SOME EFFECTS OF PRE-EMERGENCE HERBICIDES ON ASPARAGUS GROWTH, WEED GROWTH, AND RESIDUAL EFFECTS ON OAT AND SOYBEAN PLANTS

by

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INTRODUCTION

Present-day agriculture, with its specialized crops and methods, its gradual mechanization, and its efficient handling of plant diseases and insect pests, demands adequate weed control. The study of herbicides is of great importance to both research workers developing chemical weed control methods and to growers employing these newer techniques. It is further desirable to know whether herbicides applied to soil will persist and be cumulative, and if subsequent crops will be affected.

Pre-emergence weed control is one of the most recent in the long series of technological advances in modern agriculture. In the case of those applications where timing is critical and results vary with such factors as soil types, moisture, and temperature, the activity and persistence of herbicides are of paramount importance.

Asparagus (*Asparagus officinalis*, var. *altilis Linn.*, Washington 500) is a perennial, dioecious herb belonging to the Lily family. It is one of the most delicate, wholesome, and appetizing food products grown. This species often occupies the same land for periods of 20 to 25 years.
This investigation was designed to evaluate selected herbicides and their:

(1) phytotoxicity to asparagus plants;

(2) phytotoxicity to weed species;

(3) residual effect by bioassay methods; and

(4) movement into the soil.

Applications of the herbicides were made at yearly intervals after the cutting season.

REVIEW OF LITERATURE

Some herbicides tend to persist in the soil for a considerable period of time and may injure susceptible crops planted in the area. Hill et al. (12) found that applications of one or two pounds of monuron per acre in southeastern United States lost its toxicity in four to eight months. Burnside et al. (5) reported that monuron, simazine, and atrazine applied to fallow land at two pounds per acre in western Nebraska occasionally carried over in the soil and injured the following wheat crop. When monuron was applied at 1.6 pounds per acre to a loam soil in Ontario, Canada, Birk (3) found that 31 per cent disappeared within two weeks after application, after which the rate of disappearance was much reduced.

Possible factors in loss of toxicity of a herbicide from a soil are as follows: volatilization, soil adsorption, leaching, chemical decomposition, photodecomposition, and removal by plants. Volatilization may not be the cause of a significant loss of monuron, simazine, or atrazine due to low vapor pressures of these compounds. Photodecomposition has been definitely shown with monuron as reported by Hill et al. (12); therefore, when a herbicide is not incorporated into the soil, it can undergo detoxification from exposure to light.

Upchurch and Mason (23) found that the adsorption of herbicides has been correlated with a number of soil factors, but organic matter appears to be the most important in reducing their toxicity. Adsorption of monuron, simazine, and atrazine onto soil colloids accounts for a significant loss of toxicity according to Coggin and Crafts (9).

Upchurch and Pierce (25) found that leaching of herbicides is probably directly related to their water solubilities; so leaching should be greatest with monuron, intermediate with atrazine, and lowest with simazine. They also considered the effect of amount, frequency, and intensity of rainfall on leaching of monuron and concluded that amount of rainfall would be most directly correlated with the distribution of a herbicide under field conditions.

Rainfall and irrigation have had little effect on penetration of monuron in most soils. However, in Oregon, Sherburne et al. (21) found that monuron leaching was proportional to water percolation. They also found leaching to be greater in a sandy soil than in a clay loam and much less when moisture was near field capacity prior to application.

Sheets (20), comparing the toxicities of monuron and simazine in soils, found that simazine in solution was more toxic than monuron to oats and both were equally injurious to soybeans which were used as indicator plants. Leaching of these herbicides through soil columns by percolating water was at the same rate; however, the leaching was greater because of better water percolation and less soil adsorption of the herbicides in sandy loam soil.

Chemical breakdown of monuron to p-chloroaniline and smaller reaction products has been suggested by Rahn and Baynard (19). Castelfranco and Deutsch (6) have shown decomposition of simazine in soil by calcium-polysulfide.

The uptake of herbicides by growing plants is another means of removing residues from soil. Tolerant plants may deactivate the herbicides or accumulate considerable quantities, which could be removed from the area along with the crop. The plant uptake of monuron, simazine and atrazine is shown by the symptoms on the plants, radioautographs, and extraction procedures. Davis et al. (11) have shown detoxification of simazine by plants and plant extracts.

Behrens (2) pointed out from his residual studies that organisms of one kind or other in the soil will deactivate nearly all herbicides. Micro-organism breakdown of TCA, dalapon, 2,4-D and CDAA is usually quite rapid and is the major factor in the reduction of soil residues of these compounds. On the other hand, the deactivation of atrazine, simazine, monuron, and CDAA-T by micro-organisms is relatively slow. This is the major reason that we have residue problems with these compounds.

Crafts and Drever (10) studied the persistence of several herbicides in three California soil types using Kanota oats as indicator plants. They found the initial toxicity of the herbicides in order of decreasing toxicity as follows: fenuron and monuron, CIPC, dalapan and TCA, and TBA. They suggested that the substituted ureas, the symmetrical triazines, and all other herbicides of similar persistence in soils should be very thoroughly tested before being used on crop lands.

Burnside et al. (4) studied the dissipation of simazine from soil. They found that repeated plantings of soybeans in simazine-containing soil resulted in reduced phytotoxicity. Loss of simazine by volatilization was not detectable even when simazine suspensions were boiled. Deactivation of simazine occurred under conditions conducive to micro-organism growth, but the rate of breakdown was fairly slow. No deactivation of simazine occurred in sterile or frozen soil.

Jones et al. (13) reported that after 10 months diphenamid residues were found throughout the 0 to 9 inch soil depth. In silt loam soils under climatic conditions prevailing in the bluegrass region of Kentucky, diphenamid residues in soils may be present at phytotoxic levels in the plow layer 10 to 11 months after application at rates required for weed control in tobacco.

Climatic factors generally affect dissipation rates of monuron, simazine, and atrazine. Temperature has been shown to have little effect on leaching of monuron as reported by Upchurch and Pierce (25) but considerable effect on microbial and chemical breakdown of herbicides. Physical adsorption is an exothermic process so, with other things being equal, less will probably occur at higher temperatures. Moisture possibly affects all avenues of herbicide breakdown.

McWhorter and Wooten (15), using a fluorescent tracer for the study of spray deposits in soils, found that the use of a wide angle nozzle tip on an underground applicator, followed or not followed by rotary hoeing, appeared the most promising for effective application of volatile herbicides.

Mosier and Gustafson (17) described the method of control used on a weed-free plot as "scraping with a sharp hoe so as to produce practically no mulch." This same method was used by Cates and Cox (7) in 1912. They stated, "Particular care was to be paid not to stir the soil any more than absolutely necessary." They believed that the principal value of cultivation lay in the killing of weeds and not the aeration of the soil or the conservation of moisture.

MATERIALS AND METHODS

Herbicide Study (Field)

The investigations reported here were carried out in 1964 at Kansas State University Horticulture Farm, Manhattan, Kansas.

The field experiment was started in Spring, 1960. A planting of Washington 500 cultivar of asparagus was established in 1960 from crowns. This planting was used for the pre-emergence herbicide treatments included in this study (Table 1).

Table 1. Pre-emergent herbicides which were applied in 1963 and 1964 to the same plots of asparagus.

Common name of the herbicide	Chemical name of the herbicide	Formulation	Rates per acre in pounds
Alipur	N-cyclooctyl-dimethylurea (OMU)+Butynyl-N-(3-chloro-phenyl) carbamate (BiPc)	2#/g	3 and 6
Dacthal	Dimethyl 2,3,5,6 tetrachloro-terephthalate	75 W.P.	8 and 16
Dymid	N, N-dimethyl-2,2-diphenyl-acetamide	80 W.P.	3 and 6
Enide	N, N-dimethyl-2,2-diphenyl-acetamide	50 W.P.	4 and 8
Lorox	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea	50 W.P.	1 and 2
Monuron*	3-(p-chlorophenyl)-1,1-di-methylurea	80 W.P.	1 and 2
Simazine*	2-chloro-4,6-bis(ethylamino)-S-triazine	80 W.P.	2 and 4
Zytron	O-(2,4-dichlorophenyl) O-methyl isopropylphosphoramidothioate	3#/g	7.5 and 15

*Monuron and simazine are suggested herbicides for weed control in commercial asparagus planting as reported by Anderson et al. (1).

The experimental area was disked to destroy germinated weeds. The area was divided into 54 plots, 10 feet by 6.5 feet (Plate I). The distances between rows and plants were 6.5 feet and 1.5 feet, respectively.

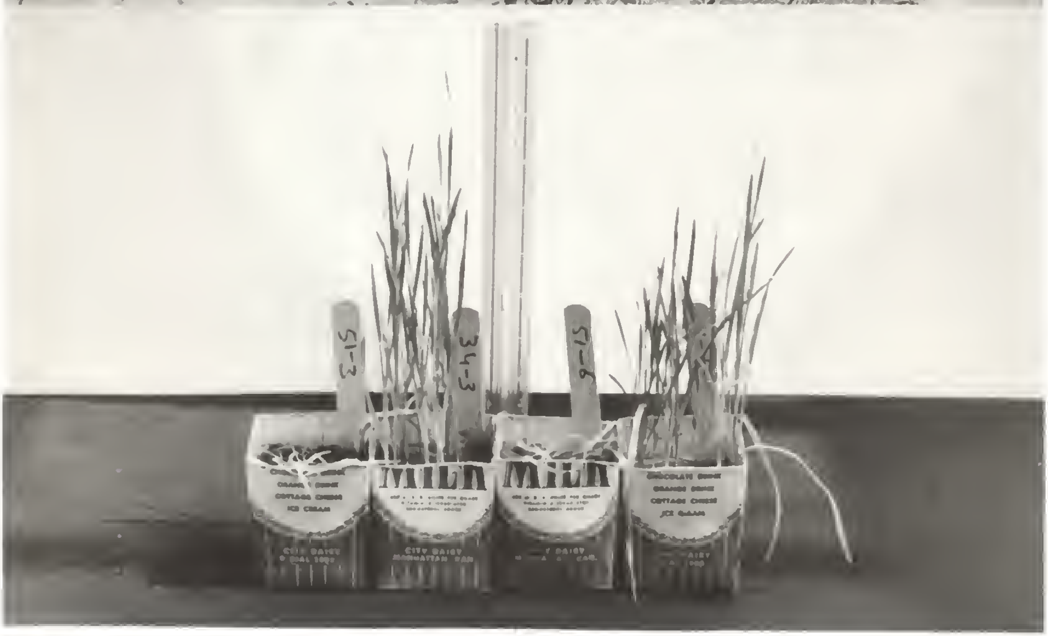
EXPLANATION OF PLATE I

Top. Field arrangement of asparagus plots at time of application of herbicide treatments. Darkened plots indicate that herbicides have just been applied.

Middle. Close up pictures indicating the effect of selected herbicides on weed control.

Bottom. Oat plants grown in a residue study, from left to right, (1) from 0-3 inch soil depth to which simazine had been applied at four pounds per acre, (2) soil sampled from 0-3 inch depth to which herbicides had not been applied, (3) soil sampled 3-6 inch depth to which simazine had been applied at four pounds per acre, and (4) soil sampled 3-6 inch depth to which herbicides had not been applied.

PLATE I



1 2 3 4

The study included the following treatments: (a) chemical treatments; (b) cultivated checks, which were kept free from weeds during growing seasons by hoeing; and (c) control or no weeding. Each replication consisted of 16 chemical treatments, 1 cultivated check, and 1 control. Three replications in a randomized block constituted the study. The above-mentioned herbicides had been applied for two years previously to evaluate their effectiveness in controlling weeds in asparagus and their residual life in soil. After application of the herbicides, sprinkler irrigation was used on the same day to apply approximately one-half inch of water. Menges (16) reported that better weed control was obtained by herbicides if overhead irrigation was used. No additional cultural practices were used during the growing season, except for the clean cultivated plots.

According to the data in Table 2, it appears that the total precipitation in 1963 was below normal for most of the months. This resulted in dry conditions during the growing season. In 1964, the total precipitation was normal. These weather records were taken at the Kansas State University campus. Some variation was probable at the farm.

The comparative visual ratings of the weed population were made among the treated plots to evaluate the extent of weed control. For this work the following scale was used:

1 = excellent control, trace or no live weeds, distinct evidence of killing.

2 = good control, few live weeds but not considered to offer appreciable competition, good evidence of killing.

3 = fair control, a number of weeds remain alive, may range in size from very suppressed to apparently healthy plants, some evidence of killing.

4 = poor control, most weeds apparently making growth, some suppression of size, little or no evidence of killing.

5 = no control, all weeds normal and healthy.

Table 2. Monthly precipitation during experimental period from January 1, 1963, to November 30, 1964.

Month	1963		1964	
	Precipitation in inches	Deviation from normal in inches	Precipitation in inches	Deviation from normal in inches
January	0.48	-0.38	0.38	+0.48
February	0.06	-0.90	0.44	-0.52
March	1.84	+0.13	2.01	+0.30
April	1.70	-0.90	4.22	+1.62
May	2.49	-1.88	2.92	-1.45
June	2.90	-2.21	6.58	+1.47
July	1.24	-2.76	3.68	-0.32
August	1.80	+2.38	3.71	-0.47
September	2.16	-1.55	2.68	-1.03
October	2.16	-0.16	0.31	-2.01
November	1.41	+0.17	3.53	+2.29
December	0.29	+0.07		
Total	18.53	-13.42		

In March, 1964, four asparagus plants per plot from the previous season crop were harvested, dried in a forced air oven at 65° C, and weighed.

In September, 1964, random samples of one square foot of weeds from each plot were harvested. The weeds were dried in a forced air oven at 65° C, and the dry weights of each sample were recorded. The data were subjected to analysis of variance as outlined by Cochran and Cox (8) for randomized blocks.

Bioassay

To determine the depth to which the chemicals had leached, three soil depths varying from 0-3 inches, 3-6 inches, and 6-9 inches were taken from each plot in the first week of April, 1964. A Pit-O-Matic core sampler from the Soil Testing Equipment Company, Ames, Iowa was used to take the samples. Four samples per plot were taken. The core sampler was 2 inches in diameter. The soil samples were thoroughly mixed, air-dried, and sieved before conducting the bioassay study.

On April 23, 1964, 300 grams of soil from 0-3 inch and 3-6 inch depths were put in the containers. Twenty-five seeds of the Andrew Oat variety and 20 seeds of the America Spinach variety were planted in each container as indicator plants. The field capacity of the soil was previously determined, and measured amounts of water were applied to each pot to bring the soil up to field capacity. The initial weight of the samples at field capacity was maintained on successive days by adding the differential evaporated amount of water to the containers. The plant stand was counted and thinned to 19 per container in case of oats, but in the case of spinach, survival of the plants was poor due to "dampening off" so the study was discontinued. The oat containers were weighed and watered every morning until harvested. The plant height was measured in centimeters during the third week. This was accomplished by recording the length of shoots representative of the majority of plants in the container. After one month, the oat plants were harvested, dried in an oven at 65° C for 24 hours, and weighed.

The soil was again air-dried and screened after harvesting the oat plants. Twenty-five seeds of Andrew Oats were planted again on July 3, 1964, in each container. Twelve seeds of Clark soybeans were planted in the containers originally seeded to spinach. The plants were watered, measured, harvested, dried, and weighed as described above. The oats and soybeans were thinned to 19 and 6 plants per container, respectively. Fifteen samples of soil from 6-9 inch depths were also included in this study to determine whether these chemicals had been leached to this depth. The reductions in dry weight and height were used as a measure of residual toxicity of the herbicides used.

EXPERIMENTAL RESULTS

Herbicide Study (Field)

Mean dry weights of asparagus plants grown in soils treated with various herbicides are represented in Table 3. Significant increases occurred in plant weight from plots treated with simazine 4[1], simazine 2, and zytron 15 when compared to the check plots (Table 4). Other significant differences in dry weight of asparagus plants did not occur. Therefore, these results indicate a residual toxicity of the other herbicides tested or the inability of the herbicides to control weed competition.

Mean weed ratings by dates and dry weight of weeds per square foot are given in Table 5. Significant differences for weed ratings occurred on the July 9 date (Table 6). Weed ratings indicated that all herbicide treatments significantly reduced the weed population when compared to the check plots. Significant decreases in weed population also occurred between herbicide treatments (Plate I). Alipur 6, dymid 3 and 6, lorox 2,

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[1]Number following herbicide is active ingredient in pounds per acre.

zytron 15, monuron 2, enide 8 and simazine 2 and 4 significantly reduced the weed population when compared to lorox 1, alipur 3, zytron 7.5 and dacthal 16.

The August 5 weed ratings again indicated that all herbicide treatments significantly reduced the weed population when compared to check plots. All herbicide treatments (Tables 5 and 7) significantly reduced the weed population more than lorox 1, alipur 3 and zytron 7.5. Simazine at both rates of application significantly reduced the weed population better than any other herbicide treatment.

Significant differences in dry weight of weeds per treatment occurred (Table 8). Dry weight of weeds per square foot at the end of the growing season indicated that the following herbicides significantly reduced the weed population when compared to the check treatment: lorox 1 and 2, dacthal 16, monuron 1, alipur 6, simazine 2 and 4, enide 8 and dymid 6.

Dry weights of weeds from both simazine treatments were significantly less than weed weights from all other herbicide treatments (Table 5). The major weed species in this planting were Digitaria, Amaranthus and Kochia.

Bioassay

A bioassay using Andrew oats as indicator plants in soil samples taken at the 0-3 inch depth from the various treatments applied 9 months previously gave a significant reduction in dry weights from the plots treated with monuron 2, monuron 1, simazine 2, simazine 5 (Tables 9 and 10). Burnside et al. (4) observed that simazine concentration was greatest at one-half and one inch depths of the top surface layer and very low at depths of 3 and 6 inches. There was no significant reduction in plant height in any treatment except simazine 4 (Table 11). Slight reduction in dry weights of oat plants occurred when grown in soils sampled 3-6 inches deep that had been treated with simazine 2 and simazine 4 (Tables 9 and 12). These results do not agree with those of Burnside et al. (4). Plant height was also significantly reduced in simazine 4 treated plots (Table 13). The persistence of the above-mentioned herbicides inhibited the growth as well as the dry weight (Plate II).

Dry weights and plant heights of Clark soybeans grown as indicator plants in 0-3 inch soil depths indicated statistically non-significant results (Tables 14, 15 and 16). In the 3-6 inch soil depth (Tables 17 and 18) monuron 1 and monuron 2 reduced the plant height significantly when compared to the check plants. Hill et al. (12) found that most of the breakdown of monuron in agricultural soils was due to microbial activity. If this is true the microbial population must have been small because of the persistence of monuron. Significant differences in dry weights did not occur between the check treatment and the herbicide treatments; however, significant differences in dry weight of oat plants did occur among herbicides. The oat plants grown in the alipur 3 treatment weighed significantly more than those grown in the following treatments: enide 4 and 8, zytron 15, dymid 3 and 6 and lorox 2. It is apparent from these data that residues of diphenamid, which is formulated as both enide and dymid, occurred in the soil and reduced the growth of soybeans. This decrease in growth occurred from rates of application of diphenamid from 3 to 8 pounds per acre.

Andrew oats grown as a second crop in the same soil samples taken from the 0-3 inch depth revealed a significant reduction in dry weight of

EXPLANATION OF PLATE II

Top. Oat plants in second residue study from soils sampled 0-3 inch depth. Treatments from left to right are: (1) monuron 2, (2) check, (3) simazine 4, (4) lorox 2, (5) enide 8, (6) zytron 15, (7) alipur 6, (8) dacthal 16 and (9) dymid 6 pounds per acre.

Middle. Oat plants in second residue study from soil sampled 3-6 inch depth. Treatments from left to right are the same as in top photograph.

Bottom. Oat plants in second residue study from soils sampled 6-9 inch depth. Treatments from left to right are: (1) monuron 2, (2) simazine 2, (3) check, (4) simazine 4 and (5) monuron 1 pound per acre.

PLATE II

1 2 3 4 5 6 7 8 9

1 2 3 4 5 6 7 8 9

1 2 3 4 5

the plants grown in the simazine 4 treatment when compared to any other treatment (Tables 19 and 20). Plants grown in soils from the simazine 2 plots weighed significantly less than other herbicide treatments, but not less than the check plants. Plant height was significantly reduced for plants grown in soils treated with simazine 2 and 4, monuron 1 and alipur 3 when compared to the plants grown in the checks (Table 21).

Phytotoxicity did not affect plants grown in samples taken from 3-6 inch depths regardless of previous herbicide application except simazine 4 treated plots which showed significant reduction in dry weights (Tables 19 and 22). Plant heights were not significantly different (Table 23).

Average dry weight and plant height of Andrew oats and Clark soybeans grown in soils sampled at the 6-9 inch depth from plots treated with monuron 1 and 2, simazine 2 and 4 showed no significant differences (Tables 24, 25, 26, 27 and 28). Evidently these herbicides did not leach to this depth (Plates II and III).

DISCUSSION

Herbicide Study (Field)

It was found that dry weights of asparagus plants at the end of the growing season were significantly increased for the simazine treatments and zytron 15 treatment. Evidently these treatments reduced the weed population so that water, nutrients and/or light were not limiting factors for asparagus growth. None of the herbicide treatments reduced the weight of the asparagus plants below the weight of the check plants. Therefore, it is assumed that the herbicides used were not phytotoxic to asparagus.

EXPLANATION OF PLATE III

Top. Soybean plants in residue study from soils sampled 0-3 inch depth. Treatments from left to right are: (1) monuron 2, (2) check, (3) simazine 4, (4) lorox 2, (5) enide 8, (6) zytron 15, (7) alipur 6, (8) dacthal 16 and (9) dymid 6 pounds per acre.

Middle. Soybean plants in residue study from soils sampled 3-6 inch depth. Treatments from left to right are the same as in top photograph.

Bottom. Soybean plants in residue study from soils sampled 6-9 inch depth. Treatments from left to right are: (1) monuron 2, (2) simazine 2, (3) check, (4) simazine 4 and (5) monuron 1 pound per acre.

PLATE III

1 2 3 4 5 6 7 8 9

1 2 3 4 5 6 7 8 9

1 2 3 4 5

Weed populations were reduced by the application of all herbicides from observations recorded on both July 9 and August 5. It was apparent that simazine at both rates of application was more persistent than the other herbicides because weed populations did not increase with time as was the case with the other herbicides. Stevens and Sutherland (22) reported that hand cultivation was unnecessary when two or three pounds of simazine per acre was used in raspberry nurseries. Lorox 1, alipur 3 and zytron 7.5 became relatively ineffective in controlling weeds between the first observation on July 9 and the second observation on August 5. At the end of the growing season it was evident that simazine at both rates of application and lorox 2 were effective in controlling weeds for the entire season.

Bioassay

Results of the residual studies of the herbicides have given a comparison of the persistence encountered in the use of certain herbicides and so are valuable in assessing the usefulness of herbicides on asparagus. Because of the extreme persistence of the triazine herbicides as indicated by the plant indicators oats and soybeans, it seems necessary that they should be used with great care on agricultural lands. Leopold (14) stated that the lethal dosage per plant for soil applications is generally somewhat lower than the amount required for killing by foliar application.

Burnside et al. (5) found monuron and simazine, when applied at the rate of two pounds per acre, indicated residual toxicity to wheat the following year. In the present study, none of the herbicides indicated a toxic effect to the following year's asparagus crop (Table 3). Leaching of the herbicides was probably at a minimum, because precipitation was below normal during the months of application in 1963 and 1964 (Table 2).

Upchurch and Pierce (25) reported that leaching of herbicides is probably directly related to their water solubilities, so leaching should be greatest with monuron and lowest with simazine. The present investigations showed that monuron 1 and monuron 2, simazine 2 and simazine 4 leached to the 3-6 inch depth. Simazine showed more severe injuries to the plant indicators than monuron (Tables 3 and 5). Plants in the simazine treatments showed a significant decrease in dry weights and plant heights. This injurious effect could have been caused by the rate of application used on this fine sandy loam soil which contains relatively little organic matter. There was no harmful effect on oat and soybean plants grown in soils from the 6-9 inch soil depth from the simazine or monuron treated plots (Table 9). Hill et al. (12) stated that the application of one and two pounds of monuron per acre in the southeastern United States lost its toxicity in four to eight months. This fact is further strengthened by Birk (3) who found that 31 per cent of monuron when applied at one to six pounds per acre disappeared within two weeks after application, after which the rate of disappearance was much less.

Sheets (20) comparing the toxicities of monuron and simazine in soils, found that simazine in solution was more toxic than monuron to oats, and both were equally injurious to soybeans used as indicator plants (Tables 5, 6, and 7). This study confirms Sheet's results.

Loss of toxicity through soil adsorption, chemical decomposition, and deactivation by soil micro-organisms was not measured.

From his residual studies Behrens (2) pointed out that micro-organisms in the soil will deactivate most herbicides. Micro-organism breakdown of TCA, Dalapon, 2,4-D and CDAA is usually quite rapid and is the major factor in the reduction of soil residues of these compounds. On the other hand, the deactivation of atrazine, simazine, and monuron by micro-organism is relatively slow. This is the major reason that we have residue problems with these compounds.

Volatilization in this case may not have been too important a factor with these herbicides, since they were incorporated with irrigation. Photodecomposition has been shown with monuron, but importance of this in the present study is difficult to assess.

SUMMARY

A field investigation was carried out to determine the overall effectiveness and residual effect of experimental and commercial herbicides on asparagus. Significant differences in plant growth (dry weight basis) from the 1963 applications of these herbicides did not occur.

Visual evaluation of the treated plots was made on July 9 and August 5, 1964. Simazine at 2 and 4 pounds per acre was the most effective herbicide in controlling weeds, but a residue remained for several months.

Bioassay studies with Andrew oats and Clark soybeans indicated the residual toxicity of simazine 4, simazine 2, monuron 2, and monuron 1 in 0-3 inches and 3-6 inches of soils collected in April, 1964, from an asparagus planting to which the herbicides were applied since 1962. The reductions of dry weight and plant height were used as a measure for detecting herbicide residues in soil samples. Bioassays from the 6-9 inch soil depth indicated that herbicide residues were not sufficiently large to modify oat and soybean growth.

Table 3. Mean dry weight of asparagus plants grown in soils treated with various herbicides, 1963. (Plants were harvested in February, 1964).

Treatment	Lbs./A active ingredient	Dry weight in g/plant
Simazine	4	188
Zytron	15	145
Simazine	2	142
Zytron	7.5	134
Enide	8	132
Dymid	3	126
Dymid	6	122
Monuron	1	122
Enide	4	120
Alipur	6	110
Cultivated check	--	104
Dacthal	16	104
Monuron	2	102
Alipur	3	98
Lorox	2	98
Dacthal	8	97
Lorox	1	92
Check	--	90
LSD 5%		46

Table 4. Analysis of variance for the weight of asparagus plants grown in soils treated with various herbicides.

Factors	Df	Ss	Ms	F
Total	53	60893	----	----
Treatments	17	30443	1790.76	2.35*
Replications	2	4647	2323.50	----
Error	34	25903	761.85	----

*Significant at 5% level.

Table 5. Mean weed ratings by dates and dry weight of weeds per square foot at conclusion of growing season (1964).

Treatment	Rate/acre active ingredient	Weed ratings July 9	Weed ratings Aug. 5	Dry wt. g/sq. ft.	Predominate species
Check	--	5.0	5.0	79	Digitaria sanguinalis and Amaranthus retroflescus
Lorox	1	2.3	4.0	50	Digitaria sanguinalis
Alipur	3	2.3	5.0	65	Digitaria sanguinalis
Zytron	7.5	2.3	4.0	81	Amaranthus retroflescus
Dacthal	16	2.3	2.7	47	Amaranthus retroflescus
Dacthal	8	1.7	2.3	75	Amaranthus retroflescus
Enide	4	1.7	2.7	70	Digitaria sanguinalis
Monuron	1	1.7	3.0	36	Digitaria sanguinalis
Alipur	6	1.7	3.0	49	Digitaria sanguinalis
Dymid	3	1.3	3.0	53	Kochia scoparia
Lorox	2	1.3	2.0	17	Clean
Zytron	15	1.3	2.3	70	Amaranthus retroflescus
Monuron	2	1.0	3.3	73	Digitaria sanguinalis
Simazine	2	1.0	1.0	0	Clean
Simazine	4	1.0	1.0	0	Clean
Enide	8	1.0	1.7	42	Digitaria sanguinalis
Cultivated check	--	1.0	1.3	0	Clean
Dymid	6	1.0	2.3	28	Amaranthus retroflescus
LSD 5%		.7	.6	27	

Table 6. Analysis of variance for weed ratings by July 9, 1964.

Factors	Df	Ss	Ms	F
Total	53	----	----	----
Treatments	17	47.500	2.7647	12.0**
Replications	2	0	0	----
Error	34	7.337	0.2185	----

**Significant at 1% level.

Table 7. Analysis of variance for weed ratings by August 5, 1964.

Factors	Df	Ss	Ms	F
Total	53	----	----	----
Treatments	17	72.537	4.267	3.82**
Replications	2	3.370	1.685	----
Error	34	37.963	1.117	----

**Significant at 1% level.

Table 8. Analysis of variance for dry weight of weeds per square foot.

Factors	Df	Ss	Ms	F
Total	53	----	----	----
Treatments	17	39016	2295.05	5.6**
Replications	2	1307	653.5	----
Error	34	13964	410.07	----

**Significant at 1% level.

Table 9. Mean dry weights and plant heights of Andrew oats (first crop) grown in soils from an asparagus planting to which herbicides had been applied on June 19, 1963. The soil samples were collected in March, 1964, at 0-3 and 3-6 inch depths.

Treatments	0-3 inch depth		3-6 inch depth	
	Dry wt. in g/pot	Plant height in cm.	Dry wt. in g/pot	Plant height in cm.
Dacthal 16	0.657	15.6	0.637	14.4
Enide 4	0.645	15.7	0.668	16.5
Dymid 6	0.613	14.6	0.635	13.9
Dacthal 8	0.595	16.3	0.593	16.6
Cultivated check	0.595	15.3	0.674	16.6
Zytron 7.5	0.591	14.1	0.592	14.5
Dymid 3	0.586	14.7	0.647	15.1
Zytron 15	0.565	15.0	0.607	16.7
Check	0.554	14.9	0.563	15.3
Lorox 1	0.547	15.2	0.618	15.8
Alipur 3	0.546	13.6	0.591	15.0
Enide 8	0.544	13.4	0.554	14.1
Alipur 6	0.543	14.1	0.650	15.0
Lorox 2	0.532	14.0	0.576	13.3
Monuron 2	0.461	15.0	0.541	15.6
Monuron 1	0.458	14.7	0.543	14.2
Simazine 2	0.303	15.6	0.479	17.5
Simazine 4	0.147	10.0	0.141	9.7
LSD 5%	0.082	2.6	0.075	3.3

Table 10. Analysis of variance for dry weight of oats (first crop) 0-3 inch depth.

Factors	Df	Ss	Ms	F
Total	53	0.8675	---	---
Treatments	17	0.7729	0.0455	17.05**
Replications	2	0.0040	0.0020	---
Error	34	0.0906	0.0027	---

**Significant at 1% level.

Table 11. Analysis of variance for plant height of oats (first crop) 0-3 inch depth.

Factors	Df	Ss	Ms	F
Total	53	188.53	---	---
Treatments	17	94.74	5.58	2.09*
Replications	2	2.69	1.34	---
Error	34	91.10	2.68	---

*Significant at 5% level.

Table 12. Analysis of variance for dry weight of oats (first crop) 3-6 inch depth.

Factors	Df	Ss	Ms	F
Total	53	0.8166	---	---
Treatments	17	0.7225	0.0425	19.42**
Replications	2	0.0198	0.0099	---
Error	34	0.0743	0.0022	---

**Significant at 1% level.

Table 13. Analysis of variance for plant height of oats (first crop) 3-6 inch depth.

Factors	Df	Ss	Ms	F
Total	53	307.51	---	---
Treatments	17	157.84	9.28	2.16*
Replications	2	3.94	1.97	---
Error	34	145.73	4.29	---

*Significant at 5% level.

Table 14. Mean dry weights and plant heights of Clark soybeans grown in soil from an asparagus planting to which herbicides had been applied on June 19, 1963. The soil samples were collected in March, 1964, at 0-3 and 3-6 inch depths.

Treatments lb/A, active ingredient	0-3 inch depth: Dry wt. in g/pot	0-3 inch depth: Plant height in cm.	3-6 inch depth: Dry wt. in g/pot	3-6 inch depth: Plant height in cm.
Enide 4	1.52	28.0	0.93	25.3
Alipur 6	1.44	26.0	1.15	25.0
Zytron 7.5	1.40	24.0	1.00	24.0
Zytron 15	1.27	24.3	0.93	24.0
Check	1.22	24.3	1.13	24.0
Enide 8	1.22	26.3	0.92	24.0
Dacthal 8	1.18	25.0	1.02	22.3
Dymid 6	1.12	26.6	0.94	22.0
Lorox 2	1.11	25.3	0.89	24.3
Dymid 3	1.11	25.3	1.22	22.3
Lorox 1	1.08	24.0	1.00	23.0
Alipur 3	1.05	26.0	1.33	23.0
Cultivated check	1.04	27.3	1.11	23.3
Simazine 4	1.04	23.3	1.03	22.6
Monuron 1	0.99	24.0	1.04	20.6
Dacthal 16	0.99	27.3	1.03	24.6
Simazine 2	0.73	24.6	1.04	24.3
Monuron 2	0.68	26.3	1.22	21.3
LSD 5%	N.S.	N.S.	.34	2.23

Table 15. Analysis of variance for dry weight of soybeans 0-3 inch depth.

Factors	Df	Ss	Ms	F
Total	53	8.4507	---	---
Treatments	17	2.4225	0.1425	0.85
Replications	2	0.3248	0.1624	---
Error	34	5.7033	0.1677	---

Table 16. Analysis of variance for plant height of soybeans 0-3 inch depth.

Factors	Df	Ss	Ms	F
Total	53	269	---	---
Treatments	17	90	5.2941	1.2
Replications	2	29	14.5000	---
Error	34	150	4.4117	---

Table 17. Analysis of variance for dry weight of soybeans 3-6 inch depth.

Factors	Df	Ss	Ms	F
Total	53	3.1679	---	---
Treatments	17	1.7462	0.1114	2.73**
Replications	2	0.0375	0.0198	---
Error	34	1.3842	0.0407	---

**Significant at 1% level.

Table 18. Analysis of variance for plant height of soybeans 3-6 inch depth.

Factors	Df	Ss	Ms	F
Total	53	159	---	---
Treatments	17	82	4.8235	2.69**
Replications	2	16	8.0000	---
Error	34	61	1.7941	---

**Significant at 1% level.

Table 19. Mean dry weight and plant heights of Andrew oat plants (second crop) grown in soil from an asparagus planting to which herbicides had been applied on June 19, 1963. The soil samples were collected in March, 1964, at 0-3 and 3-6 inch depths.

Treatments lbs/A, active ingredient	0-3 inch depth		3-6 inch depth	
	Dry wt. in g/pot.	Plant height in cm.	Dry wt. in g/pot	Plant height in cm.
Alipur 6	1.23	29.6	1.05	26.0
Dacthal 16	1.22	29.3	1.12	24.3
Lorox 2	1.22	28.3	1.11	25.0
Enide 8	1.22	28.6	1.09	23.0
Dymid 3	1.19	27.0	1.00	22.3
Lorox 1	1.17	28.0	1.10	23.3
Enide 4	1.16	27.6	1.16	25.6
Alipur 3	1.16	25.6	1.12	25.0
Monuron 2	1.13	28.3	0.94	23.3
Cultivated check	1.11	28.6	1.13	25.3
Dymid 6	1.08	27.3	1.17	25.0
Zytron 7.5	1.03	28.0	1.03	24.3
Check	1.00	27.3	1.12	22.3
Dacthal 8	0.99	27.0	1.00	25.3
Monuron 1	0.94	26.6	0.93	23.0
Zytron 15	0.89	27.3	0.92	24.3
Simazine 2	0.80	26.3	1.05	24.3
Simazine 4	0.12	16.3	0.35	18.0
LSD 5%	.33	.53	0.24	N.S.

Table 20. Analysis of variance for dry weight of oats (second crop) 0-3 inch depth.

Factors	Df	Ss	Ms	F
Total	53	5.1058	---	---
Treatments	17	3.5063	0.2063	5.26**
Replications	2	0.2655	0.1328	---
Error	34	1.3340	0.0392	---

**Significant at 1% level.

Table 21. Analysis of variance for plant height of oats (second crop) 0-3 inch depth.

Factors	Df	Ss	Ms	F
Total	53	685	---	---
Treatments	17	422	24.8235	3.47**
Replications	2	20	10.0000	---
Error	34	243	7.1471	---

**Significant at 1% level.

Table 22. Analysis of variance for dry weight of oats (second crop) 3-6 inch depth.

Factors	Df	Ss	Ms	F
Total	53	2.8532	---	---
Treatments	17	1.7432	0.1025	4.63**
Replications	2	0.3587	0.1794	---
Error	34	0.7513	0.0221	---

**Significant at 1% level.

Table 23. Analysis of variance for plant height of oats (second crop) 3-6 inch depth.

Factors	Df	Ss	Ms	F
Total	53	407	---	---
Treatments	17	173	10.1765	1.74
Replications	2	35	17.5000	---
Error	34	199	5.8529	---

Table 24. Mean dry weights and plant heights of Andrew oats and Clark soybeans grown in soils from an asparagus planting to which herbicides had been applied on June 19, 1963. The soil samples were collected in March, 1964, at 6-9 inch depths.

Treatments	6-9 inch depths (oats)		6-9 inch depths (soybeans)	
	Dry wt. in g/pot	Plant height in cm.	Dry wt. in g/pot	Plant height in cm.
Monuron 1	0.5641	16.3	1.8976	22.0
Check	0.5423	16.0	1.7938	21.6
Monuron 2	0.4992	15.6	1.8181	21.3
Simazine 2	0.4308	15.6	1.7942	23.3
Simazine 4	0.4110	15.0	1.6475	21.6
LSD 5%	N.S.	N.S.	N.S.	N.S

Table 25. Analysis of variance for dry weight of oats 6-9 inch depth.

Factors	Df	Ss	Ms	F
Total	14	0.1776	--	--
Treatments	4	0.0541	0.0135	1.11
Replications	2	0.0263	0.0131	--
Error	8	0.0972	0.0122	--

Table 26. Analysis of variance for plant height of oats 6-9 inch depth.

Factors	Df	Ss	Ms	F
Total	14	27	--	--
Treatments	4	3	0.7500	0.50
Replications	2	12	6.0000	--
Error	8	12	1.5000	--

Table 27. Analysis of variance for dry weight of soybeans 6-9 inch depth.

Factors	Df	Ss	Ms	F
Total	14	0.3491	--	--
Treatments	4	0.0981	0.0245	0.09
Replications	2	0.0324	0.0162	--
Error	8	0.2186	0.2732	--

Table 28. Analysis of variance for plant height of soybeans 6-9 inch depth.

Factors	Df	Ss	Ms	F
Total	14	24	--	--
Treatments	4	7	1.7500	0.87
Replications	2	1	0.5000	--
Error	8	16	2.0000	--

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SOME EFFECTS OF PRE-EMERGENCE HERBICIDES ON ASPARAGUS GROWTH, WEED GROWTH, AND RESIDUAL EFFECTS ON OAT AND SOYBEAN PLANTS

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The present day extensive use of herbicides has resulted in a great deal of interest in the breakdown of these chemicals in the soil. The investigations reported in this thesis were designed to evaluate: the phytotoxicity of herbicides to asparagus; the phytotoxicity to weed species; the residual effect of these herbicides by bioassay methods; and the soil depths to which these herbicides would leach.

The field experiment reported in this study was started in the spring of 1964. The Washington 500 cultivar of asparagus was the test crop. Eight pre-emergent herbicides were included in the experiment. Two rates of application were used for each. These treatments were compared to a control treatment and to a cultivated treatment. The herbicides were applied in 1962, 1963 and 1964 to the same plots of asparagus.

Bioassays of soil samples from the asparagus plots were made about nine months after the second application of the herbicides. Using Andrew oats and Clark soybeans as indicators, it was found that monuron 1 and 2, simazine 2 and 4 leached to 0-3 and 3-6 inch soil depths. It was found that simazine was more toxic than monuron to oats, but both were equally injurious to soybeans. There was no harmful effect on oats and soybean plants grown in soils from 6-9 inch depths from any of these herbicides.

The phytotoxicity of these herbicides is further confirmed by visual observation and dry weight of weeds per square foot. Simazine at 2 and 4 pounds per acre proved to be the most effective herbicides for controlling annual weed species in asparagus. Lorox 2, dymid 6, monuron 1, dacthal 16, and enide 8 satisfactorily controlled weed species, while the other herbicides were less effective.

The herbicides used in 1963 did not produce any toxic effects to the asparagus plants that year. Significant increases were noted in the dry weights of asparagus plants from plots treated with simazine 4, simazine 2, and zytron 15.