with alfalfa (fig. 22) and sugar beet foliage (fig. 24). The sprinkler-irrigated samples contained more residue than did the furrow samples and amounts detected decreased with time from 7 to 30 days. For the 0.01-mg/L treatment, simazine was found only in samples from the sprinkler irrigation plots sampled at 7 days following application in which 0.6 µg/L was detected. The 30-day samples, from the same plots, contained no herbicide residue. The highest levels of simazine in the 0.1-mg/L treated plots also occurred in the 7-day samples with sprinkler irrigation where 2.5 µg/L was detected. This level dropped to 0.7 µg/L at 30 days. Foliage from the corresponding furrow-irrigated plots contained 0.8 µg/L in 7-day samples, but declined to zero by 30 days. Corn foliage residue data are summarized on figure 26.

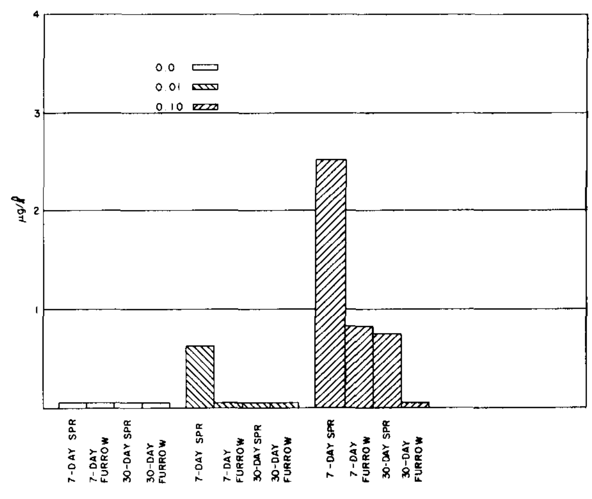

Figure 26.–Simazine residue levels in corn foliage.

Pinto bean samples were divided into pod and foliage categories (figs. 27 and 28). The recovery levels for both pod and foliage samples average 93 percent. No trace of simazine was detected in any of the pod samples. The same was true of the pinto bean foliage samples, with the exception of several untreated controls. One sample of four replicates from the 7-day sprinkler and furrow plots and the 30-day furrow plot contained simazine. Contaminated glassware was thought to be the cause of the problem, but reextraction of fresh sample using acid-cleaned glassware confirmed the presence of simazine. Another possible explanation is that the plastic bags used in the collection of samples may have been contaminated with simazine.

In summary, no simazine residue was found in corn grain, pinto bean pods and foliage, and cucumbers. Trace amounts ranging from 0.5 to 2.9 µg/L were found in sugar beets, corn foliage, and tomatoes. Larger amounts of herbicide residue occurred in sugar beet foliage in which 5 µg/L (5 p/b) were detected in the 7-day samples collected from plots sprinkler irrigated with water containing 0.01 and 0.10 mg/L simazine. Alfalfa, which contained the largest amounts of residue of the crops tested, contained 6.4 µg/L in samples collected from plots sprinkler irrigated with water containing 0.1 mg/L (0.1 p/m) simazine.

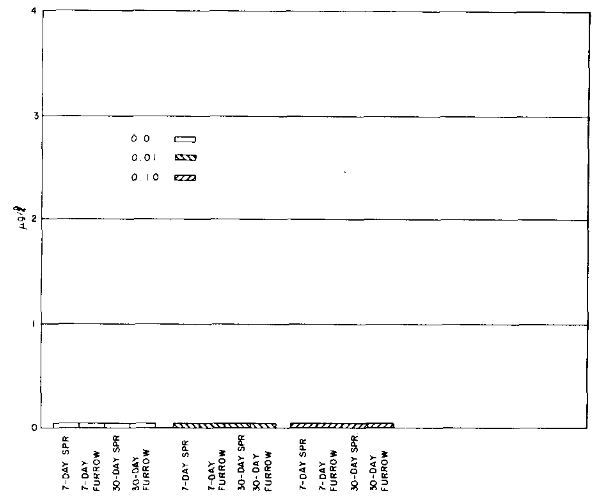

Figure 27.–Simazine residue levels in pinto bean pods.

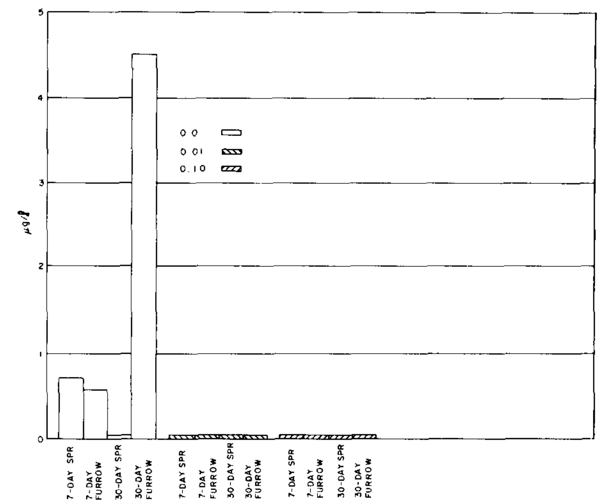

Figure 28.–Simazine residue levels in pinto bean foliage.

BIBLIOGRAPHY

[1] Thompson, Lafayette, Jr., "Metabolism of Chloro-s-triazine Herbicides by Paricum and Setaria," Weed Science, vol. 20, No. 6, November 1972.

[2] Houston, W. R., and Van Der Sluijs, D. H., "Increasing Crude Protein Content of Forage with Atrazine on Shortgrass Range," Production Report No. 153, Agricultural Research Service, U.S. Dep. Agric., in cooperation with Colorado State University Experiment Station, December 1973.

[3] [Glenn Berry], "Use of Residual, Soil Applied Herbicides for Ditchbank Weed Control Along the East Side of the Southern San Joaquin Valley, Fresno, California," Bur. Reclam., Mid-Pacific Region, Fresno, Calif. 1976.

[4] "Tolerances and Exemptions from Tolerances for Pesticide Chemicals in or on Raw Agricultural Products, Simazine," Federal Register, vol. 40, No. 63, pp. 14592-14597, April 1, 1975.

[5] "Tolerances for Pesticides in Food Administered by the Environmental Protection Agency, Food Additives Permitted in Food for Human Consumption, Simazine," Federal Register, vol. 40, No. 63, pp. 14592-14597, April 1, 1975.

[6] Ellis, J., Higgins, E., Pruss S., and Norton J., "Management of Aquatic Vegetation with Simazine," Proc. Northeastern Weed Sci. Soc., vol. 30, pp. 86-91, 1976.

[7] Mayer, F. L., and Sanders, H. O., "Simazine Effects on Non-Target Aquatic Organisms," Preliminary Report, 30th Annu. Meet. Southern Weed Sci. Soc., 1977.

[8] Burgett, Charles A., Smith, Douglas H., Bente, H. Bryan, Wirfel, James C., and Goodhart, Steven E., "Chromatographic Capabilities of the Nitrogen-Phosphorus Selective Detector," Hewlett-Packard Application Note ANGC 2-76, Hewlett-Packard Co., Anondale, Pa., 1976.

[9] Bruns, V. F., and Kelley, A. D., "Effect of Sprinkler Irrigation with Xylene-Treated Water on Six Crops," Bulletin 796, College of Agriculture Research Center, Wash. State Univ., 1974.

[10] "Determination of Chlorotriazine Residues in Plant Material, Animal Tissues, and Water Using the Ultraviolet Method," Geigy Agricultural Chemicals Analytical Bulletin No. 7, 1967.

Additional References Cited in Appendix B

Cope, O. B., "Some Responses of Freshwater Fishes to Herbicides," Proc. 18th Annu. Southern Weed Conf., pp. 439-445, 1965.

Gilderhus, P. A., "Some Effects of Long-term Exposure to Simazine on Goldfish, Bluegills, and Aquatic Invertebrates," unpubl. report, U.S. Dep. Int., Wis., 1969.

Jones, R. O., "Tolerance of the Fry of Common Warm-water Fishes to Some Chemicals Employed in Fish Culture," Proc. 16th Annu. Conf. S.E. Assoc. Game Fish Comm., pp. 436-445, 1962.

Mauck, W. L., "A Review of the Literature on the Use of Simazine in Fisheries," NTIS No. PB-235 445, National Technical Information Service, Springfield, Va. 22151, 46 pp., 1974.

Mauck, W. L., Mayer, F. L., Jr., and Holz, D. D., "Simazine Residue Dynamics in Small Ponds," Bull. Environ. Contam. Toxicol., vol. 16, No. 1-8, 1976.

Mayer, F. L., Jr., and Sanders, H. O., "Simazine Effects on Non-Target Aquatic Organisms: A Preliminary Report," Pap. presented at 30th Annu. Southern Weed Conf., 15 pp., 1977.

Pierce, P. C., Frey, J. E., and Yawn, H. M., "Field Evaluations of Newer Aquatic Herbicides," Georgia Game, Fish Comm. Rep., Atlanta, 30 pp., 1964.

Rodgers, C. A., "Uptake and Elimination of Simazine by Green Sunfish (*Lepomis cyanellus* Raf.)," Weed Sci., vol. 18, No. 134, 1970.

Sanders, H. O., "Toxicities of Some Herbicides to Six Species of Freshwater Crustaceans," J. Water Pollut. Control Fed., vol. 42, No. 8, pp. 1544-1550, 1970.

Snow, J. R., "Simazine as an Algicide for Bass Ponds," Prog. Fish-Cult., vol. 25, No. 1, pp. 34-36, 1963.

Walker, C. R., "Simazine and Other S-triazine Compounds as Aquatic Herbicides in Fish Habitats," Weeds, vol. 12, No. 2, pp. 134-139, 1964.

Wellborn, T. R., Jr., "The Toxicity of Nine Therapeutic and Herbicidal Compounds to Striped Bass," Prog. Fish-Cult., vol. 31, No. 1, pp. 27-32, 1969.

"Simazine: Safety Evaluation on Fish and Wildlife," Woodard Research Corp., Rep. to Ciba-Geigy, 10 pp., October 6, 1965.

APPENDIX A

HERBICIDAL EFFECTIVENESS OF EXPERIMENTAL PLOTS TREATED WITH SIMAZINE

SIMAZINE FIELD TRIAL

Central Valley Project–Fresno Office
Friant-Kern Canal (Water in Canal)

Summer–Early Fall 1976: 4.5 kg/ha (4 lb/acre)

Date of application: August 11, 1976

Site No. 1: Mile 9.65 to 10.08, left bank

Plot size: 3 by 692 m (10 by 2270 ft)

Rate: Equivalent to 1.8 kg (4 lb) of simazine active ingredient in water at 935 L/ha (100 gal/acre)

Soil texture: Sandy loam

Organic matter: 0.5 percent

Vegetation present: At application, winter annual plants constituting the bulk of vegetation present had matured and dried up. Green plants, amounting to less than two percent of the vegetative cover, were prostrate spurge *(Euphorbia supina)*, bermuda grass *(Cynodon dactylon)*, turkey mullein *(Eremocarpus setigerus)*, Spanish clover *(Lotus Americanus)*, and vinegar weed *(Trichostema lanceolatum)*.

Weed control: The above plants were unaffected by the simazine when observed 30, 60, and 90 days after treatment. Drought conditions prevailed during this period, and lack of fall rainfall, the mature stage of plant growth, and a natural tolerance to low rates of simazine, together with a lack of foliar activity of the compound, were factors responsible for poor weed control at this time.

Sparse winter rainfall occurred during the winter of 1976-77. A total of approximately 200 mm (8 in) was recorded mostly in the spring. This rainfall was adequate to activate the compound after moving it through the soil into the root zone of the plants. The effectiveness of the herbicide on the following species of plant was observed in the spring and summer of 1977. The weed control rating was based on a scale of 0 to 10 where 0 = no control and 10 = perfect weed control.

Species	Rating
Ripgut *(Bromus rigidus)*	7
Red brome *(Bromus rubens)*	7
Wild barley *(Hordeum leporinum)*	7
Foxtail fescue *(Festuca megalura)*	7
Wild oats *(Avena fatua)*	7
Redstem filaree *(Erodium cicutarium)*	6
Common tarweed *(Hemizonia congesta)*	6
Popcorn flower *(Plagiobothrys nothofulvus)*	6
Douglas fiddleneck *(Amsinckia douglasiana)*	6
Prostrate spurge *(Euphorbia supina)*	3
Bermuda grass *(Cynodon dactylon)*	0
Turkey mullein *(Eremocarpus setigerus)*	3
Spanish clover *(Lotus Americanus)*	7
Vinegar weed *(Trichostema lanceolatum)*	5

Summer–Early Fall 1976: 2.25 kg/ha (2 lb/acre)

Date of application: August 11, 1976

Site No. 2: Mile 2.46 to 2.84, left bank

Plot size: 3 by 610 m (10 by 2000 ft)

Rate: Equivalent to 1.8 kg (4 lb) of simazine active ingredient in water at 935 L/ha (100 gal/acre)

Soil texture: Sandy loam

Organic matter: 0.5 percent

Vegetation present: As per site No. 1, mile 9.65 to 10.08

Weed control: As per site No. 1, mile 9.65 to 10.08 (see information under this paragraph)

Rating: Spring and summer of 1977; on a scale of 0 to 10 where 0 = no control and 10 = perfect weed control

Species	Rating
Ripgut *(Bromus rigidus)*	4
Red brome *(Bromus rubens)*	4
Wild barley *(Hordeum leporinum)*	4
Foxtail fescue *(Festuca megalura)*	4
Wild oats *(Avena fatua)*	5
Filaree *(Erodium cicutarium)*	3
Common tarweed *(Hemizonia congesta)*	4
Popcorn flowers *(Plagiobothrys nothofulvus)*	4
Douglas fiddleneck *(Amsinckia douglasiana)*	4
Prostrate spurge *(Euphorbia supina)*	3
Vinegar weed *(Trichostema lanceolatum)*	4
Bermuda grass *(Cynodon dactylon)*	0
Spanish clover *(Lotus Americanus)*	4
Turkey mullein *(Eremocarpus setigerus)*	2

SIMAZINE FIELD TRIAL

Central Valley Project–Fresno Office
Friant-Kern Canal (Dry Canal)

Fall–Winter 1976: Dry canal

Date of application: November 11, 1976

Site No. 1: Located at mile 58.81 to 61.00–right bank. Only one site was established this fall-winter at 2.25 and 4.5 kg/ha (2 to 4 lb/acre) rate was applied.

Plot size: 3.7 by 350 m (12 by 1150 ft)

Rate: Equivalent to 4.5 kg/ha (4 lb) active ingredient in water at 935 L/ha (100 gal/acre)

Soil texture: Clay, loam

Organic matter: 0.5 percent

Vegetation present: At application, winter annual plants constituting the bulk of vegetation present had matured and dried up. Green plants amounting to less than 5 percent of the vegetative cover were: prickly lettuce *(Lactuca scariola)*, horseweed *(Erigeron canadensis*, puncture vine (Tribulus terrestris), spike weed *(Centromadia pungens)*, sacred datura or tolguacha *(Datura meteloides)*, watergrass *(Echinochloa* spp.), dallisgrass *(Paspalum dilatatum)*, knotroot foxtail *(Setaria geniculata)*, and Bermuda grass *(Cynodon dactylon)*.

The plants were mature and unaffected by the application when observed 30, 60, and 90 days following treatment.

With the advent of sparse winter rainfall, winter annual plants germinated and they were affected by the herbicides which rainfall had carried into the root zone of the plants. Summer growing plants germinating in the spring and summer were also affected.

Weed control: Spring and summer of 1977, rating where 0 = no control and 10 = perfect weed control:

Species	Rating
Wild oats *(Avena fatua)*	10
Foxtail barley *(Hordeum jubatum)*	10
Ripgut *(Bromus rigidus)*	10
Foxtail fescue *(Festuca megalura)*	10
Filaree *(Erodium cicutarium)*	8
Turkey mullein *(Eremocarpus setigerus)*	7
Bur clover *(Medicago hispida)*	10
Prickly lettuce *(Lactuca scariola)*	10
Sow thistle *(Sonchus oleraceus)*	10
Horseweed *(Erigeron canadensis)*	9
Puncturevine *(Tribulus terrestris)*	8
Sacred datura or tolguacha *(Datura meteloides)*	8
Bermuda grass *(Cynodon dactylon)*	0
Spikeweed *(Centromadia pungens)*	9

Species	Rating
*Watergrass *(Echinochloa* spp.)	5
*Dallisgrass *(Paspalum dilatatum)*	4
*Knotroot foxtail *(Setaria geniculata)*	3
Mustard (*Brassica* spp.)	10

*Summer growing, waterline grasses are not controlled with simazine.

SIMAZINE FIELD TRIAL

Columbia Basin Project
WB 10 and WB 5 Laterals (Dry Canals)

Fall 1976: 2.25 kg/ha (2 lb/acre) WB 10

Date of application: November 12, 1976

Plot size: 2.4 by 804 m (8 by 2640 ft)

Vegetation present: At the time of evaluation some effects were noted, but very little weed control. The Canada thistle and showy milkweed present showed some chlorosis. Evaluations were made on May 23, 1977, and August 12, 1977. Weed control on a scale of 0 to 10 where 0 = no control and 10 = complete control, was:

Species	Rating	
	May 23	Aug. 12
Russian thistle *(Salsola kali* L.)	1	1
Canada thistle *(Cirsium arvense* L.)	1	1
Showy milkweed *(Asclepia speciosa* Torr.)	1	1
Horsetail *(Equisetum* sp.)	0	0

Fall 1976: 4.5 kg/ha (4 lb/acre) WB 5

Date of application: November 12, 1976

Plot size: 2.4 by 644 m (8 by 2112 ft)

Vegetation present: The area treated at the 4.5 kg/ha (4 lb/acre) rate had a few Russian thistle *(Salsola kali* L.), some Canada thistle, showy milkweed, and horsetail at the time of the May 23, 1977 evaluation. When a repeat evaluation was made on August 12, 1977, some sand bur and barnyard grasses were in evidence. The weed control evaluations were:

Species	Rating	
	May 23	Aug. 12
Russian thistle *(Salsola kali* L.)	7	8
Canada thistle *(Cirsium arvense* L.)	1	2
Showy milkweed *(Asclepias speciosa* Torr.)	1	3
Horsetail *(Equisetium* sp.)	1	0
Sand bur grass *(Cenchrus* sp.)	–	0
Barnyard grass *(Echinochloa* sp.)	–	0
Perennial grasses	–	3

APPENDIX B

A SUMMARY OF THE IMPACT OF SIMAZINE ON NONTARGET AQUATIC BIOTA

A SUMMARY OF THE IMPACT OF SIMAZINE ON NONTARGET AQUATIC BIOTA

Numerous laboratory and field studies have indicated that simazine as an aquatic herbicide produces minimal adverse effects on nontarget aquatic organisms [Gilderhus 1969; Mauck 1974; Mauck et al., 1976; Mayer and Sanders 1977; Pierce et al., 1964; Sanders 1970; Snow 1963; Walker 1964]. This includes both direct toxic effects and indirect effects on food, growth, and reproduction. Direct toxicity of simazine to fish and aquatic invertebrates has almost invariably been shown to occur at concentrations well above the 5.0-mg/L maximum solubility of simazine in water (Mauck 1974, table 1). Lethal effects on fish reported from application of simazine to lakes and ponds have usually been linked to oxygen depletion rather than direct simazine toxicity [Mauck 1974]. Such oxygen depletion problems result from improper application and can be eliminated by following label application directions.

Chronic exposure of fish and aquatic invertebrates to simazine has produced few adverse results. Mayer and Sanders [1977] demonstrated that fathead minnow egg hatchability and fry growth were unaffected by "use-pattern" exposure to simazine where initial concentration was progressively decreased over time to simulate the natural degradation of simazine in aquatic environments. However, continuous exposure to 1.7 mg/L (1.7 p/m) did reduce egg hatch and fry growth in fathead minnows; but this exposure pattern would be unlikely to occur under actual field conditions [Mayer and Sanders 1977]. Adult fathead minnows and several aquatic invertebrate species showed no ill effects from chronic exposure to simazine at all levels tested, although midge emergence was significantly delayed at 0.66 and 2.2 mg/L continuous exposure. After 20 and 25 days daphnid reproduction was stimulated at 0.86 mg/L [Mayer and Sanders 1977]. More detailed studies are in progress with simulated "use-pattern" exposures to better define the effects of simazine on daphnids, midges, and fathead minnows.[1]

Several field studies have also shown the rarity of deleterious effects on aquatic fauna from prolonged exposure to simazine [Gilderhus 1969; Mauck et al., 1976; Pierce et al., 1964; Snow 1963; Walker 1964]. In nearly every instance, simazine application produced no demonstrably harmful effects on fish or fish food organisms in the treated habitat.

Bioaccumulation of simazine residues in fish [Mayer and Sanders 1977] and aquatic invertebrates [Mauck et al., 1976] has been reported, but with an accumulation factor much lower than those for organochlorine insecticides [Mayer and Sanders 1977]. Some investigations have shown simazine residues in fish and/or invertebrates comparable to the treatment concentrations in water [Mauck et al., 1976; Rodgers 1970]. In all cases, simazine residues in fish have disappeared within several days after placement of treated specimens in fresh water [Mayer and Sanders 1977; Rodgers 1970].

Based on available information, the use of simazine in or near aquatic habitats should produce minimal impact on nontarget aquatic organisms.

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[1] F. L. Mayer, Jr., Fish Pesticide Lab., Fish and Wildlife Service, Columbia, Mo., personal communication.

Table 1.—*Simazine toxicity to nontarget aquatic fauna [after Mauck 1974]*

Organism	LC50, mg/L[a]	Exposure, hour	Temp., °C	Comments	Reference
Aquatic oligochaetes	28.0	96	21	LC50 far exceeds herbicidal rates	Walker 1964
Water flea (*Daphnia magna*)	1.0[b]	48	21	Immobilization rather than death used as the response	Sanders 1970
Seed shrimp (*Cypridopsis vidua*)	3.2[b]	48	21	Immobilization rather than death used as the response	Sanders 1970
Aquatic sowbug (*Asellus brevicaudus*)	>100.0	48	15.5	Mortality response	Sanders 1970
Scud (Amphipod) (*Gammarus fasciatus*)	>100.0	48	15.5	Mortality response	Sanders 1970
Glass shrimp (*Palaemonetes kadiakensis*)	>100.0	48	21	Mortality response	Sanders 1970
Crayfish (*Orconectes nails*)	>100.0	48	15.5	Mortality response	Sanders 1970
Common midge larvae (*Tendipedidae*)	28.0	96	21	LC50 far exceeds herbicidal rates	Walker 1964
Rainbow trout (*Salmo gairdneri*)	5.6	96	–		Cope 1965
Rainbow trout (*Salmo gairdneri*)	2.8	96	16		Woodard 1965
Carp x Goldfish (*Cyprinus x Carassius*)	190.0	96	20		Walker 1964
Goldfish (*Carassius auratus*)	>32	96	13.9	Similar to standard static tests	Woodard 1965
Bluntnose minnow (*Pimephales notatus*)	63.0	96	20	Loading of 0.5 g/L	Walker 1964
Channel catfish (*Ictalurus punctatus*)	>100.0	96	23-25	Fish size = 15-18 mm	Jones 1962
Channel catfish (*Ictalurus punctatus*)	85.0	96	20	Loading of 0.5 g/L	Walker 1964
Striped bass (*Roccus saxatilis*)	0.25	96	21	Loading of 0.75 g/L	Wellborn 1969
Pumpkinseed (*Lepomis gibbosus*)	28.0	96	20	Loading of 0.5 g/L	Walker 1964
Bluegill (*Lepomis macrochirus*)	11.6	96	–		Cope 1965
Bluegill (*Lepomis macrochirus*)	36.0	96	20	Loading of 0.5 g/L	Walker 1964
Bluegill (*Lepomis macrochirus*)	16	96	17.7	Similar to standard static tests	Woodard 1965
Bluegill (*Lepomis macrochirus*)	>100.0	48	24	Mortality response	Sanders 1970
Bluegill (*Lepomis macrochirus*)	>100.0	96	25-27	Fish size = 19.7 mm	Jones 1962
Redear sunfish (*Lepomis microlophus*)	55.0	96	20	Loading of 0.5 g/L	Walker 1964
Largemouth bass (*Micropterus salmoides*)	>25.0	96	20	Fish size = 10-15 mm	Jones 1962

Table 1.—*Simazine toxicity to nontarget aquatic fauna [after Mauck 1974]* —Continued

Organism	LC50, mg/L[a]	Exposure hour	Temp., °C	Comments	Reference
Largemouth bass (*Micropterus salmoides*)	45.0	96	20	Loading of 0.5 g/L	Walker 1964
Yellow perch (*Perca flavescens*)	100.0	96	20	Loading of 0.5 g/L	Walker 1964

[a] LC50 values given as mg of 80 percent wettable powder formulation per liter of water.

[b] These values are given as EC50 or the "effective concentration" producing 50 percent immobilization among test organisms.

GPO 847-443

ABSTRACT

Field studies determined the quantities of simazine (2-chloro-4,6-bis-(ethylamino)-s-triazine) found in irrigation water after experimental ditchbank treatment for weed control. Simazine applications to watered and dewatered canal banks were made at 2.25 and 4.5 kg/ha to provide selective control of annual weeds. Simazine levels in flowing canal water immediately following herbicide application did not exceed 60 μg/L. First flow water samples taken in the spring from treated canals, when dewatered the previous fall, showed a peak concentration of 250 μg/L within the treated reach which was diluted to < 5 μg/L immediately downstream. To determine residues that might accumulate in crops from canal waters containing low levels of simazine, a field study was initiated in which six crops representing nine commodity groupings were sprinkler and furrow irrigated with water containing 0.01 and 0.1 mg/L simazine. Crops harvested at 7 and 30 days' posttreatment revealed no detectable simazine residue in corn grain, pinto bean pods and foliage, and cucumbers. Trace amounts ranging from 0.5 to 2.9 μg/L were found in sugar beets, corn foliage, and tomatoes. Sugar beet foliage sprinkler irrigated with both rates of simazine contained 5 μg/L at 7 days' posttreatment. Alfalfa sprinkler irrigated with 0.1 mg/L simazine contained 6.4 μg/L, which was the largest residue found in crop samples. Included is a literature review that suggests water residue levels resulting from experimental application of simazine to inside slopes of canals were within established tolerances for potable water and probably would not impact adversely on crops and nontarget aquatic organisms.

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