Herbicidal Activity of Chloroacetamides and Pyridazinones on Sugarbeets and Weeds[1]

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In the irrigated regions of the central High Plains and intermountain West several herbicides are applied singly or in mixtures before planting to control annual weeds in sugarbeets *(Beta vulgaris* L.). The principal herbicides used are *S*-ethyl *N*-ethylthiocyclohexanecarbamate (cycloate), *S*-(2,3-dichloroallyl) diisopropylthiocarbamate (diallate), 5-amino-4-chloro-2-phenyl-3(2*H*)-pyridazinone (pyrazon), and *N, N*-dimethyltridecylamine salt of 7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid (endothall) (TD 283). Although these herbicides control several annual weeds satisfactorily in many areas, weed control has averaged only 68% in six Western States (7).[3]

Complete control of annual weeds with herbicides applied before planting in sugarbeets has been difficult because of the diversity of weed species that can infest a field. Sullivan (10) reported that 11 annual weeds are troublesome pests in the Western arid region. These 11 weeds belong to eight different families. Of the 11 weed species, common lambsquarters *(Chenopodium album* L.) and kochia *(Kochia scoparia* (L.) Schrad.) belong to the Chenopodiaceae — the same family to which sugarbeets belong.

A need still exists to discover and develop herbicides that will control a broader spectrum of annual weeds when herbicides are incorporated with the soil or applied to the soil surface. This study was conducted to: (a) evaluate the herbicidal activity of structurally related compounds with respect to sugarbeet tolerance and the control of common lambsquarters, foxtail millet *(Setaria italica* (L.) Beauv.), kochia, pigweed *(Amaranthus* spp.), and wild buckwheat *(Polygonum convolvulus* L.; (b) compare the effectiveness of these herbicides when incorporated with the soil before planting and when applied as a surface treatment after planting; and (c) determine the relative persistence of several of these chemicals in the soil.

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[3] Numbers in parentheses refer to literature cited.

Herbicides were chosen from two major groupings — the α-chloroacetamides and pyridazinones. The α-chloroacetamides studied were 2-chloro-*N*-isopropylacetanilide (propachlor) and 2-chloro-*N*-(isobutyoxymethyl)-2',6'-acetoxylidide (delachlor). The water solubilities of propachlor and delachlor are 700 and 59 ppm at 20 C.

The pyridazinones studied were pyrazon, 5-amino-4-bromo-2-phenyl-3(2*H*)-pyridazinone (hereinafter referred to as BAS 2430), and 5-(α-hydroxy-β -β- β-trichloroethyl)amino-4-bromo-2-phenyl-3 (2*H*)-pyridazinone (hereinafter referred to as BAS 2572). The water solubilities of pyrazon, BAS 2430, and BAS 2572 are 300, 200, and 10 ppm at 20 C.

Materials and Methods

Field studies were conducted in 1968 and 1969 at Fort Collins, Colorado. The soil, each year, was a clay loam with a pH of 7.7 or 8.0 and an organic matter content of 2.1 or 2.5%. Randomized complete block designs with four replications were used. The plots were four rows wide and 45 or 50 ft long each year. The rows were 22 inches apart.

The herbicides were sprayed in water on a 7-inch band over the row at 60 gpa broadcast. The soil was moist and tilth was excellent. The herbicides, applied before planting, were incorporated 1½ inches deep with a power-driven, hooded incorporator that was mounted on the tractor. In 1968, the experiment was furrow-irrigated 7 days after planting. In each year 1.4 inches of precipitation was received within 9 days after planting.

Monogerm sugarbeet seed, size 2, was planted approximately 1¼ inches deep April 9, each year, at the rate of eight seed per foot of row. The average dates of emergence were April 26, 1968, and April 22, 1969. The sugarbeet plants were thinned to one plant per 8 to 10 inches of row June 2 each year.

We also planted a mixture of weed seed by dropping the seed from an applicator directly into the hooded incorporator. Weeds that emerged beyond a 5-inch band centered over each row were controlled by cultivation. As a measure of weed control, we counted and removed all the weeds that remained in the 5-inch band in each plot 11 to 12 weeks after planting. Any weeds that emerged later were removed by hand from all plots. One plot in each replication was hand-weeded all season. The stand of weeds present has been expressed as a percentage reduction from the weedy, cultivated plots which were not treated with herbicides.

We determined the response of sugarbeets to the herbicides in June by counting the number of plants and by visually assessing the vigor of the plants. In October, sugarbeets were harvested from 40 or 45 ft of each of the inner two rows of each plot. The roots were washed, weighed, and analyzed for sucrose content.

The data were analyzed for variance by the techniques for a randomized complete block design. When treatment effects were significant, single degree of freedom orthogonal comparisons were made between method of application, types of herbicides, and other treatment effects. In this paper any reference to a treatment difference will mean that the difference was significant at least at the 5% level of probability. The least significant difference (LSD) also has been shown in each table. In Table 1, the LSD values should be used only for differences between the standard cycloate treatment and the other treatments. In the other tables, the use of the LSD values should be restricted to comparisons between the hand-weeded check and the other treatments.

Bioassay for herbicide residues. Soil was collected from plots treated with BAS 2430, delachlor, cycloate, and pyrazon September 26, 1968, and September 23, 1969. Six samples of soil were taken from the center two rows of each plot. A galvanized can, 3.25 inches in diameter and 4.25 inches tall, was inverted and forced into the soil profile until it was full of soil. The unsealed cans of soil were stored for 2½ months in an unheated building which ranged in temperature from about 10 to 85 F. The air-dried soil was pulverized, mixed, screened through a ¼-inch mesh screen, and placed in a 1-qt plastic container.

Eight seed each of barley *(Hordeum vulgare* L. cultivar Heiland) and corn *(Zea mays* L. cultivar Kitely's hybrid) and six seed of field beans *(Phaseolus vulgaris* L. cultivar Idaho No. 111) were planted in each container in the greenhouse. After the seedlings emerged, barley and corn were thinned to three, and field beans to two, seedlings per container. Four weeks after planting, the plants were harvested, oven-dried, and weighed.

Results and Discussion

Weed control. The herbicide by year subclass means are presented in Table 1 because the treatment × year interaction was significant, except for pigweed and wild buckwheat. The control of the five weed species by the different herbicide treatments varied with method of application, herbicide class, and year. Most, if not all of the herbicide treatments, were expected to control weeds best when they were incorporated because in irrigated areas herbicides have controlled weeds best when they are mixed with the soil (1,4,6). However, in this experiment incorporation improved the effectiveness only with respect to

Table 1.—Weed control in sugarbeets approximately 12 weeks after planting and applying six herbicides.

Herbicides	Rate (lb/A)	Method of application[a]	Percentage control (reduction in stand): Foxtail millet 1968	Foxtail millet 1969	Common lambs-quarters 1968	Common lambs-quarters 1969	Kochia 1968	Kochia 1969	Pigweed 1968	Pigweed 1969	Wild buckwheat 1968	Wild buckwheat 1969	Avg 1968	Avg 1969
delachlor	1.5	incorp	45	92	24	67	10	43	74	94	30	48	37	69
delachlor	3.0	incorp	86	99	56	83	25	61	94	99	59	83	64	85
delachlor	1.5	surf	70	85	54	59	64	40	84	88	40	37	62	62
delachlor	3.0	surf	92	97	85	82	44	61	89	97	81	49	78	77
propachlor	4	incorp	28	65	37	78	35	53	56	54	8	30	33	56
propachlor	4	surf	28	75	47	81	35	63	36	69	14	16	32	61
BAS 2430	4	incorp	74	81	95	98	42	63	88	96	88	91	77	86
BAS 2430	4	surf	84	72	84	97	53	46	78	91	75	93	75	80
BAS 2572	4	incorp	72	65	88	98	27	50	85	92	81	91	71	79
BAS 2572	4	surf	73	46	63	90	25	19	67	63	68	80	59	60
pyrazon	4	incorp	43	44	82	90	2	21	70	81	77	69	55	61
pyrazon	4	surf	73	45	84	85	21	12	82	76	83	66	69	57
cycloate	4	incorp	70	93	87	94	7	13	77	82	21	19	52	60
LSD (0.05)			19		20		22		12		19		14	
LSD (0.01)			25		27		30		16		25		18	

[a]incorp = soil-incorporated before planting; surf = surface-applied after planting.

control of pigweed. This resulted principally because BAS 2572 consistently controlled pigweed better each year when it was incorporated. Similar comparisons for the other four weed species showed that performance of many herbicide treatments varied with method of application and years. The surface-applications probably controlled weeds on the average as well as the soil-incorporated applications, because adequate precipitation occurred each year within 6 to 9 days after planting.

The pyridazinones controlled common lambsquaraters and wild buckwheat considerably better than the chloroacetamides, but they were generally less effective against foxtail millet (Table 1). Both classes of compounds controlled pigweed effectively, but not kochia.

Of the two chloroacetamides, delachlor at 3 lb/A out-performed propachlor at 4 lb/A in controlling foxtail millet, pigweed, and wild buckwheat. Delachlor controlled common lambsquarters only slightly better than did propachlor.

Within the pyridazinone group, pyrazon and both pyridazinone analogs controlled common lambsquarters and wild buckwheat similarly. BAS 2430, the bromo analog, was superior to pyrazon for the control of foxtail millet, kochia, and pigweed. BAS 2430 also controlled all broadleaf weeds better than the standard cycloate treatment. Furthermore, overall weed control with BAS 2430 averaged 13% better than that previously reported where other herbicides have been incorporated in six Western States (7).

In general, cycloate controlled foxtail millet, common lambsquarters, and pigweed as well as or better than the chloroacetamide and pyridazinone treatments. However, cycloate did not control kochia or wild buckwheat effectively. The soil-surface application of delachlor at 3 lb/A, the soil-incorporated application of BAS 2572, and both applications of BAS 2430 were superior to the treatment with cycloate at the 95% level of probability, with respect to reducing the average stand of all weed species.

Sugarbeet tolerance. In general, none of the treatments with these herbicides injured sugarbeets seriously. There were, however, indications that treatments with propachlor, pyrazon, and BAS 2430 were less safe than treatments with the other herbicides. At least one treatment with each of these three herbicides reduced the pre-thinning stands, suppressed growth, or did both, in at least one year (Table 2). All visible symptoms in suppression of foliar growth disappeared within 7 to 9 weeks after planting.

Table 2.—Response of sugarbeets to herbicides applied to the soil surface or incorporated.

Herbicides	Rate (lb/A)	Method of application[a]	Injury rating (%)[b] 1968	Injury rating (%)[b] 1969	Pre-thinning stand reduction (%) 1968	Pre-thinning stand reduction (%) 1969
delachlor	1.5	incorp	0	2	0	0
delachlor	3	incorp	0	12	0	0
delachlor	1.5	surf	0	2	0	0
delachlor	3	surf	15	7	16	0
propachlor	4	incorp	2	12	0	0
propachlor	4	surf	39	2	8	0
BAS 2430	4	incorp	6	27	12	28
BAS 2430	4	surf	25	0	29	0
BAS 2572	4	incorp	0	0	10	0
BAS 2572	4	surf	10	0	18	0
pyrazon	4	incorp	4	0	7	0
pyrazon	4	surf	15	0	22	0
cycloate	4	incorp	0	5	0	1
Hand-weeded check	0	----	0	0	0	0
LSD (0.05)					18	
LSD (0.01)					23	

[a] incorp = soil-incorporated before planting; surf = surface-applied after planting.
[b] Injury rating (0 no foliar suppression; 100 = all plants killed).

None of the herbicide treatments affected the sucrose content in roots (Table 3). Although the benefits of weed control by herbicides on yields of roots and sucrose could not be measured directly since all plots were weeded 11 to 12 weeks after planting, weed control by herbicides was beneficial because the only plots that yielded significantly less roots and sucrose per acre than the hand-weeded plots were the weedy check plots. However, several herbicide treatments yielded less roots and sucrose per acre than the hand-weeded plots, but these differences in yield were not significant at the 95% level of probability. Plots treated with 4 lb/A of propachlor applied to the soil surface reduced the yields of roots and sucrose per acre the most, about 10%, in one year.

Dawson (3,4) also has reported injury to sugarbeets from treatments with propachlor and pyrazon in Washington, but the yield of roots was not reduced unless these two herbicides reduced the population of sugarbeets below levels sufficient for acceptable stands after thining. In this study, the population of sugarbeets was not reduced below a level that was detrimental to yield. However, the pyridazinones, and particularly BAS 2430, reduced the pre-thinning stand by 29% or less. This level of reduction in stand by these treatments might result in a significant reduction in yields where sugarbeets are planted to a final stand or are thinned mechanically with a random thinner.

Table 3.—Yield and sucrose content of sugarbeet roots and yield of sucrose with herbicides applied to the soil surface or incorporated.

Herbicides	Rate (lb/A)	Method of application[a]	Root yield 1968	Root yield 1969	Root yield Avg	Sucrose 1968	Sucrose 1969	Sucrose Avg	Sucrose 1968	Sucrose 1969	Sucrose Avg
				T/A			%			lb/A	
delachlor	1.5	incorp	21.0	24.5	22.7	18.6	16.4	17.5	7840	8020	7930
delachlor	3	incorp	21.9	24.1	23.0	18.6	16.3	17.4	8150	7860	8000
delachlor	1.5	surf	22.5	24.3	23.4	18.8	16.6	17.7	8490	8060	8270
delachlor	3	surf	22.9	24.4	23.6	18.6	16.4	17.5	8500	8020	8260
propachlor	4	incorp	20.6	24.4	22.5	18.7	16.5	17.6	7720	8080	7900
propachlor	4	surf	19.8	24.8	22.3	18.7	16.4	17.5	7410	8170	7790
BAS 2430	4	incorp	22.0	25.0	23.5	18.9	16.4	17.6	8310	8210	8260
BAS 2430	4	surf	21.2	25.2	23.2	18.8	16.3	17.5	7970	8190	8080
BAS 2572	4	incorp	21.8	25.0	23.4	18.7	16.2	17.4	8130	8130	8130
BAS 2572	4	surf	21.0	24.5	22.7	18.7	16.5	17.6	7850	8090	7970
pyrazon	4	incorp	23.0	24.5	23.7	18.4	16.4	17.4	8460	8010	8230
pyrazon	4	surf	23.0	24.3	23.6	18.8	16.5	17.6	8620	8010	8310
cycloate	4	incorp	22.0	24.4	23.2	18.7	16.6	17.6	8260	8110	8180
Weedy check	0	—	20.7	21.9	21.3	18.6	16.6	17.6	7700	7260	7480
Hand-weeded check	0	—	22.3	24.8	23.5	18.6	16.2	17.4	8300	8050	8170
LSD (0.05)					1.3			N.S.			460
LSD (0.01)					1.7			N.S.			620

[a] incorp = soil-incorporated before planting; surf = surface-applied after planting.

In the irrigated regions of the central High Plains and intermountain West most sugarbeets are not planted to a final stand, and are thinned with a hoe or electronically. Under these conditions, a 29% reduction in pre-thinning stands should not be detrimental to yields.

Persistence of herbicides in soil. Eight months after application, residues of delachlor, BAS 2430, and pyrazon were detected in soil by bioassay in at least one year, irrespective of method of application (Table 4). Delachlor at 3 lb/A was generally less phytotoxic to barley and field beans than the pyridazinones, except it injured barley more in one year. Residues of BAS 2430 and pyrazon were the most phytotoxic to both crops when they had been applied to the soil surface in one year. The pyridazinones produced chlorosis in the first pair of true leaves of many field beans within 10 to 14 days after emergence and by 28 days some plants had died and others were stunted severely. Residues of delachlor, BAS 2430, and pyrazon injured both crops more than did cycloate (Table 4). Corn was not injured significantly by any herbicide in either year, but in one year the dry weights varied considerably within treatments. The height of corn was reduced 10% or less by herbicide residues.

Table 4.—Persistence of herbicides in a furrow-irrigated clay loam as indicated by percent growth reduction of greenhouse grown barley and field beans planted 8 months after application of herbicides in sugarbeets.

Herbicides	Rate (lb/A)	Method of application[a]	Percentage reduction in dry weight			
			Barley		Field beans	
			1968	1969	1968	1969
delachlor	1.5	incorp	15	2	0	11
delachlor	3	incorp	10	8	0	5
delachlor	1.5	surf	9	13	0	9
delachlor	3	surf	11	18	3	9
BAS 2430	4	incorp	19	0	4	9
BAS 2430	4	surf	45	9	40	11
pyrazon	4	incorp	15	4	0	13
pyrazon	4	surf	40	11	36	10
cycloate	4	incorp	8	0	0	7
none	0	—	0	0	0	0
LSD (0.05)			17		13	
LSD (0.01)			23		27	

[a]incorp = soil-incorporated before planting; surf = surface-applied after planting.

Burrill *et al.* (2) found that residues of delachlor injured annual bluegrass (*Poa annua* L.) and Italian ryegrass (*Lolium multiflorum* Lam.), but not sugarbeets when these species were planted in the field 79 days following a 3 lb/A surface-application of delachlor in Oregon. Pyrazon residues in soil were directly related to the organic matter content of soil and inversely related to rainfall during the growing season in Michigan (9). Pyrazon disappeared consistently in soils which contained 3.8% organic matter or less; and residual phytotoxicity was low 5 months after application (9). In Colorado, similar results were reported in a clay loam which contained 1.1% organic matter.[4]

Neither delachlor or pyrazon appears to move much in soils. Leaching studies indicate that the application of 6 inches of water concentrated delachlor in the 2- to 4-inch horizon in a silt loam (5). Pyrazon movement occurred in nonirrigated soils that contained 3.8% organic matter or less, but it did not move below a depth of 4 inches (8). In Colorado, pyrazon remained in the upper 3 inches of a clay loam which contained 1.1% organic matter for over 3 months even though precipitation was greater than normal.[4]

The level of chemical residues from BAS 2430, delachlor, and pyrazon that were detected in soil 8 months following soil-incorporated applications appears to be relatively non-phytotoxic, even though all samples were collected within the treated 7-inch band. Since only one-third of the field area was treated with each herbicide, further dilution of the chemical residues would occur before the next cropping season as a result of fall and spring tillage and microbial degradation. Hence, chemical residues from delachlor and pyrazon that would be phytotoxic to field crops in Colorado, such as barley, corn, and field beans appear unlikely in heavier soil types. Chemical residues of these herbicides may pose problems in lighter soils or if these herbicides were applied to the soil surface.

Summary

The chloroacetamides controlled foxtail millet the best, whereas the pyridazinones were more effective against common lambsquarters and wild buckwheat. Both groups of compounds controlled pigweed effectively, but not kochia. The herbicides BAS 2430 and delachlor surpassed the standard herbicide cycloate in reducing the average stand of all five weeds, and yields of roots and sugar were equivalent to that produced in plots treated with cycloate or hand-weeded. Residues of BAS 2430, delachlor, and pyrazon were detected biologically in soil 8 months following application.

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