HERBICIDE RESIDUES

in California agricultural soils

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The question of herbicide residues, and possible effects on succeeding crops, is one of great importance to agriculture, particularly with increasing use of such chemicals to minimize hand labor requirements as well as soil compaction from weed cultivation equipment. This study, involving tests with 13 herbicides, used under typical field conditions at six locations in California, showed great differences in residual characteristics. At high rates (approaching four times the amounts normally used for weed control), simazine, bromacil, and trifluralin caused soil residue problems. Location of the tests also affected the amounts of residue for different herbicides.

ASIDE FROM an apparently irreversible adsorption not yet clearly understood, herbicides leave the root zone of plants through evaporation from the soil surface, deep leaching, chemical (and biological) destruction, or by the removal action of resistant crops. Herbicide removal from soil by any of these means is not independent. Considering variations in soil types, in rainfall, in irrigation practices, in methods of application, and in subsequent soil preparation, it is quite likely that it will be some time before accurate predictions can be made on how long most herbicides remain in the soil. However, some guidelines are available from the chemical industry and from other areas of research. The early greenhouse work on a number of California agricultural soils emphasized the importance of organic matter and clay content of soil in the over-all activity of herbicides.

This report summarizes seven field experiments at six locations in California. Test sites included a wide range of soil types and environmental conditions. The 13 herbicides were applied in small (5- by 5- or 5- by 10-ft) plots in the spring of 1964, from March through July. The various crops were harvested, counted, and weighed at 5 to 6 weeks after seeding. Herbicidal phytotoxicity ratings were recorded during the growth of each crop. The organic matter content of the soil ranged from 1.3% to 12.6%; sand, from 24% to 60%; silt, from 27% to 56%; and clay, from 9% to 32%. The amount of moisture received was approximately 30 to 45 inches (depending upon rainfall, the number of croppings, and test locations). The most representative data were obtained from the 0 to 10 phytotoxicity ratings and the stand counts. The results presented here were taken from the average phytotoxicity rating and the stand counts and converted to a 0 to 10 scale.

The range of crop phytotoxicity varied greatly between chemicals at the six locations. Bromacil (Hyvar X), simazine, and picloram (Tordon) showed injury for the longest periods of time to the broadest spectrum of crops.

Crop sensitivity to specific herbicides varied greatly. The residual characteristics of trifluralin (Treflan), for example, varied with the test plant species. Milo showed some sensitivity for about 18 months after the application of 1 lb of trifluralin per acre in one test, but toxicity dropped to a minimum in about one year in most tests. In sugar beet tests, toxic effects were minimal at about eight months, and at about six months for barley. The crop most sensitive to each herbicide was used to express herbicide disappearance.

Effects of location differences were also notable. Diuron, for example, was phytotoxic for only about three months at Tulelake, but for well over two years at both the South Coast and West Side field stations. A brief summary of test results with individual herbicides follows:

Simazine is slow to break down in soils, and appeared to last well over two years at a 4-lb-per-acre rate (table 3). Phytotoxic effects declined after 12 to 18 months at all locations except the West Side Field Station. The effect of organic matter was not as apparent in tests with simazine as with some of the other herbicides. Barley, alfalfa, sugar beets, and tomatoes were among the crops most sensitive to simazine (table 1).

Diuron (Karmex) is also used as a long-term soil sterilant, but in this study it averaged out showing less herbicide residue than simazine. Locations with soils having 4.5% or less organic matter showed diuron persistence, however. All plants were sensitive to diuron initially (table 1), but by a year after treatment, a number were showing some tolerance—particularly alfalfa and milo (table 2). Tomatoes, sugar beets, and barley were more susceptible to injury.

Prometryne (Caporal) is used commercially as a short-term selective herbicide, and showed a residual picture of considerable variation. The loss in chemical activity at 1 lb per acre was quite rapid. However, at the 4-lb-per-acre rate, the activity varied greatly from location to location—lasting over two years at the

TABLE 1. RELATIVE CROP RESISTANCE TO HERBICIDES

Initial phytotoxicity to first crops planted up to two weeks after herbicide application and incorporation—averages of all locations having crops planted.

Herbicide	Rate lbs/A	Average phytotoxicity*					
		Barley	Milo	Sugar beets	Alfalfa	Tomatoes	Cotton
Simazine	4	9.1	6.3	9.9	10.0	9.9	7.2
Diuron	4	8.5	9.0	8.5	7.4	9.5	8.5
Prometryne	1	7.5	5.6	8.0	4.5	7.2	4.0
Prometryne	4	9.6	9.8	10.0	8.5	10.0	5.0
Bromacil	1	9.5	8.8	9.8	10.0	10.0	9.2
Bromacil	4	9.9	9.9	10.0	10.0	10.0	10.0
Trifluralin	1	5.2	8.9	8.5	5.0	7.5	3.8
Trifluralin	4	7.2	9.4	9.6	6.3	8.1	6.8
DCPA	8	1.7	7.1	6.1	1.8	5.1	4.0
DCPA	32	2.7	9.8	9.2	4.8	7.0	2.8
Diphenamid	4	6.9	7.1	5.5	3.5	3.6	3.8
Diphenamid	16	8.7	9.2	7.4	3.0	5.2	4.8
Bensulide	4	2.3	5.3	4.5	2.5	3.3	2.8
Bensulide	16	4.6	8.6	9.2	4.0	5.5	4.0
Pyrazon	4	2.7	1.8	1.1	3.8	6.1	3.8
Pyrazon	16	7.0	4.7	6.3	7.0	9.6	6.0
FW-925	4	2.1	1.7	1.8	2.0	3.0	2.5
FW-925	16	6.1	5.8	4.2	4.0	6.4	1.8
Dicamba	4	8.7	9.2	9.6	10.0	9.6	10.0
Dicamba	16	9.5	10.0	10.0	10.0	10.0	10.0
Picloram	1	5.9	7.9	10.0	9.8	10.0	10.0
Picloram	4	8.6	9.4	10.0	10.0	10.0	10.0
TBA	4	4.6	4.1	6.1	9.0	8.1	1.8
Check	–	0.1	2.9	1.0	0.2	1.6	2.8

* Average 0–10 phytotoxicity rating on crops where 0 = no effect; 5 = severe chlorosis, stunting, or stand reduction; 10 = all plants dead or no stand.

TABLE 2. RESIDUAL TOXICITY AT APPROXIMATELY ONE YEAR AFTER HERBICIDE APPLICATION AS MEASURED BY AVERAGE CROP PHYTOTOXICITY RATING FROM A NUMBER OF UNIFORM TRIALS

Herbicide	Rate lbs/A	Average phytotoxicity*					
		Barley	Milo	Sugar beets	Alfalfa	Tomato	Wheat
Simazine	4	3.2	1.8	5.6	9.1	4.7	4.2
Diuron	4	3.6	1.9	3.6	0	4.1	2.6
Prometryne	1	0.9	0	0.6	0	0.3	1.6
Prometryne	4	2.1	1.0	1.5	1.8	3.4	3.4
Bromacil	1	2.5	2.0	3.2	4.6	4.6	4.3
Bromacil	4	4.5	4.2	5.5	10.0	6.0	6.2
Trifluralin	1	0.2	2.1	0.4	0.6	0	0.5
Trifluralin	4	1.4	5.3	4.0	1.1	1.8	0
DCPA	8	1.3	0	0.9	2.0	0.7	1.8
DCPA	32	0.8	3.9	3.0	0	1.3	0.3
Diphenamid	4	1.9	1.1	1.9	0	0.7	0.7
Diphenamid	16	2.1	1.4	2.0	0.9	1.8	2.0
Bensulide	4	0.6	2.0	2.3	0	1.4	0.2
Bensulide	16	1.4	5.5	3.7	2.0	0.5	1.3
Pyrazon	4	1.2	0	0.5	0.4	3.9	0.7
Pyrazon	16	2.3	1.4	1.9	0.7	2.8	3.3
FW-925	4	0.4	0	0.5	1.7	0	0
FW-925	16	1.4	1.1	1.5	2.0	1.7	0.8
Dicamba	4	1.1	1.3	0.9	2.4	1.5	0.3
Dicamba	16	1.5	1.9	2.0	2.9	2.4	1.2
Picloram	1	1.4	1.4	4.2	9.6	5.2	1.7
Picloram	4	2.3	2.9	5.3	10.0	5.8	2.5
TBA	4	0.4	0.2	0.7	2.9	0.3	0.5
No. of locations averaged		7	5	6	2	3	2

* Average 0–10 phytotoxicity rating on crops where 0 = no effect; 5 = severe chlorosis, stunting, or stand reduction; 10 = all plants dead or no stand.

West Side Field Station. At the 4-lb-per-acre rate the chemical disappeared within three months at most of the other locations. Prometryne showed least toxicity to cotton initially (table 1) and milo later (table 2). It was most phytotoxic after one year to tomatoes and wheat.

Bromacil (Hyvar X) is a long-term, broad-specrum soil sterilant, and generally lasted in the soil longest of all herbicides tested. At every location, the bare plots of this herbicide were visibly obvious (table 3). At the 1-lb-per-acre rate some selectivity was evident at one year for milo and barley (table 2). This herbicide will find little, if any, use in crop rotation because of its extremely long residual effects.

Trifluralin (Treflan) is a highly effective selective herbicide that showed considerable variation in effects on crops and in test location effects. Organic matter did not appear to have a great influence on the disappearance of trifluralin from the soil. Because of the variable effects from location to location, other factors are believed to be involved—such as clay quantity or quality, since soils low in clay (Fresno and South Coast Field Station) showed the most rapid breakdown. The soil with the most clay (West Side Field Station) showed the longest carry-over of trifluralin. At 1 lb per acre, there was little trifluralin residue problem after one year in any crop. At higher rates, the crops showing least tolerance were milo and sugar beets. Those showing the most tolerance were alfalfa, bean, safflower, lettuce, melon, tomatoes, barley, and wheat (table 2).

DCPA (Dacthal) is one of the most selective herbicides—and showed few problems from herbicide residues in the soil at 8 lbs per acre. In milo, however, DCPA was active in the soil up to about a year. Milo was more sensitive than most of the broadleaf crops. Although the damage to most crops was minimal, there were indications of the presence of DCPA longer than a year at 32 lbs per acre (table 2). Most resistant were alfalfa, beans, safflower, tomatoes, and barley. Most susceptible were milo, sugar beets, and lettuce. Injury to barley was noted in stubbing of the roots, sometimes without noticeable effect to the tops—therefore, under dry farming this herbicide might prove to be much more damaging to grain (these tests were conducted with sprinkler irrigation, for the most part adequate for normal growth).

Diphenamid (Dymid or Enide) is another very selective herbicide which showed considerable variation between crops and locations. Barley, one of the most sensitive crops, showed the presence of diphenamid 12 to 16 months after application even at 4 lbs per acre. At the West Side Field Station, there were indications that effects of diphenamid persisted for two years on sensitive crops. The over-all picture indicated that diphenamid had disappeared after one year (table 3). Even at 16 lbs per acre, reports from three of five locations indicated no residue problems. However, problems even at one location would suggest caution with its use and emphasize the importance of planting resistant crops following the use of diphenamid. Most resistant to injury were tomatoes, cotton, alfalfa, and beans (table 1); most affected were barley, milo, and sugar beets as well as lettuce and melons. Although tested at fewer locations, cotton appeared quite resistant to diphenamid.

Bensulide (Prefar) is another very selective herbicide. Bensulide, like diphenamid, was active in the soil for a long time at some locations. There was usually an appreciable amount of residue for well over a year after applications at 4 lbs per acre. Chemical activity ranged from a few months to more than two years on

TABLE 3. GROSS SUMMARY OF DATA FROM ONE TO FIVE HERBICIDE RESIDUE TRIALS WHERE + = RESIDUE PRESENT ON ONE OR MORE SUSCEPTIBLE CROPS AND – = NO APPARENT RESIDUAL EFFECT EVEN ON SENSITIVE CROP BY LOCATIONS

Herbicide	Rate lbs/A	3 Months*	12 Months†	24 Mon.†	30 Mon.‡
Simazine	4	+++++	+++++	++	+
Diuron	4	+++++	–++++	+–	+
Prometryne	1	–++++	----+	––	–
Prometryne	4	+++++	----+	+–	–
Bromacil	1	+++++	++--+	++	+
Bromacil	4	+++++	+++++	++	+
Trifluralin	1	++–++	----+	––	–
Trifluralin	4	+++++	+–+++	++	–
DCPA	8	+++++	---+–	––	–
DCPA	32	+++++	+++++	+–	–
Diphenamid	4	+++++	+----	––	–
Diphenamid	16	+++++	++---	+–	–
Bensulide	4	+++++	----+	––	–
Bensulide	16	+++++	+–+–+	++	–
Pyrazon	4	++–++	---+–	+–	+
Pyrazon	16	+++++	++–+–	+–	+
FW-925	4	++ ++	-----	––	–
FW-925	16	++ ++	--++–	––	–
Dicamba	4	+–++	-----	––	–
Dicamba	16	++ ++	+---+–	+–	–
Picloram	1	++ ++	+–++–	++	+
Picloram	4	++ ++	+–+++	++	+
TBA	4	++ ++	-----	––	–

* Missing + or – means no conclusive data at the timing, or crops lost for other reasons.

† West Side Field Station (Fresno County) and Tulelake Field Station only. Other locations generally showed no residue except for simazine, bromacil and picloram—after about 18 months or test concluded for other reasons.

‡ West Side Field Station only. Seeded 9/66, rated 10/28/66.

a few crops like milo (table 3). An herbicide with this kind of variability could only be used in a rotation with resistant crops. Alfalfa, beans, tomatoes, lettuce, cotton, melon and safflower were quite resistant to bensulide; wheat and barley were intermediate; and milo and sugar beets were susceptible (table 1).

Pyrazon (Pyramin) was another selective herbicide in these tests, that showed a wide range (in disappearance time) for susceptible crops. In tomatoes or melons, very little residue problem existed after about eight months (even at the four-times-normal rate of 16 lbs per acre). The West Side Field Station again proved to be an exception, with substantial residue even two years after applications at 4 lbs per acre. These results were substantiated by chemical analysis of the soil. After two and a half years, however, only the 16-lb-per-acre rate showed a residue on susceptible crops. Among the crops studied, melon, lettuce, tomato, safflower, beans, alfalfa, and barley were the most sensitive, and milo and sugar beets most resistant (table 1). At Tulelake, there was no evidence of residual effects on even the sensitive crops after 16-lb-per-acre applications, which again suggests the importance of organic matter.

FW-925 (TOK-E-25) is a nonincorporated selective herbicide that showed few residue problems. However, sufficient herbicide residues remained after a 4-lb-per-acre application to be detected at three months (table 3) and enough remained from the 16-lb-per-acre rate to be detected at one year. Tomatoes appeared to be the most sensitive crop.

Dicamba (Banvel D) is a selective herbicide when used at low rates and, at 4 lbs per acre, residues were apparent on broadleaf crops for more than a year. Although initially very toxic to all crops (table 1), even the high rate of 16 lbs per acre caused only minor damage after one year (table 2). Alfalfa and beans were the most sensitive crops and the monocots were most resistant.

TBA (also a benzoic acid) showed a pattern of breakdown very similar to that of dicamba. Since it is normally used at four to five times the level of dicamba, it is quite likely to cause more herbicide carry-over problems than dicamba, and would probably not be used in a cropping situation. Alfalfa, tomatoes, and sugar beets were most susceptible.

Picloram (Tordon) is one of the broadest spectrum potent herbicides yet tested, and it also presents one of the most difficult residue problems of any herbicide studied—particularly under certain conditions. None of the variables measured appears to have any bearing on the residual characteristics of picloram. Under conditions at two locations, 1 lb per acre of picloram was essentially gone in a year (table 3). However, enough hazard is involved to warrant recommending against the use of picloram in crop rotation. The monocot crops were more resistant than the dicots. Lettuce was by far the most sensitive to picloram of the crops studied in the testing program.

Summary

A number of the more selective herbicides such as trifluralin, DCPA, diphenamid, bensulide, pyrazon—although showing measurable response in sensitive crops—may not cause problems when resistant crops are planted. On the other hand, very phytotoxic herbicides such as triazines, the substituted ureas, and the uracils dissipate before most crops can be planted. Simazine and bromacil show little promise for use in rotation. Diuron, under certain conditions (particularly where the organic matter is high), may cause no residue problem. Where organic matter is low, diuron should not be used in rotation. Prometryne, except under certain conditions, has a fairly short residual life. To be completely safe, it would be necessary to know whether or not the crop would tolerate the use of prometryne in rotation, or to test the residual nature of the soil in small test plots.

Growth regulators

The growth-regulator herbicides show little selectivity in broad-leaved crops; however, at very low rates, they may have some promise in monocotyledonous crops. Generally, they could not be used in crop rotation because of the severe symptoms in most crops from the use of dicamba, and the longer residual herbicide, picloram (the latter even at the rate of 1 lb per acre). Herbicides like FW-925, which are deactivated rather rapidly after being incorporated into the soil, represent a minimum residue problem.

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