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EFFECTS OF 2,4,5-T ON MAN AND THE ENVIRONMENT

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BEFORE THE
SUBCOMMITTEE ON ENERGY, NATURAL
RESOURCES, AND THE ENVIRONMENT,
U.S. Commerce, Science, & Education OF THE
COMMITTEE ON COMMERCE,
UNITED STATES SENATE
NINETY-FIRST CONGRESS
SECOND SESSION
ON
EFFECTS OF 2,4,5-T ON MAN AND THE ENVIRONMENT

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*Dr. Ned Bayley
Director of Science and Education
Department of Agriculture.*

STATEMENT OF DR. NED D. BAYLEY, DIRECTOR OF SCIENCE AND EDUCATION, DEPARTMENT OF AGRICULTURE; ACCOMPANIED BY DR. T. C. BYERLY, ASSISTANT DIRECTOR OF SCIENCE AND EDUCATION

Dr. BAYLEY. Mr. Chairman, I am Ned Bayley, Director of Science and Education, Office of the Secretary, Department of Agriculture.

I have with me Dr. T. C. Byerly, Assistant Director of Science and Education.

Before I proceed with the formal statement, I would like to respond to some extent to the information which has been presented already this morning.

Senator HART. Let me make it easier. Let me encourage you to do it, and any succeeding witnesses, too.

To make the record as useful as possible, we would welcome exchanges in the nature of reply.

Dr. BAYLEY. I appreciate in doing this I am putting myself in an impromptu position and, therefore, would appreciate the privilege to provide to the committee, for the record if they desire, fuller statements regarding the activities of the Department of Agriculture in regard to pesticides.

Senator HART. Very well.

Dr. BAYLEY. I testified before this committee previously regarding the broad policies and positions of the Department in the pesticide area, and stated that we recognize that all pesticides are economic poisons. They are only one group of the tremendous number of economic poisons which we use for a large number of useful reasons, not only for economic purposes but also to take care of public health.

We recognize also, as part of our civilization and as part of the standard of living and the food supply that we already have, that without these economic poisons and their judicious use, we would be in a very serious situation from the standpoint of our ability to produce food and fiber for this country.

Now, I also want to point out very briefly the references to the activities of the Department of Agriculture regarding the registration of pesticides. I will be the first to agree that there have been some problems in regard to these registration procedures and I will be the first to agree that we haven't resolved all of them.

We have, however, particularly during the past year, taken a number of steps towards eliminating some of the complexities and bureaucratic difficulties which have existed in the area of registration.

The references which have been made here this morning primarily reflect the relationship among the departments that did exist, but, I think I am safe in saying, do not exist now.

Senator HART. I remember in those earlier hearings we discussed this problem.

Dr. BAYLEY. Yes, we did.

Senator HART. And I had the impression that there was a transition period.

Dr. BAYLEY. I will very briefly refer to that. The crux of the problem was that there was an interagency agreement for resolving differences in regard to registration. There was a procedure within the agreement of bringing differences to the attention of the three Secretaries involved.

Unfortunately, however, over the years this agreement was in existence, not one of the departments ever used this procedure to resolve their differences.

We in the Department of Agriculture must share the major responsibility for not getting the differences resolved primarily because the enforcement of FIFRA was primarily our responsibility. But I am glad to say that since that time, with the initiative of Secretary Hardin and Secretary Finch and Secretary Hickel, there has been a new agreement worked out between the departments. This agreement specifically provides the basis whereby differences in judgments regarding pesticide regulation can be brought up through the decisionmaking procedure and the three Secretaries can share in this as needed.

We believe this is a sound basis for increasing the interdepartmental relationships and providing a basis for all three departments to have a rightful input into this.

I think you are also acquainted with the fact—

Senator HART. Doctor, if you are going to leave that new agreement, I would like to ask one question. In the event of disagreement, when the three Secretaries' attention is invited to the competing claims, is the decision made by majority vote, or does the Secretary of Agriculture retain the final voice?

Dr. BAYLEY. It is my understanding that they will pursue the disagreement until they agree. The Secretary of Agriculture does retain the final voice according to the law, however. We believe that based on the way we are operating today this procedure can be effective.

Senator HART. A meeting in Paris?

Dr. BAYLEY. Well, we are not dealing with that. I think we recognize that three Cabinet officers have the public interest in mind when they get together and can make a decision along these lines.

Senator HART. Just to push you a little harder on it, and I suppose this is academic at the moment since no such dispute has yet reached the three Secretaries?

Dr. BAYLEY. This is correct.

Senator HART. If one does get there, it will involve the tricky balance that Senator Baker was talking about, the economic claims, the public health claims, and the environmental concerns. HEW will tend, I assume, to emphasize the health factor. Is Interior the third department?

Dr. BAYLEY. Yes.

Senator HART. They would I suppose, be concerned principally with effects on fish and wildlife, and Agriculture would think primarily of the utility to the agricultural economy.

To put it harshly, why shouldn't the fellow who says it has not yet been established as safe for humans have the ultimate vote and voice?

Dr. BAYLEY. May I say this, that from the standpoint of the Department of Agriculture, we recognize that issues involving human health should have priority over all other issues.

The reference which was made earlier that the emphasis in USDA had been primarily on effectiveness is not only incorrect regarding the past but it is utterly incorrect regarding our position now.

Senator HARR. Whatever the past, I would hope that human health does have the overriding concern of three or any other numbers of men that meet on this kind of claim.

I interrupted you.

Dr. BAYLEY. Surely.

With those preliminary comments, I will be glad to turn to the issue of 2,4,5-T and the facts as we see them at the present time.

The herbicide 2,4,5-T has been recognized as the most effective herbicide registered for use for control of certain weeds and brush species for more than 20 years. About four-fifths of the domestic use of 2,4,5-T is for nonfarm use, the largest such use being for control of brush on rights-of-way. It is also used extensively to control brush on forest lands and certain weeds in turf. 2,4,5-T has been used in the production of fruit crops, cereal grains, and sugarcane. It is the most effective herbicide for control of brush on several million acres of rangeland in the Southwestern United States.

2,4,5-T is degraded in the environment within a few months after application so that residues do not persist from one season to the next. Residues on foods are unusual. Among 5,300 food samples analyzed by FDA for 2,4,5-T during the past 4 years, 25 were reported to contain trace amounts; i.e., amounts less than the 0.1 p.p.m. limit of accuracy of present analytical procedures for foods. Two samples showed residues of 0.19 and 0.29 p.p.m., respectively.

No finite tolerance has been established for 2,4,5-T in food. In the absence of such tolerances, any detectable amount of 2,4,5-T in food would make such food subject to seizure if found in the channels of interstate commerce. From the data cited above—

Senator PERCY. Do I understand your statement to mean, Doctor, that in the absence of the establishment of human tolerances for 2,4,5-T, it is the present policy of the Department of Agriculture to seize any shipments that show any measurable trace of 2,4,5-T on food shelves?

Dr. BAYLEY. It is the responsibility of the Food and Drug Administration to enforce the procedures and make the seizures.

Senator PERCY. I understood you to say there are no tolerances established; therefore in the absence of any established human tolerances for 2,4,5-T, it is the present operation of the U.S. Department of Agriculture to seize any food stuffs that contain any measurable trace amounts of 2,4,5-T.

Dr. BAYLEY. It is the present obligation of the Food and Drug Administration to do so.

Senator PERCY. Thank you very much.

Dr. BAYLEY. From the data cited above, it is apparent that contamination of food with 2,4,5-T is very infrequent and then only at very low levels.

There is current concern over the continued use of 2,4,5-T arising from the report of a research study completed under contract by the

National Cancer Institute by Bionetics, Inc. This study was based on a commercial lot of 2,4,5-T acquired for the study in 1965. It was fed to pregnant mice and rats. Many of their developing young had birth defects.

After review of this information and after consultation with Federal agencies concerned, Dr. Lee A. DuBridge, the President's Science Adviser, announced on October 29, 1969, a coordinated series of actions being taken by those agencies with respect to the use of 2,4,5-T.

Among them was the announcement that: "The Department of Agriculture will cancel registrations of 2,4,5-T for use on food crops effective January 1, 1970, unless by that time the Food and Drug Administration has found a basis for establishing a safe legal tolerance in and on foods."

USDA was informed in January that the lot of 2,4,5-T used in the Bionetics study contained significant amounts of a highly toxic contaminant, tetrachlorodibenzo paradiioxin. The Department was further informed that lots of 2,4,5-T of current and recent manufacture were reported to contain less than 1 p.p.m. of this contaminant in contrast to the 27 p.p.m. reported for the lot used in the Bionetic study.

Extensive studies are underway to determine whether 2,4,5-T is itself teratogenic. Preliminary reports are consistent with the hypothesis that the teratogenic results reported in the Bionetics study were due to the contaminant dioxins or to interactions of such contaminants with the 2,4,5-T rather than to 2,4,5-T per se.

The Department announced on February 6 that it would undertake examination of 2,4,5-T and 17 related compounds registered for pesticidal use to determine whether or not they are contaminated with dioxins. Preliminary results on 2,4,5-T show that those lots examined of current manufacture and those now in channels of trade gave the following results—I can summarize these quickly—the amounts ranged from a trace to 2.9 parts per million, and they were conducted both by the Department of Agriculture and the Food and Drug Administration.

(The table follows:)

TABLE 1.—AMOUNTS OF TCDD FOUND IN COMMERCIAL 2,4,5-T BY TWO METHODS

Sample	Manufacturer	Lot	Grade ¹	Collected	TCDD content p.p.m. ²	
					USDA	FDA
2,4,5-T.....	Dow.....	123110	TG	2/70	trace.....	0.07
2,4,5-T.....	Monsanto.....	07-020	TG	2/70	1.1.....	2.9
2,4,5-T.....	Hercules.....	X-17394-21-5	TG	2/70	N.D. ³	N.D.
2,4,5-T ⁴	Dow.....	MM-120449	TG	2/70	.48.....	.47-.52

¹TG = Technical grade.

²TCDD Refers to the 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD).

³N.D. = Levels of TCDD are below the limits of detection or below 0.05 p.p.m.

⁴Sample supplied by Dow as a reference check and reported to contain about 0.5 p.p.m. TCDD.

These data are preliminary and are obtained from first drafts of methods developed by chemists in the Crops Research Division of the USDA and in the Pesticide Chemistry and Toxicology Division of the FDA. The dioxin values refer only to the 2,3,7,8-tetrachloro-

dibenzo-p-dioxins (TCDD) and do not indicate levels of other halogenated dioxins (containing 5, 6, 7, or 8 chlorines) in the 2,4,5-T samples.

In view of all the information now available, we have not found that registered use of 2,4,5-T without a finite tolerance on food crops constitutes a hazard requiring cancellation or suspension of such registered uses.

There has been and is concern over the ecological effects of 2,4,5-T used as a defoliant in Vietnam. Dr. Fred Tschirley, Assistant Chief of our Crops Protection Research Branch, has reported the results of his examination of areas treated in Vietnam. He has reported no evidence of irreversible ecological damage. Allegations that defoliation will lead to extensive laterization of Vietnamese soils, that Mangrove areas will not recover, that fish production in wetland areas will be reduced were not verified.

Dr. Tschirley also headed a team of scientists who investigated allegations of injury to humans and animals due to herbicide treatment for control of Chapparal by the Forest Service on the Tonto National Forest near Globe, Ariz. They found that apparent damage consisted of damage to susceptible plants near the treated area from drift of the herbicides used. The alleged injuries to a duck and a goat were found to be groundless. Human illnesses were those expected in a normal population with the possible exception of one man with skin irritation on his eyelids. Clinical chemistry on specimens obtained during the investigation is in process.

Mr. Chairman, that is the completion of my formal statement. We primarily presented it to provide you with the latest findings that we have in the particular area.

Senator HART. Thank you very much, Doctor.

To summarize with respect to the sequence of events on the DuBridge announcement of October 29, 1969, the Department did not in fact deregister 2,4,5-T as DuBridge indicated would occur unless these affirmed findings came along. But you tell us your action was based upon information that the tests by Bionetics used samples that contained the contaminant dioxin, and that the current production of that product was free of the dioxin; is that right?

Dr. BAYLEY. Not completely free. The dioxin was at a sufficiently low level that we believed that—

Senator HART. That the test material had sufficiently more dioxin than the normal production amount?

Dr. BAYLEY. Yes.

Senator HART. Are you aware that the preliminary results of tests conducted by Food and Drug, Dow, and by the National Institute of Dental Research and by the National Institute of Environmental Health Scientists all indicate that 2,4,5-T contaminated with no more dioxin than is found in the currently produced 2,4,5-T is teratogenic?

Dr. Bayley. We are fully aware of this. The critical facts in regard to those experiments is that those low level dioxin contaminated 2,4,5-T samples were fed at sufficiently high dosages that they would be comparable to the dosages used for the 27 parts per million or nearly so.

Therefore, we do not believe this in any way changes the hypothesis that the low level of dioxin is safe.

Senator HART. You say in your statement "Should the teratogenic nature of 2,4,5-T be confirmed, registration for use on food crops will be canceled."

I am attempting to establish what will confirm it. What events do you look to to determine whether these preliminary indications which you say resulted from the contamination in fact did? Is there something in particular that you look to?

Dr. BAYLEY. Yes, the important considerations here are the usages for which the 2,4,5-T are permitted or which in actual practice are carried out.

The difference between the possibility of teratogenicity of the contaminate and the teratogenicity of the material that is used in the field is based on the rates of application, the losses which occur. All these effect the possibility of contamination of human beings.

Incidentally, my advice is that the one part per million level is at least tenfold below what they would consider a safe level in terms of allowances. In other words, that is the safety margin in this estimate.

Senator HART. In other words, there would have to be a finding of 10 times more?

Dr. BAYLEY. That is what I am told, yes. This is a statement based on scientific information provided to me.

Senator HART. Do you have any opinion as to whether Food and Drug might set a safe tolerance level in food?

Dr. Bayley. The action we have taken is to extend the time in which information can be provided or application made with Food and Drug Administration regarding the establishment of tolerances on food. I would not in any way want to prejudge what their actions should be, because it should be based on the data provided.

If I may elaborate on that, a petition was filed with the Food and Drug Administration in December of 1967 requesting the establishment of tolerances of 0.2 parts per million for residues of 2,4,5-T on apples, barley, blueberries, corn, oats, rye, sugarcane, and wheat. Those were the only crops to which that petition would apply.

The petitioner withdrew his petition on December 29, 1969, as provided under the pesticide regulations. We have extended to December 1970 the opportunity for him to provide the data needed to reach a decision on this.

There is one thing I think is important here, and that is the earlier reference to the concept of first, the burden of proof, and secondly, that we should not believe their data. We have to watch out for this paradox.

We in the Department of Agriculture, as you know, with the cooperation of the Food and Drug Administration, are not simply accepting the proof from industry in these cases. We are going out to obtain samples and testing them ourselves in order to verify the kind of information that is coming in.

Senator HART. I am not sure it is a paradox to say that the burden of proof is on the fellow that wants to expose the public to a product and some saying you cannot trust his data. They are two separate problems.

Dr. BAYLEY. I recognize that.

Senator HART. Let us be assured that the data is reliable and objective, and let us insist that the burden of proof may be on the fellow who may or may not be proposing the introduction of the chemical.

Dr. BAYLEY. I suspect I am sensitive to this because some people challenge why we test products. We think it should be done in the public interest when it is needed.

Senator HART. On the matter of the dioxin that was found to exist in the samples in a much higher percentage than the normal production thereof—

Dr. BAYLEY. You mean the samples that the Bionectics group had?

Senator HART. Yes, that the Bionectics group used. That was the reason, was it not, that led you not to follow through on the DuBridge pronouncement of October? Is that the meat and potatoes of it?

Dr. BAYLEY. This is an often misunderstood situation. I think it is important to realize that the date we chose in regard to the possibility of taking such action was chosen because the Food and Drug Administration had agreed to complete their action on the petition by that time. When they had not completed their action, I wrote Dr. Roger Egeberg a letter on January 7, asking for a statement regarding the status of their considerations on the petition.

On January 21, I received a response indicating that they had further data which changed the position in regard to the need for immediate cancellation.

We will be glad to provide these letters for the record.

Senator HART. I think it may be helpful.

(The letters follow:)

JANUARY 7, 1970.

DR. ROGER O. EGERBERG, *Assistant Secretary for Health and Scientific Affairs, Office of the Secretary, Department of Health, Education, and Welfare, Washington, D.C.*

DEAR DR. EGERBERG: On December 13, 1967, a petition was filed with the Food and Drug Administration to establish tolerances for 2,4,5-T on specific food crops. In accordance with the interdepartmental agreement reached in Dr. DuBridge's office on October 29, 1969, we announced that we would issue notice of cancellation of the registered uses of 2,4,5-T on these crops unless the Food and Drug Administration found a basis for establishing tolerances by January 1, 1970. This date was chosen because the Food and Drug Administration agreed to complete action on the petition by that time.

We would appreciate receiving without delay a statement from the Food and Drug Administration regarding the status of their considerations on the petition in order that we may take appropriate action. This request is made in accordance with our mutual interest to take responsible action on this matter and also in full cognizance of the exchange of letters between Secretary Hardin and Secretary Finch regarding public health responsibilities in pesticide registration.

Sincerely,

NED D. BAYLEY, *Director, Science and Education.*

SURGEON GENERAL OF THE PUBLIC HEALTH SERVICE,
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
Washington, D.C., January 21, 1970.

DR. NED N. BAYLEY, *Director of Science and Education, Office of the Secretary, U.S. Department of Agriculture, Washington, D.C.*

DEAR DR. BAYLEY: In reply to your letter of January 7, 1970, inquiring as to the status of Pesticides Petition SF0069 (2,4,5-T), submitted by the National

We have been advised by Dow Chemical Company:

(1) That a sample of the 2,4,5-T herbicide used in the Bionetics study contained 27 ± 8 ppm of a highly active (biologically) contaminant, tetrachloro-dibenzo-para-dioxin. (This has been confirmed by the National Institute for Environmental Health Sciences.)

(2) That this material produced serious inflammation in rabbit ear tests and that the presence of the contaminant had been confirmed by chromatography.

(3) That standard production 2,4,5-T contains less than 1 ppm of this contaminant and does not produce inflammation in the rabbit ear test.

(4) That Sprague-Dawley female rats as dams have been under test in their laboratory at Zionsville, Indiana, at five levels (25 rats each) of the standard production line material. They came to term January 7, 8 and 9, 1970, at which time they were killed by carbon dioxide inhalation and fetuses were removed by cesarean section and subjected to standard examinations for malformations and anatomical anomalies of various kinds; further examination will include clearing, staining and histopathologic procedures.

Dr. Howard L. Richardson, Chief, Pathology Branch, FDA, participated in the evaluation which related to full-term rat embryos subjected to 2,4,5-T during gestation, as well as a number of full-term rabbit embryos. He reports that no signs of malformations were found in gross and microscopic dissection of these embryos, but that histologic examinations are yet to be made. Personnel from the National Institute of Environmental Health Sciences were unable to participate, but will be involved in the examination of this and other informational material.

Further characterization of the contaminant tetrachloro-dibenzo-para-dioxin is currently under way and Dr. Leo Friedman will welcome participation by your research staff in this effort. We would point out the resemblance if not the "practical identity" of the tetrachloro-dibenzo-para-dioxin with the "chick edema factor." This substance is of extremely high toxicity to all species of animals that have been exposed, and until now, its source in contaminated fatty materials has been a mystery.

Considering the imminence of the availability of this additional information and the legitimate question as to whether or not the teratology reported by the Bionetics study was due to the 2,4,5-T or to the contaminant, we have elected to delay action on the petition for a few more days. As you know, the petitioner had requested, on December 5, 1969, an extension of 3 additional months.

We will advise you of our decision as soon as our scientific staff assays the results of this nearly completed test and considers them together with the results of other current research on 2,4,5-T at the National Institute for Dental Research and in the Food and Drug Administration. Thus far, no one has confirmed the Bionetics results although 2,4,5-T (with 27 ± 8 ppm contaminant) has been found to be embryotoxic.

Sincerely yours,

JESSE L. STEINFELD, M.D.,
Surgeon General.

Senator HART. At the beginning of your testimony you say residues on food are unusual. When they do occur, are they the result of unauthorized use of 2,4,5-T or authorized use, or both?

Dr. BAYLEY. Mr. Chairman, I am going to ask Dr. Byerly to respond to that.

Dr. BYERLY. Sir, one of the two significant values, 0.19, was on milk, and the other was on sugar beets. As far as sugar beet use, I would have to verify whether or not there is a registered use on sugar beets. There is on sugarcane. There is certainly none on milk. This would be unauthorized use in the case of milk, certainly.

Senator HART. Is it authorized for use on grass?

Dr. BAYLEY. Yes, sir.

Senator HART. It is?

Dr. BAYLEY. It is authorized for use on grass.

Senator HART. And clearly not on milk?

Dr. BYERLY. No.

Senator HART. What do you say to the suggestion that if you know that there is a regular unauthorized use of a pesticide going on you ought not permit it to be registered? How can you register a pesticide even for safe usage when regularly it is used in an unsafe, unauthorized manner?

Dr. BAYLEY. The law provides, and I will not pretend to quote it exactly, that if despite the registration restrictions, including use, the Department finds there is injury to people and to the environment or desirable environmental organisms, that we can consider this as misbranded and cancel the registration.

So the pattern of the enforcement of that part of the law is for a surveillance program to determine the extent to which their unauthorized uses are providing injury and then we take action.

This is very clearly shown in the action we took recently involving a mercurial seed treatment program compound. It was this type of action, where unauthorized use was creating an injury and we immediately suspended it.

Senator HART. You say the use is authorized on grass, not milk. Could not cows eat grass, thus producing residues in our milk.

Dr. BAYLEY. This is based on the recommendations for use and also based on the degradation properties of 2,4,5-T itself. Good practice would require withholding the grazing of cows from these pastures until such time as we can be sure there will be no residue in the animal product.

The widespread use of this as herbicide on ranges and pastures indicates that farmers are following these practices with the possible one exception that we know of at this point.

Senator HART. What information can you add to this record substantiating the statement that 2,4,5-T degrades in a matter of—how did you put it?

Dr. BAYLEY. We will be glad to supply for the record the scientific information indicating the degradation time of 2,4,5-T as well as the circumstances under which this will vary.

Senator HART. That will be printed in the record.

(The information follows:)

There is a voluminous body of published literature on the degradation and persistence of herbicides. Enclosed are five reprints available to us that deal specifically with 2,4,5-T. For a more comprehensive discussion of 2,4,5-T and other pesticides, we recommend the following publications:

(1) Kearney, P. C. and D. D. Kaufman (Editors). 1969. *Degradation of Herbicides*. Marcel Dekker, Inc., New York.

(2) Miller, M. W. and G. G. Berg (Editors). 1969. *Chemical Fallout—Current Research in Persistence of Herbicides*. Charles C. Thomas Publishers.

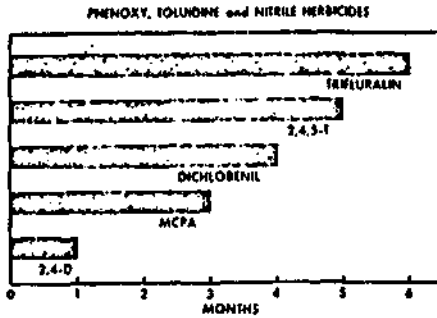
(3) *Nature and Fate of Chemicals Applied to Soils*. 1960. U.S. Department of Agriculture, ARS 20-9.

The literature supplied herewith substantiates our statement that 2,4,5-T is degraded in the soil in a few months. There will, of course, be some exception to any general statement. Greater persistence would be expected in a cool, dry environment having a low microfloral activity.

[From: Chemical Fallout—Current Research on Persistent Pesticides Ed. by Morton W. Miller & G. G. Berg. Charles C. Thomas, Publisher, 1969]

Soil Persistence of 2,4,5-T

The persistence of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), when applied at recommended rates (0.25 to 8 lb/A) is 4 to 5 months as compared to about 1 month for 2,4-dichlorophenoxyacetic acid (2,4-D) as shown in the figure below.



DeRose (3) found that a 3 lb/A field application of 2,4,5-T was no longer phytotoxic to soybeans 3 months later. However, rates of 10 and 20 lb/A remained highly phytotoxic after 3 months. Newman, et al (4) found that 2,4,5-T lost its phytotoxicity after 4 months when applied at rates up to 26 lb/A. Burger, et al (1) found a similar loss of phytotoxicity to alfalfa 4 months after the application of 25 ppm (50 lb/A). However, these were both laboratory studies in which the soils were maintained moist and warm, two conditions that facilitate the microbial inactivation of phenoxyacetic acid herbicides. The 6 month persistence of 2,4,5-T in soil, DeRose and Newman (3), appears to be one of the largest persistences reported.

Microorganisms are primarily responsible for degrading phenoxyacetic acid herbicides in soils. The kinetics of 2,4-D, 2-methyl-4-chlorophenoxyacetic acid (MCPA), and 2,4,5-T detoxification in soil-perfusion experiments were exactly what would be expected if microorganisms were the detoxicating agents (4); in addition, detoxication was blocked by the bacterial inhibitor sodium azide. The bacteria and actinomycetes responsible for degrading phenoxyacetic acids are shown in Tables 1-2 (4).

The metabolism of the phenoxyacetic acid herbicides has been studied extensively (4). There appear to be two major pathways of degradation, i.e., via a hydroxyphenoxyacetic acid intermediate and degradation via the corresponding phenol. Some of the important steps in microbial metabolism of representative phenoxyacetic acids are shown in Figures 1-6 (4).

TABLE 1-2
Bacteria and Actinomycetes which Degrade Phenylacetic Acids

Organism	References	Phenylacetic acids metabolized										M. A. LODGE
		Phenylacetic acid	2-Chlorophenylacetic acid	4-Chlorophenylacetic acid	2,4-Dichlorophenylacetic acid	2,6-Dichlorophenylacetic acid	2,4-Dibromophenylacetic acid	4-Fluoro-2-chlorophenylacetic acid	2-Methyl-4-chlorophenylacetic acid	4-Hydroxyphenylacetic acid	2-Hydroxy-4-chlorophenylacetic acid	
Bacteria												
<i>Paenibacillus</i> sp.	84,85				+							
<i>Paenibacillus</i> sp.	84,86			+								
<i>Mycobacterium</i> sp.	87	+	+	+					+			
<i>Achromobacter</i> sp.	88			+						+		+
<i>Achromobacter</i> sp.	88,89		+	+					+			
<i>Achromobacter</i> sp.	90,91	+	+	+	+		+		+			
<i>Flavobacterium</i> <i>parvum</i> m	88,89		+	+	+							
<i>F. parvum</i> m	92,93				+							
<i>F. parvum</i> m	99				+					+		
<i>Corynebacterium</i> sp.	94				+							
<i>Corynebacterium</i> -like organisms	95,96				+					+		
<i>Arthrobacter globiformis</i> (<i>Bacterium globiformis</i>)	78,79				+							
<i>Arthrobacter</i> sp.	97,98	+	+	+	+				+			
<i>Sporotrichopsis congregata</i> (<i>Flavobacterium aquatilis</i>)	95,96,100				+					+		
Actinomycetes												
<i>Nocardia</i> sp.	82			+	+							
<i>Streptomyces viridochromogenus</i>	101											+

* Substrate in enrichment and isolation media.

M. A. LODGE

PHENOXYACETIC ACIDS

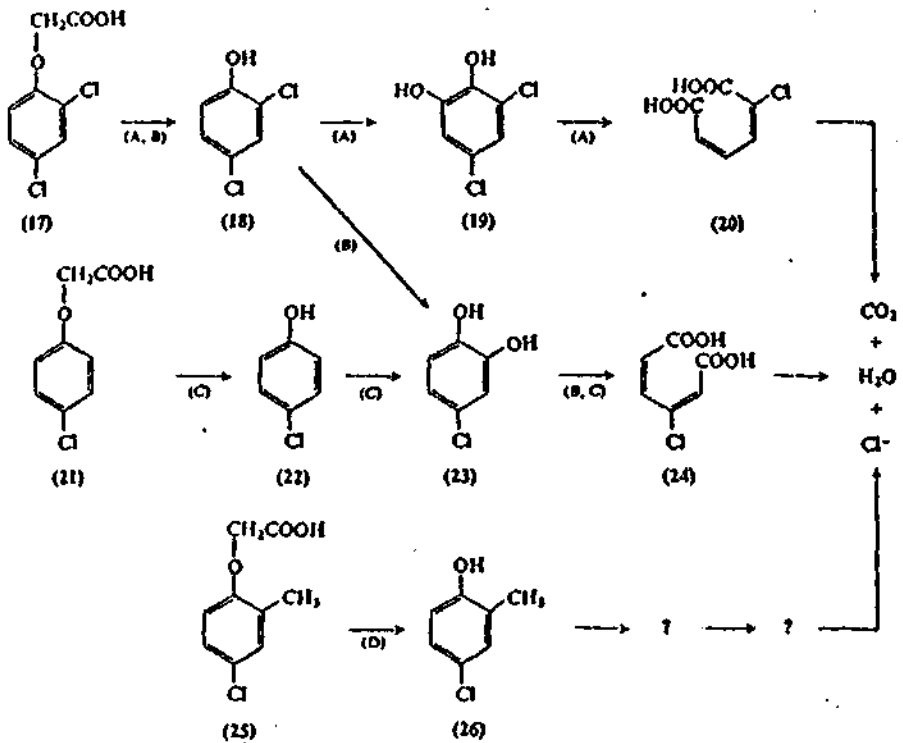


Fig. 1-6. Microbial degradation of phenoxyacetic acids via the corresponding phenols. (A) 2,4-D (17) degradation via 2,4-dichlorophenol (18), 3,5-dichlorocatechol (19), and α -chloromuconic acid (20); (B) 2,4-D degradation via 2,4-dichlorophenol, 4-chlorocatechol (23), and β -chloromuconic acid (24); (C) 4-CPA (21) degradation via 4-chlorophenol (22), 4-chlorocatechol, and β -chloromuconic acid; and (D) MCPA (25) degradation via 2-methyl-4-chlorophenol (26). [After (83,89).]

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Growth of Crops in Soils After Herbicidal Treatments for Brush Control in the Tropics¹

R. W. Bovey, F. R. Miller, and J. Diaz-Colon²

ABSTRACT

Herbicides 4-amino-3,5,6-trichlorophenoic acid (picloram), a 1:1 mixture of the butyl esters of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid (2,4-D:2,4,5-T), and a 2:2:1 mixture of the isooctyl esters of 2,4-D:2,4,5-T:picloram at 8.7, 26.9, and 16.8 kg/ha (6, 24, and 15 lb/A) respectively, were applied as foliar sprays to control guava (*Psidium guajava* L.). Six crop species were planted in soil collected from each plot, 1, 2, 3, 6, 9, and 15 months after treatment, to detect herbicide residues and to determine crop tolerance. Corn, sorghum, wheat, rice and cotton could be grown without reduction in fresh weight so early as 3 months after application. Soybeans were the most susceptible crop to herbicide residues.

Additional index words: herbicide residues, picloram, 2,4-D, 2,4,5-T, guava.

A COMBINATION of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) is an established herbicide for woody plant control (2,4,5). Herbicide 4-amino-3,5,6-trichlorophenoic acid (picloram) and combinations of picloram with 2,4,5-T show promise for control of woody species which exhibit resistance to phenoxy herbicides (1). Since high herbicide dosages are required for adequate brush control in the tropics (10, 11) damage to agronomic and forage crops seeded following treatment could result from herbicide residues.

Disappearance of 2,4-D and 2,4,5-T from warm moist soils in the temperate zone is rapid. Accumulation of harmful residues is unlikely from year to year if recommended rates for weed control are followed (4,5). Factors responsible for decomposition of phenoxy herbicides include microbial activity, leaching and volatility (9). It is assumed that phenoxy compounds would have an accelerated rate of disappearance in tropical soils compared to temperate climates because of higher temperatures and greater rainfall. Available information suggests that picloram remains in soils much longer than 2,4-D (3) (R. W. Bovey, 1968. Unpublished data). Decomposition by microorganisms is very slow (12). Bioassay studies indicated that the half-life of picloram in soils throughout the United States varied with location, but some persisted 1 year after treatment (3). Similar studies in Texas (6) and Puerto Rico indicated that less than 0.05 ppm was present 1 year after treatment of picloram at 8 lb/A (8.96 kg/ha) and 9 lb/A (10 kg/ha), respectively (C. C. Dowler, 1968. Unpublished data). However, the Texas determinations were made from sandy loam soils and samples were taken to a depth of 24 inches (61 cm). Additional work has indicated that the main routes of picloram disappearance and decomposition

from soil profiles are by leaching and photo-decomposition (7).

Jungle areas in Hawaii were aerially treated with 2-methoxy-3,6-dichlorobenzoic acid (dicamba), 2-(2,4,5-trichlorophenoxy) propionic acid (silvex), combination of paraquat plus dicamba and 2,4-D plus picloram (8). When treated plots were planted to Monkey pod trees (*Samanea saman* (Jacq.) Merrill) 1 month after application, the trees developed no injury from herbicide residues in the soil.

This paper reports the growth of six crop species in a tropical soil treated with picloram and combinations of 2,4-D:2,4,5-T and 2,4-D:2,4,5-T:picloram collected from a guava control area, to determine the longevity of herbicide residues and the tolerance of individual crop species to each herbicide.

MATERIALS AND METHODS

Herbicidal treatments were made on mature stands of guava (*Psidium guajava* L.) near Mayaguez, Puerto Rico. Characteristics of guava, the physical environment, and responses to herbicides have been described (11). Herbicides were applied to guava with a pump sprayer designed to cover a 12.14-m (40-ft) diameter circle (Dowler, C. C., and F. H. Tschiley, 1966. Defoliation Project Mayaguez, Puerto Rico. Ann. Rep., USDA). Herbicides applied included the potassium salt of picloram at 6.72 kg/ha (6 lb/A), a 1:1 mixture of the butyl esters of 2,4-D:2,4,5-T at 26.88 kg/ha (24 lb/A) and a 2:2:1 mixture of the isooctyl esters of 2,4-D:2,4,5-T:picloram (8-11-6) at 16.80 kg/ha (15 lb/A).

Soil samples were taken from herbicide treated plots 1, 2, 3, 6, 9, and 15 months after treatment by collecting the top 1 ft (32.49 cm) of soil at three or four locations in each plot. Soil samples 1 and 2 months after treatment were not taken for M-5140. To prevent contamination, a clean shovel was used for each plot. Soil was placed in plastic bags, sealed, and immediately transported to the greenhouse. Each soil was pulverized by hand and placed in 38 × 30.5 × 13-cm (15 × 12 × 5-inch) boxes lined with plastic to prevent leaching of the herbicide. Each worker was required to wash his hands thoroughly between each soil treatment. Untreated soil samples were prepared first, followed by longest field applied treatment (15 months) to the shortest (1 month). Four replications were prepared for each treatment. Soil from the treated area was a Mucara clay loam (11).

Twenty-five seeds of corn (*Zea mays* L.) var. 'USDA-94', sorghum (*Sorghum bicolor* L.) var. 'Combine Kafir-60', wheat (*Triticum aestivum* L.) var. 'Montana', rice (*Oryza sativa* L.) var. 'Taichung Native No. 1', cotton (*Gossypium hirsutum* L.) var. 'Blightmaster', and soybeans (*Glycine max* (L.) Merrill) var. 'Jank' were planted in each replication, covered with a 0.6 to 1.3-cm (¼ to ½-inch) layer of soil and watered. The crops were grown for 21 days. Aerial portions of all plants in each replication were weighed on an electronic balance and recorded as fresh weight. Numerical values presented in the tables that follow are percentage of the control.

RESULTS

Rainfall is important in the decomposition and disappearance of herbicides from soil profiles. Rainfall data are presented in Table 1 for each of the treatment periods.

Picloram. Growth of six crops in soil treated with picloram at 6.72 kg/ha (6 lb/A) is given in Table

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Table 1. Amount of rainfall from each date of herbicide application to date of sampling soil (Dec. 6, 1967).

Months after application	Date herbicide applied	No. of days	mm	inches
1	Dec. 9, 1967	30	2.76	10.9
2	Dec. 2, 1967	42	15.03	59.1
3	Aug. 20, 1967	30	32.30	127.4
4	Mar. 12, 1967	300	52.75	207.6
5	Feb. 9, 1967	300	58.02	228.5
12 1/2	Oct. 22, 1966	447	95.51	375.6

2. All crops showed a significant reduction in growth when seeded 1 and 2 months after application of the herbicide. Rice, soybeans, and cotton were severely affected and showed essentially no growth when seeded in soils 1 month after treatment. Soybeans and corn continued to be adversely affected when seeded in soils 3 months after treatment; while sorghum, wheat, rice and cotton were not significantly affected. Since the leaching of picloram is much dependent upon leaching the 58.4 cm (23 inches) of rainfall received in the 3 months after treatment (Table 1) undoubtedly removed lethal amounts of picloram. These data suggest that all crop species studied could be safely seeded in soils 6 months after picloram treatment without adversely affecting growth.

2,4-D:2,4,5-T. Crop growth was retarded in soil treated with the 2,4-D:2,4,5-T combination 1 and in some cases 2 months before seeding (Table 2). At 1 and 2 months this combination of herbicides was less inhibitory than picloram although the rate of treatment was four times as great. This suggests that the phenoxy compounds either dissipated more rapidly than picloram or that the crops were more tolerant to the herbicide combination or both. Wheat and cotton produced growth comparable to the control when seeded in soils 2 months after treatment. Soybeans were the most readily inhibited of all crops grown. Reasons for reduced growth in soils treated for 13 1/2 months are unknown. That this may be a chance variation is indicated by over 100% production in samples of soil taken in plots having a shorter time after these same treatments (excepting soybeans). Average (means) for all crops did not differ significantly at the 5% level of Duncan's Multiple Range Test.

M-3140. Blended rates of treatment for M-3140 were 6.72, 6.72, and 3.36 kg/ha (6, 6, and 3 lb/A) of 2,4-D, 2,4,5-T, and picloram, respectively. No significant differences (5%) in growth occurred among averages for months but did for crop species when M-3140 was applied. Soybeans showed injury in soils treated for 9 1/2 months or less before seeding (Table 2). Cotton seeded 3 months after treatment was slightly injured. Apparently, sufficient picloram persisted for the described intervals to cause damage to soybeans and cotton; but other crops were unaffected.

DISCUSSION

These studies indicate that high rates of herbicides used to control vegetation in tropical and subtropical areas disappear rapidly, even though persistent compounds such as picloram are used. Hence, most crops could be safely grown within 6 months after application with few if any adverse effects.

Soybeans were the crop most sensitive to herbicidal residues in soil. Use of an alternative crop should be considered, if seedlings are made during the first

Table 2. Percentage growth of six crops in soils from foliar applied herbicides on years 1, 2, 3, 6 1/2, 9 1/2, and 13 1/2 months after treatment (growth of control plants as 100%).

Species	Control	Herbicide applied, 10.0 kg/ha						Avg. (groups)
		2,4-D	2,4,5-T	2,4,5-T	picloram	M-3140	M-3140	
1	100	0	100	100	100	100	100	100
2	100	0	100	100	100	100	100	100
3	100	0	100	100	100	100	100	100
6 1/2	100	0	100	100	100	100	100	100
9 1/2	100	0	100	100	100	100	100	100
13 1/2	100	0	100	100	100	100	100	100
Avg. (groups)	100	0	100	100	100	100	100	100
1	100	0	100	100	100	100	100	100
2	100	0	100	100	100	100	100	100
3	100	0	100	100	100	100	100	100
6 1/2	100	0	100	100	100	100	100	100
9 1/2	100	0	100	100	100	100	100	100
13 1/2	100	0	100	100	100	100	100	100
Avg. (groups)	100	0	100	100	100	100	100	100

* Numbers followed by the same letter do not differ significantly at the 5% level using Duncan's multiple range test.

few months after treatment. Gramineae species such as corn, sorghum or wheat may be used first in treated areas, because these are more tolerant to the residues of herbicides used for controlling brush.

Rainfall (Table 1) is important in leaching herbicides from soil profiles. In areas of more abundant precipitation one could expect more rapid disappearance than was encountered in this study, providing that other soil and environmental factors are equal. We have concluded that harmful residues of herbicides in the soil would not occur in tropical areas after chemical brush removal if a reasonable deferment of land was observed after application.

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Effect and Persistence of Herbicides Applied to Soil in Puerto Rican Forests¹

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Abstract. Six herbicides were applied at 3, 9, and 27 lb/A to the soil in forests of three types in Puerto Rico. The forests differed in soil type, amount and pattern of rainfall, and species composition. Defoliation occurred slowly, but the correlation between percentage defoliation and plants killed was significant at the 1% level of probability. Some defoliation was evident 1 month after treatment and increased slowly during the next 6 to 8 months. The most effective herbicide was Laminol (3,5,6-trichloropicolinic acid (picloram)). Generally, 2-methoxy 3,6-dichlorobenzoic acid (dicamba), 2-methoxy 0-6-isopropoxypropylamine oxazine quaternary, and 3-bromo 3-oxo butyl 6-methylimidazo[2,1-b]imidazole were less effective than picloram. Both 2,3,6-trichloropicolinic acid (dicamba) and 3-(5,1-dichlorophenyl)-1,1-dimethylurea (dimuron) were ineffective. Defoliation was greatest and more plants were killed in the driest site.

One year after treatment, Laminol was the most persistent herbicide in the soil. Herbicides were found to a 56 to 100 in depth within 3 months after application.

Herbaceous and woody seedlings were present at all sites within 16 months after herbicide application. There was no definite relationship between herbicidal treatment and secondary succession, except that the number and frequency of successful species were greater on plots having the highest percentage of defoliation.

INTRODUCTION

THE effect of herbicides applied to the soil for control of woody plants in tropical forests has not been studied intensively or extensively. A short review by Mayo-McCormick (7) indicated that frill treatment to trees was the most effective method of application. Beveridge (2), Spota (11), and Wyatt-Smith (17, 18) used frill treatments successfully on a large number of tropical species but noted differential susceptibility among species. Dawkins (4) reported that a basal spraying or painting was as effective as frill treatment.

Many hardwoods can be controlled effectively with phenoxyacetic or picolinic acids applied in basal frills or as tree injections (6, 15). Many compounds are effective as foliar treatments for controlling woody plants (3, 16). Nation (9) reported that 4-amino-3,5,6-trichloropicolinic acid (picloram), when applied as a soil treatment, was an effective herbicide for controlling woody plants. He also noted differential susceptibility among species.

Inseparable from the biological effect of herbicides applied to the soil are their movement and persistence.

Factors such as rainfall, physical and chemical characteristics of the soil, microorganisms, chemical characteristics of the herbicides, and method of application may influence herbicidal movement and persistence (5, 8, 10, 12).

Our objectives were (a) to determine the toxicity of selected herbicides on tropical arboreal vegetation, (b) to determine the movement and persistence of these chemicals in the soil, and (c) to observe the short-term effects of these chemicals on secondary plant succession.

MATERIALS AND METHODS

Our studies were located in Guanica Commonwealth Forest, Maricao Commonwealth Forest, and Luquillo National Forest. The soil type at the Guanica Commonwealth Forest is Jacana clay. It is an alluvial soil normally less than 36 in deep, with very low permeability. The vegetation is xerophytic. There were 35 woody species within the test area, but *Leucaena leucocephala* Lam., DeWitt and *Harmosaxylon camberlandicum* L. comprised more than 90% of the woody plant population. Mean height of the vegetation was 15 ft. Annual rainfall in the Guanica area, estimated at approximately 30 in, occurs largely from July to October. The recorded annual rainfall at the site for 1964 and 1965 was 27.89 and 25.00 in, respectively.

The soil type at the Maricao Commonwealth Forest site is Nipe clay, a permeable, well-drained, lateritic soil derived from serpentine. The vegetation on this site is classified by Beard (1) as moist tropical forest. There were 106 woody species within the test area. The mean canopy level was approximately 50 ft. Mean annual rainfall at the Maricao site is estimated to be about 90 in. Rainfall is normally distributed throughout the year, but December to May is the driest period. The recorded annual rainfall at the site for 1964 and 1965 was 84.64 and 109.88 in, respectively.

The soil type at the Luquillo National Forest site is Los Guineos clay loam, a plastic clay with poor internal drainage. The vegetation is a tropical rain forest (1) with a mean canopy level of about 60 ft. There were 88 tree species on the test site. Mean annual rainfall is estimated to be over 100 in. The highest rainfall normally occurs from July to October, but droughts are unknown. The recorded annual rainfall near the site was 85.78 in for

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1964 and 126.12 in for 1965. Tschirley *et al.* (14) characterized the Maricao and Luquillo sites in greater detail.

The herbicides used in this study were 5-bromo-3-sec-butyl-5-methyluracil (bromacil), dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid (dicamba), 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron), Na salt of 2,3,6-trichlorophenylacetic acid (fenac), K salt of picloram, and 2-methoxy-4,6-bis(isopropylamino)-s-triazine (prometon). Each herbicide was applied at 3, 9, and 27 lb/A.

A randomized complete block design was used at each location. The treatments were replicated three times at Guanica and Luquillo, but only twice at Maricao because of topographic limitations. Each plot was 60 by 80 ft. with a 20-ft buffer separating adjacent plots. Data were collected from a centrally located 40 by 60-ft subplot. Narrow walkways were cut through the long axis of each plot to facilitate treatment and data collection.

All woody plants having a diameter breast high (hereinafter referred to as dbh) measurement of 0.75 in or greater were marked, mapped, and identified (at least to genus) at the Guanica site. At Maricao and Luquillo, only plants having a dbh greater than 1 in were marked, mapped, and identified. All defoliation data were collected only from the marked plants.

The herbicides were applied with a cyclone hand sprayer as granules, pellets, wettable powder, or liquid adsorbed on vermiculite. Vermiculite was used as a carrier to provide additional bulk for all treatments. The application dates were: Guanica—October, 1963; Maricao—December, 1963; and Luquillo—January, 1964. Percentage of defoliation of each marked plant was estimated periodically after treatment. Plot defoliation, calculated from individual plant defoliation, represents a mean percentage weighted according to the relative prevalence of various species.

The downward movement of herbicides and their persistence in the soil were studied by sampling 3, 6, and 12 months after treatment. Duplicate soil samples were collected at random from centrally located 20 by 40-ft subplots. Soil from depths of 0 to 6, 6 to 12, 12 to 24, 24 to 36, and 36 to 48 in was analyzed separately. If the soil was not 48 in deep, samples were collected to the maximum possible depth. The samples were placed into 1-qt styrene cups, then sealed and transferred to the greenhouse where a bioassay was immediately initiated. Cucumber (*Cucumis sativus* L., var. Puerto Rico 99) was used as an indicator plant. Approximately six cucumber seeds were planted in each sample. After emergence, the cucumbers were thinned to two seedlings per sample. A mean injury rating of each sample was made after 28 days of growth and compared to an established standard curve. Abnormal growth characteristics were expressed on a 10-point scale, where 0 = no effect and 10 = plants killed.

Succession data were collected from one replication at each site. Observations on the species present and their relative importance were made at Maricao, Guanica, and Luquillo in April, May, and September, 1965, respectively. The successional species on each plot were identified to family, genus, or species and grouped according to tree seedlings, grasses and sedges, or herbaceous plants and vines.

RESULTS

Herbicidal effect on woody plants. The correlation coefficient of percentage defoliation and plants killed was significant at the 1% level of probability; consequently, results are based on defoliation only.

Guanica. Picloram was clearly the most effective herbicide (Table 1). Bromacil and prometon caused high

Table 1. Percentage of defoliation and plants killed of all arboreal species in the Guanica, Maricao, and Luquillo forests approximately 2 years after herbicidal treatments.

Herbicide and rate, lb/A	Treatment sites					
	Guanica		Maricao		Luquillo	
	Def	PK	Def	PK	Def	PK
Picloram	9	5*	32	21	24	23
	6	0	91	73	55	52
	3	0	94	91	89	89
Dicamba	3	0	12	6	9	6
	1	0	18	10	14	14
	1	0	22	9	13	11
Bromacil	3	0	16	3	10	15
	2	0	32	29	24	22
	1	0	100	100	100	100
Prometon	3	0	8	3	0	0
	2	0	56	33	3	19
	1	0	77	57	21	18
Diuron	3	0	2	11	0	0
	2	0	18	10	5	2
	1	0	18	10	5	2
Fenac	3	0	2	15	3	6
	2	0	26	11	2	6
	1	0	14	19	6	9
Check	3	0	2	2	1	1

*Def = percentage defoliation; PK = percentage plants killed.

defoliation at the higher rates but were less effective when only 3 lb/A was used. Dicamba, diuron, and fenac caused only slight defoliation even at the highest rate.

Differential susceptibility of the five principal species at Guanica is shown in Table 2. Picloram, considering all

Table 2. Percentage of defoliation of the five principal species in Guanica test site 2 years after herbicidal treatments to the soil.

Herbicide and rate, lb/A	Defoliation of major species in decreasing order of importance				
	1	2	3	4	5
	Picloram	3	61	41	30
	2	82	100	100	0
	1	100	100	100	100
Dicamba	3	11	0	0	0
	2	14	2	22	17
	1	13	13	24	4
Bromacil	3	24	48	14	0
	2	50	76	100	61
	1	100	100	100	44
Prometon	3	22	1	21	2
	2	70	25	50	91
	1	100	96	100	100
Diuron	3	8	0	40	0
	2	18	1	45	24
	1	17	6	60	40
Fenac	3	0	2	2	0
	2	36	11	47	13
	1	27	14	20	45
Check	3	1	0	5	2

1. *Leucaena leucocephala* (Lam.) DeWitt 2. *Hemipiptadenia confertiflora* L. 3. *Acacia* spp. 4. *Clusia* spp. 5. *Prosopis juliflora* (Sw.) DC. 6. *Trichilia hirta* L.

rates, had the broadest spectrum of herbicidal activity. Prometon was more effective than was any other herbicide for defoliating *Prosopis juliflora* (Sw.) DC. and *Trichilia hirta* L.

At Guanica, the maximum percentage of defoliation resulting from treatments with picloram was obtained about 3 months after treatment (Figure 1). Defoliation

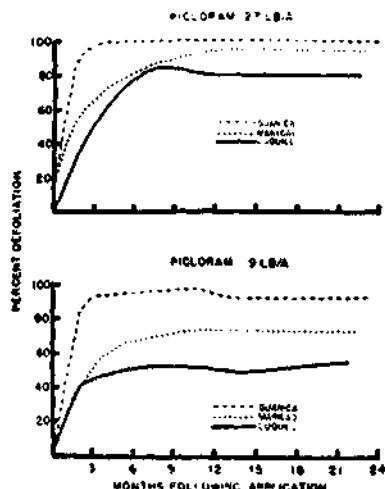


Figure 1. Percentage of defoliation at specified intervals after picloram was applied to the soil in three forested areas in Puerto Rico.

remained essentially constant for the rest of the 24-month period.

Total vegetation control was short-lived, even on plots that had been treated with 27 lb/A. No treatment prevented plant succession for more than 18 months. Two years after treatment, *Ipomoea* spp., *Indigofera suffruticosa* Mill., and cacti (*Opuntia* spp.) were abundant. Grass and tree seedlings were less numerous. *Leucaena leucocephala* (Lam.) DeWitt was the most abundant tree seedling. Seedling density was directly related to percentage of defoliation.

Maricao. Picloram caused the highest percentage plot defoliation (Table 1). Dicamba at 27 lb/A caused 50% defoliation, but this was considerably lower than that caused by picloram at 9 lb/A. Bromacil, prometon, diuron, and fenac were considerably less effective.

Picloram affected the broadest spectrum of tree species (Table 3). *Alseodaphne stenianii* Cogn. was more susceptible to picloram than were the other eight species. *Rapanea ferruginea* (R. & P.) Mez appeared to be most susceptible to bromacil. *Ocotea leucoxylon* (Sw.) Mez tolerated all the herbicides except picloram at 9 and 27 lb/A.

Maximum defoliation resulting from treatment with picloram was obtained at Maricao about 1 year after treatment (Figure 1). There was essentially no change during the second year of observation.

No herbicidal treatment prevented the succession of tree seedlings, grasses and sedges, or vines and herbaceous plants at Maricao. Tree seedlings were sparse on plots treated with picloram at 9 and 27 lb/A, but composition

Table 3. Percentage of defoliation of the nine principal species in Maricao test site after herbicidal treatments to the soil. Treated December, 1963 and raised October, 1965

Herbicide and rate, lb/A	Defoliation of major species in decreasing order of importance								
	1	2	3	4	5	6	7	8	9
Picloram 3	0	45	0	0	32	29	50	33	—
27	33	70	50	41	34	87	100	100	57
9	16	100	90	93	65	87	100	100	40
Dicamba 3	12	10	0	5	50	9	43	0	—
9	2	25	41	0	19	7	49	0	—
27	7	53	100	8	50	0	100	77	—
Bromacil 3	10	0	85	17	39	0	35	0	—
9	13	10	45	47	73	0	100	0	66
27	47	0	100	34	74	19	93	40	37
Prometon 3	18	1	37	0	—	0	0	—	0
9	25	0	19	0	17	0	27	0	55
27	27	2	75	63	0	57	0	100	0
Diuron 3	3	0	14	35	—	—	9	0	—
9	3	0	10	4	15	0	30	0	—
27	3	—	9	24	0	0	35	0	15
Fenac 3	—	3	15	25	30	37	0	0	16
9	—	0	25	32	0	0	0	0	0
27	—	22	0	33	0	0	7	0	0
Check	0	3	16	0	0	0	37	0	0

1. *Colophylloides caldas* Jacq. 2. *Coccoloba-Drypetis*. 3. *Rapanea ferruginea* (R. & P.) Mez. 4. *Alseodaphne stenianii* Cogn. 5. *Tournefortia nitida* (Vahl) Spreng. 6. *Ocotea leucoxylon* (Sw.) Mez. 7. *Miconia tomentosa* Cogn. 8. *Cuculoba* sp. 9. *Teucrium domingense* (Lam.) R. & P.

and density of the seedling complex could not be definitely associated with herbicidal treatment. The most common succession species in the Maricao site were *Terebraria resinosa* (Vahl) Spreng., *Clusia* spp., *Lehanthus pallens* (Sw.) Munro, *Panicum glutinosum* Sw., and *Polypodium* spp.

Luquillo. Picloram caused the highest percentage of defoliation at the Luquillo site (Table 1). The highest rates of bromacil and dicamba caused appreciable defoliation, but both herbicides were much less effective when only 3 or 9 lb/A were used. Prometon, diuron, and fenac caused only slight defoliation at all rates. Picloram was as effective at 9 lb/A as dicamba and bromacil at 27 lb/A.

Differential susceptibility was apparent among the eight most numerous species (Table 4). *Tabebuia heterophylla* (DC.) Britton was the most resistant species in that no treatment caused more than 31% defoliation. *Psychotria berteriana* DC. on the other hand, was completely de-

Table 4. Percentage of defoliation of the eight principal species in Luquillo test site 21 months after herbicidal treatments to the soil.

Herbicide and rate, lb/A	Defoliation of major species in order of decreasing importance							
	1	2	3	4	5	6	7	8
Picloram 3	5	11	17	57	20	11	33	0
9	14	44	19	100	100	33	100	17
27	30	100	72	100	100	100	100	100
Dicamba 3	4	0	0	0	2	0	0	0
9	10	71	4	0	18	6	100	0
27	31	94	59	50	0	47	100	100
Bromacil 3	10	14	7	0	32	0	74	0
9	0	87	0	13	50	12	100	13
27	37	76	49	100	75	0	100	0
Prometon 3	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
27	0	5	0	0	28	32	55	0
Diuron 3	0	0	0	0	2	0	0	0
9	0	4	0	0	11	0	0	0
27	4	0	5	0	37	10	11	0
Fenac 3	0	0	3	35	0	0	0	0
9	0	0	4	0	0	0	0	0
27	21	2	14	0	14	27	71	0
Check	0	3	2	0	0	0	0	0

1. *Tabebuia heterophylla* (DC.) Britton. 2. *Cyathus arboreus* (L.) J. E. Smith. 3. *Cordia alliodora* Urban. 4. *Psychotria tomentosa* (Griseb.) Nicholson. 5. *Miconia nitida* (Sw.) DC. 6. *Coccoloba-Drypetis*. 7. *Psychotria berteriana* DC. 8. *Rapanea ferruginea* (L.) Mez.

foliated by 9 and 27 lb A of picloram, dicamba, and bromacil. Picloram had the broadest spectrum of herbicidal activity. At the 27 lb A rate, six of the eight species were completely defoliated and the other two species, *Tabebuia heterophylla* (DC.) Britton and *Cordia alliodora* Urban, were partially defoliated. The 27 lb A rate of dicamba caused 100% defoliation of *Psychotria berteriana* DC. and *Inga jagfolia* (L.) Willd. but no defoliation of *Miconia prasina* (Sw.) DC. The 27 lb A rate of bromacil caused 100% defoliation of *Prestonia montana* (Graham) Nicholson and *Psychotria berteriana* DC. but no defoliation of *Casavia-Diurpetes* and *Inga jagfolia* (L.) Willd.

The speed at which trees defoliated was essentially the same for all herbicides applied. Data for the rate of defoliation caused by picloram indicate that maximum effectiveness was obtained about 6 to 8 months after treatment (Figure 1). The maximum defoliation occurred sooner from picloram at 9 lb A than picloram at 27 lb A. Defoliation remained essentially constant for the remainder of the 24-month period.

The relative density of new seedlings at the Luquillo site could not be correlated with the herbicidal treatment. The most common tree seedlings were *Psychotria berteriana* DC., *Ocotea leucosylon* (Sw.) Mez, and *Prestonia montana* (Graham) Nicholson. Grasses were best represented by *Panicum adpressum* Trin. and sedges by *Scleria scans* (L.). Many vines and herbaceous plants were present, *Iponoea* spp. being the most common. There was a direct relation between percentage of defoliation and number of new seedlings. One year after treatment, the forest floor of plots that had been completely defoliated was covered with vegetation. The density of new plants is shown in Figure 2.

Herbicide residue in the soil. Three months after application, the herbicides had moved downward in the soil to the 36 to 48 in depth. The bioassay data for all sampling depths indicated persistence of the herbicides in the soil 1 year after treatment for all locations was in the order of fenac > prometon > picloram > dinuron > bromacil > dicamba. An example of the residue data is shown in Figure 3. Dicamba had almost completely disappeared 1 year after treatment. Two years after treatment, fenac was still the most persistent herbicide, followed by prometon and picloram.

The persistence of the herbicides generally was greatest in the driest area (Guánica) and least in the wettest area (Luquillo) (Figure 4). One year after application, the residue of picloram in plots treated at 27 lb A remained in relatively high concentrations at all test sites, as determined by the cucumber bioassay test. The presence of picloram in plots treated at 9 lb A could be easily detected 1 year after treatment, but the concentrations were about 10 times less than in plots treated with 27 lb A. The residue data for all locations indicated a trend for all the herbicides to dissipate more rapidly in the top 12 in of soil



Figure 2. Forest floor of plot treated with picloram at 27 lb A in Luquillo. Top: Eight months after treatment; bottom: Two years after treatment. Note secondary succession.

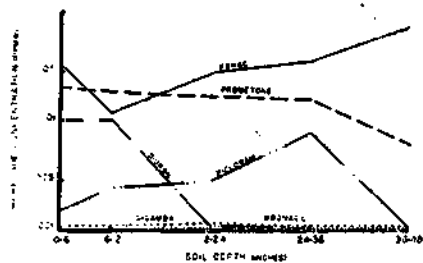


Figure 3. Concentration of six herbicides 1 year after application to Jacinto clay (Guánica sites) at 9 lb A.

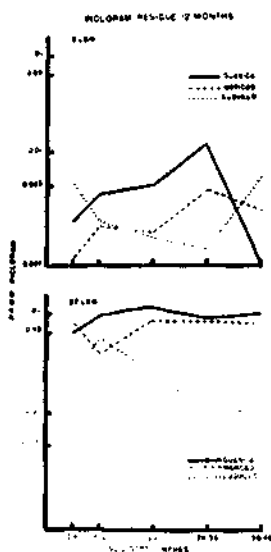


Figure 4. Pictoram residue at various depths in three forest areas of Puerto Rico 12 months after application.

Discussion

Over 200 woody species were represented on the three test sites, but several species were represented by only a few individuals. Tschirley (15) enumerated some of the problems involved in evaluating herbicides in tropical forests. Other workers (2, 9, 11, 16) have shown distinct differential susceptibility of woody plants to various herbicides. Differential species susceptibility also was evident at our test sites. When all the treatments at all locations are considered, *Tabebuia heterophylla* (DC.) Britton, *Cordia borinquensis* Urban, *Inga fujifolia* (L.) Willd., and *Ocotea leucoxyloides* (Sw.) Mez were most resistant and *Psychotria berteriana* DC., *Miconia stenensis* Cogn., *Senegalia westiana* (DC.) Britton & Rose, and *Leucaena leucocephala* (Lam.) DeWit were most susceptible. *Casahuate*, *Drypetes*, *Miconia vitensis* Cogn., and *Miconia mastua* (Sw.) DC. were represented at both Maricao and Luquillo. The reaction of these species to the herbicides followed the same general trend at both locations, but defoliation was greater at Maricao.

The effect of climatic and edaphic factors on herbicidal activity cannot be clearly elucidated in this study because of differences in species composition. At all three test sites, rainfall before application was sufficient to maintain adequate plant growth. Rainfall for 2 months after treatment was 2.41 in at Guanica, 5.16 in at Maricao,

and 5.94 in at Luquillo. Sufficient rain to leach the herbicides into the soil fell at all three locations within a few days after application.

The rapid increase in refoliation shown for dicamba and check plots in the Guanica site is the result of refoliation occurring during the rainy season (Figure 5).

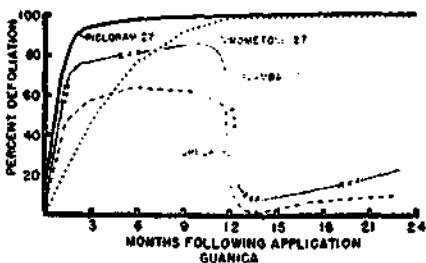


Figure 5. Percentage of woody defoliation in the dry Guanica Forest site of Puerto Rico after treatment with three herbicides applied to the soil.

The rainy season usually occurs during July to October. Most of the woody plants grow vigorously during the rainy season and are deciduous during the long dry season. Refoliation on plots treated with 27 lb A of dicamba attests to its herbicidal ineffectiveness at the Guanica site. The lack of refoliation of woody plants on plots treated with picloram and prometon is indicative of their effectiveness.

In this study, sufficient rainfall occurred after treatment to leach the herbicides into the soil and prevent large losses from volatilization and photodecomposition. The highest concentration of a herbicide in the soil profile was consistently found at the low rainfall Guanica site. On the other hand, the lowest concentrations of herbicides occurred at the continually moist Luquillo site.

Persistence was related to the amount of herbicide applied, but the effectiveness of a herbicide on woody plants was not related to its persistence. Fenac, the most persistent herbicide, was ineffective for defoliating woody plants at all test sites. Prometon was more persistent than was picloram but effectively defoliated plants only at the Guanica site. Picloram effectively defoliated woody plants at all three test sites.

Although a high degree of woody plant defoliation was obtained from several treatments, total vegetation control was short-lived. Secondary succession occurred within 18 months on all defoliated plots at all test sites. Grasses, herbaceous plants, and vines generally were more numerous than were woody tree seedlings.

The amount of rainfall and increased light penetration appeared to influence secondary succession more than did the herbicidal treatment. The number and density of successional species were greatest on the wet Luquillo site and smallest at the dry Guanica site. In general, the number and density of successional species were greater on plots that had been defoliated. This suggested that

increased light penetration was one of the major factors influencing secondary succession. There did not appear to be any relation between herbicidal residue and invading species. For example, several species such as *Psychotria berteriana* DC. were extremely susceptible to initial application of herbicides, but they were found on all treated plots 18 months after application.

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Persistence of 2,4-D, 2,4,5-T, and Dicamba in Range Forage Grasses¹

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Abstract. The herbicides 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2-methoxy-3,6-dichlorobenzoic acid (dicamba) each labeled in the carboxyl position were sprayed on a pasture consisting of a mixture of silver beardgrass (*Andropogon saccharoides* Swartz), little bluestem (*A. scoparius* Michx.), and dallisgrass (*Paspalum dilatatum* Poir.) and a sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.) pasture over a 3-year period. Plant samples were harvested at intervals between 1 hr and 16 weeks after treatment and residues determined by radioassay. No important differences were found in the persistence of herbicides or of different formulations of the same herbicide. Rainfall was the most important factor influencing the persistence of the herbicides. The little bluestem-silver beardgrass-dallisgrass samples harvested 1 hr after treatment with the butoxyethyl ester of 2,4,5-T contained both this ester and the acid of 2,4,5-T. One week after treatment, the acid of 2,4,5-T and unknown metabolites were found but no ester.

INTRODUCTION

A VARIETY of herbaceous and woody plants are controlled by 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2-methoxy-3,6-dichlorobenzoic acid (dicamba). Although the phenoxy acids have been registered and are used for weed control on lands devoted to forage production, the substituted benzoic acids have restricted usage on these areas. Little direct evidence of the persistence of these compounds in forage grasses has been published. Glastonbury *et al.* (3) sprayed peas (*Pisum sativum* L. var. Onward) with the sodium salt of 4-(2-methyl-4-chlorophenoxy)butyric acid (MCPB) and found that the half-life of the retained chemical was 3 days. Gutenmann and Lisk (4) sprayed the diethylamine salt of 4-(2,4-dichlorophenoxy)butyric acid (2,4-DB) on a pasture containing birdsfoot trefoil (*Lotus corniculatus* L.) and timothy (*Phleum pratense* L.) and found a rapid decrease in herbicide concentration in the forage after rainfall. Concentrations of 2,4-DB in the forage immediately after application of 1.5 and 3.0 lb/A rates were about 70 and 160 ppm, respectively, but were 0.32 and 0.80 ppm, respectively, after 48 days.

Klingman *et al.* (5) sprayed a Kentucky bluegrass (*Poa pratensis* L.) pasture with either the butyl ester or the 2-ethylhexyl ester of 2,4-D and found that most of the butyl and about 73% of the 2-ethylhexyl ester were hydrolyzed to the 2,4-D acid within 1/2 hr after spraying. Total concentrations of 2,4-D residues from the butyl and 2-ethylhexyl esters dropped from 58.4 and

48.4 ppm 1/2 hr after treatment to 5.0 and 15.1 ppm, respectively, 7 days after treatment.

The investigation reported herein was conducted to determine the persistence of 2,4-D, 2,4,5-T, and dicamba in range forage grasses, to compare the persistence of amine and acid formulations of 2,4,5-T, and to determine the influence of rate of application on the persistence of 2,4-D and 2,4,5-T.

MATERIALS AND METHODS

Two field sites were fenced for the study. One was at College Station, Texas, in a pasture in which silver beardgrass (*Andropogon saccharoides* Swartz), little bluestem (*A. scoparius* Michx.), and dallisgrass (*Paspalum dilatatum* Poir.) were the dominant species. The other was at Spur, Texas, in a pasture in which sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.) was the dominant species. Different areas were treated at each site each year.

Herbicides labeled in the carboxyl position with carbon-14 were mixed with technical grade herbicides in the proportions necessary to give the specified radioactive levels as well as the specified rate of herbicide per acre. In all experiments, sprays were applied at volumes equivalent to 20 gpa with a compressed air sprayer. Two replications of each treatment were used. In 1962, the plots were 2 by 10 ft and they were 2 by 12 ft in 1963 and 1964.

In 1962, we applied butoxyethyl ester of 2,4,5-T at rates equivalent to 1/2 and 2 lb/A. Sprays were applied June 11 and June 19 at Spur and College Station, respectively, which contained 5 µc of radioactivity per plot. The carrier consisted of 7 parts water and 1 part diesel fuel (v/v).

In 1963, we applied 2,4-D and 2,4,5-T acids to the silver beardgrass-little bluestem-dallisgrass pasture June 14. Each solution contained 50 µc of radioactivity and sufficient herbicide to provide 1/2 or 2 lb/A rate. The carrier was acetone-water (1:1) containing 0.5% (v/v) surfactant³.

In 1964, we applied dimethylamine salt of 2,4-D, dimethylamine salt of dicamba, and triethylamine salt of 2,4,5-T to the silver beardgrass-little bluestem-dallisgrass pasture July 1. We applied both the amine and acid of 2,4,5-T and dicamba to the sideoats grama pasture July 7. The carrier was water containing 0.5% (v/v) surfactant³ for amine salt formulations and acetone-water (1:1 v/v) for the acid of 2,4,5-T. Each solution contained 60 µc of radioactivity and sufficient herbicide to provide a rate of 1 lb/A.

³Surfactant contained alkylarylpolyoxyethylene glycols, free fatty acids and isopropanol.

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In all years, we sampled the treated plots 1 hr (0 week), 1, 2, 4, and 8 weeks after treatment. An additional sampling was obtained on the fourteenth and sixteenth weeks in 1963 and 1964, respectively. We harvested 2-sq-ft subplots from each main plot by clipping the grass plants at ground level. The clipped plants were separated into those tissues produced during the current year, designated green tissues, and those tissues produced during previous seasons, designated litter tissues. Partially decomposed plant tissues were gathered from the soil surface of the subplots and were added to the litter tissues. After separation, the samples were placed in polyethylene bags, sealed with rubber bands, weighed, and stored at -10°C . Samples harvested as Spur were transported to College Station in an ice chest for analysis.

The harvested samples were shredded, and a 20-g portion was homogenized in a blender with 80% ethanol and filtered. The homogenization was repeated until the radioactivity of the residue was less than two times background. The filtrates were combined, reduced in volume under vacuum in a rotary evaporator, and brought to volume in a 25-ml volumetric flask. Duplicate 1-ml samples of each concentrated filtrate were dried in 1-in planchets, weighed, and the radioactivity assayed with a Geiger-Müller tube. Counts were converted to weight of herbicide from standard curves with appropriate corrections for background and self-absorption. The quantity of herbicide recovered on and in the forage was calculated for each subplot and converted to parts per million equivalents of fresh weight.

In 1962 and 1963, identification and characterization of the radioactive compounds in the concentrated ethanolic extracts were made by descending chromatography on Whatman No. 1 filter paper. An isopropanol:ammonium hydroxide:water (10:1:1 v/v/v) developer was used. After development and drying, each chromatogram was scanned with an autoscanner to determine the location of radioactive substance or substances on the chromatogram. Chromatograms of the ester of 2,4,5-T treating solutions contained radioactive butoxyethyl ester of 2,4,5-T and small amounts of acid. Identifications of the butoxyethyl ester of 2,4,5-T, and acids of 2,4,5-T and 2,4-D were made by co-chromatography of the ethanolic extracts and standard solutions of these compounds.

RESULTS AND DISCUSSION

Recovery of herbicides from sprayed plots. The amount of herbicide recovered from grass tissues harvested 1 hr after treatment, calculated as a percentage of the amount applied, varied from 24% (20% green tissue and 8% litter tissue) to 102% (42% green tissue and 60% litter tissue) (Table 1). In all but two plots, greater quantities of the herbicides were recovered from the green tissues than from the litter tissues. Although the silver beardgrass-little bluestem-dallgrass stands were relatively uniform, the plants and litter did not cover all of the plot areas. The low recovery percentages were due to sparse stands and the higher recoveries to dense plant and litter cover.

Experiments in 1962. Figure 1A presents a semilogarithmic graph of the concentrations of the ester of 2,4,5-T in green tissues of silver beardgrass, little bluestem and

Table 1. Percentage of herbicides recovered in green and litter tissues of silver beardgrass, little bluestem, and dallgrass and silvets grass harvested 1 hr after treatment.*

Herbicide	Concentration rate	Silver beardgrass-little bluestem-dallgrass		Silvets grass	
		Green tissue	Litter tissue	Green tissue	Litter tissue
Ester of 2,4,5-T	1962				
	0.5	22	5	33	8
	2.0	24	16	30	10
Acid of 2,4-D	1963				
	0.5	22	17	—	—
	2.0	16	24	—	—
Acid of 2,4,5-T	0.5	46	26	—	—
	2.0	29	8	—	—
Acid of 2,4-D	1964				
	1.0	—	54	—	—
	1.0	—	68	54	24
Acid of 2,4,5-T	1.0	—	—	66	—
Decombs	1.0	54	44	52	22

*Average of two replications.

dallgrass harvested at five dates after treatment. The lines for the two rates are essentially parallel, indicating that the rate of disappearance was not affected by rate of application. Concentrations of the ester of 2,4,5-T residues decreased rapidly during the second week after treatment when 2.18 in of rainfall occurred. The ap-

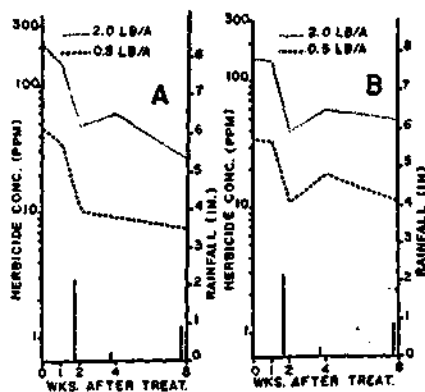


Figure 1. Concentrations of ester 2,4,5-T residues found in silver beardgrass-little bluestem-dallgrass tissues harvested at five dates after treatment June 19, 1962 at 0.5 and 2.0 lb/a at College Station. (A) Green tissues, (B) litter tissues. Solid vertical lines indicate rainfall which occurred during the indicated interval after treatment.

parent half-life of the ester of 2,4,5-T (half-life equals average length of time necessary for one-half of herbicidal residue to disappear) under the conditions of this experiment averaged 2.6 weeks. Concentrations of ester of 2,4,5-T in the green tissues 8 weeks after treatment were 25 and 7 ppm, respectively, at the 2.0 and 0.5 lb/a rates.

Figure 1B is a semilogarithmic plot of the ester of 2,4,5-T concentrations in the litter tissues of silver

beardgrass, little bluestem, and dalliagrass. Disappearance was most rapid during the second week after treatment. The rate of disappearance in litter tissues was slower than in the green tissues. The apparent half-life of ester of 2,4,5-T in the litter tissues was about 4 weeks under the conditions of this experiment. Two factors were important in the slower rate of disappearance. First, growth of the green tissues would have diluted the herbicide, but the litter samples were composed of non-living tissues and growth was not a factor in lowering the concentrations in these samples. Second, conditions for microbial decomposition of the herbicide were unfavorable due to the low rainfall.

Figure 2 presents a semilogarithmic plot of the apparent ester of 2,4,5-T concentrations in the green and litter tissues of sideoats grama. The ester of 2,4,5-T disappeared more rapidly from sideoats grama than from

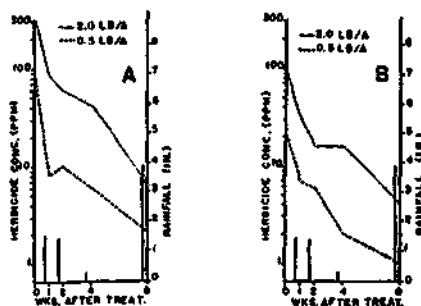


Figure 2. Concentrations of ester of 2,4,5-T residues found in sideoats grama tissues harvested at five dates after treatment June 11, 1962, at 0.5 and 2.0 lb/A at Spur. (A) Green tissues, (B) litter tissues. Solid vertical lines indicate rainfall which occurred during the indicated interval after treatment.

silver beardgrass, little bluestem, and dalliagrass. More rain fell on the sideoats grama than on the silver beardgrass, little bluestem, and dalliagrass. The apparent half-life of the herbicide averaged 1.6 weeks in the green tissues and 1.7 weeks in the litter tissues. The amount and frequency of the rainfall were conducive to leaching, microbial decomposition of the herbicide, and growth of sideoats grama plants. All of these factors contributed to a rapid reduction in herbicide concentrations.

Experiment in 1963. The concentrations of 2,4-D and 2,4,5-T residues found in green and litter tissues of silver beardgrass, little bluestem and dalliagrass harvested at six dates after treatment June 18 are shown in Figure 3. A 0.69-in rain occurred during the first week after treatment, and the concentrations of both herbicides in green and litter tissues decreased rapidly. No rainfall occurred during the second week after treatment and the rate of herbicide disappearance was slower in most of the plots than it was during the first week. During the third and fourth weeks after treatment, 1.58 in of rain occurred and the rate of herbicide disappear-

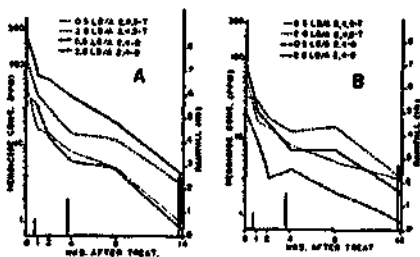


Figure 3. Concentrations of 2,4-D and 2,4,5-T residues found in silver beardgrass-little bluestem-dalliagrass tissues harvested at six dates after treatment June 14, 1963 at 0.5 and 2.0 lb/A at College Station. (A) Green tissues, (B) litter tissues. Solid vertical lines indicate rainfall which occurred during the indicated interval after treatment.

ance was more rapid in most of the plots than during the second week. During the fourth through the eighth weeks after treatment, only 0.08 in of rainfall occurred and relatively small decreases in herbicide concentrations were found. The 2.78 in of rainfall which occurred during the eighth through the fourteenth weeks after treatment probably was the primary factor responsible for the rapid rate of herbicide disappearance during this interval. The average half-life for 2,4-D in green and litter tissues was 2.3 and 2.8 weeks, respectively. The average half-life of 2,4,5-T in green and litter tissues was 2.9 and 3.4 weeks, respectively.

Experiments in 1964. Residues of amine salts of 2,4-D, 2,4,5-T, and dicamba disappeared from silver beardgrass, little bluestem, and dalliagrass tissues at about the same rate (Figure 4). The apparent average half-life for each

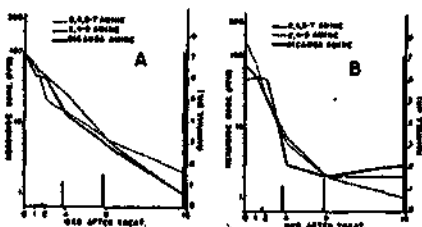
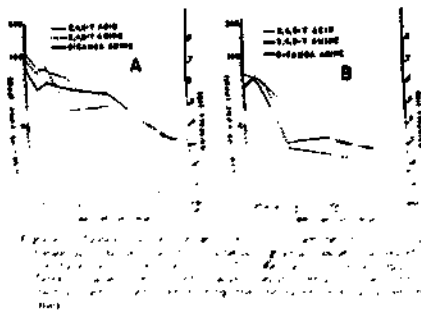


Figure 4. Concentrations of amine of 2,4-D, amine of 2,4,5-T, and dicamba residues found in silver beardgrass-little bluestem-dalliagrass tissues harvested at six dates after treatment July 1, 1964, at 1 lb/A at College Station. (A) Green tissues, (B) litter tissues. Solid vertical lines indicate rainfall which occurred during the indicated interval after treatment.

of the three compounds in green tissues was 2.0 weeks under the conditions which existed during the experiment. Because of heavy rainfall during the fifteenth week after treatment, the concentrations of the three compounds were reduced to 1 or 2 ppm in the green

tissues. Concentrations of the three herbicides decreased rapidly in the litter tissues during the first 8 weeks after treatment (Figure 4B) when frequent rainfall kept the soil and litter tissues moist. The average half-lives of 2,4-D, 2,4,5-T, and dicamba in the litter tissues were 2.8, 2.7, and 2.6 weeks, respectively.

A relatively slow disappearance rate was found for all three herbicides in the green and litter tissues of sideoats grama (Figure 5). This slow disappearance oc-



curring during a period of low rainfall. Although considerable variability occurred in the concentrations of the three herbicides at each sampling date, all herbicides had essentially the same rate of disappearance during the 16-week duration of the experiment. Concentrations of the acid of 2,4,5-T, amine of 2,4,5-T, and dicamba were 6, 5, and 4 ppm, respectively, in the green tissues at the time of final sampling 16 weeks after treatment. The concentrations of the three herbicides in litter tissues of sideoats grama are shown in Figure 5B. The acid of 2,4,5-T disappeared more slowly than the amine of 2,4,5-T and dicamba in litter tissues during weeks 2 to 4, but all three compounds were present after 8 weeks in approximately equal concentrations.

Data indicate that formulation had no significant effect upon the persistence of 2,4,5-T in the tissues of silver beardgrass, little bluestem, dallisgrass, and sideoats grama. While there were minor differences in the rates of disappearance of the three herbicides applied at College Station and Spur, their persistence in forage tissues appears to be essentially the same after several weeks. The most important factor influencing the persistence of these herbicides was rainfall. Both amount and frequency of rainfall were important.

Even when rainfall did not occur, there was a gradual reduction in the herbicide concentrations in the green tissues, particularly if rainfall had occurred prior to the interval when herbicide concentration was being measured. Dilution of the herbicides by plant growth was an important factor during the intervals after rainfall had occurred and soil moisture was adequate for growth of the plants. Important reductions in the concentra-

tions of the herbicides were not found in the litter tissues when no rainfall occurred. This is evident in Figures 1B, 3B, and 5B. The exception to this statement is found in Figure 4B where a reduction in the concentration of the amine of 2,4,5-T from 146 ppm to 78 ppm occurred during the first week after treatment.

It is not surprising that formulations had no influence on the persistence of 2,4,5-T. Phenoxy herbicides deposited on the surfaces of plant leaves as ester formulations are hydrolyzed to the acid in a relatively short period of time (1, 2, 5).

Identification of herbicide residues. Attempts to identify the radioactive components in the ethanolic extracts by paper chromatography were only partly successful. All extracts from silver beardgrass, little bluestem, and dallisgrass green tissues harvested 1 hr after treatment with ester of 2,4,5-T contained the applied herbicide and the acid of 2,4,5-T. The R_f values ranged from 0.69 to 0.78 for the herbicide and 0.78 to 0.87 for the acid. The R_f values for the acid and ester of 2,4,5-T were 0.78 and 0.87, respectively.

Sideoats grama green tissues harvested 1 hr after treatment with ester of 2,4,5-T contained the applied herbicide and the acid of 2,4,5-T. The R_f values ranged from 0.69 to 0.78 for the herbicide and 0.78 to 0.87 for the acid. The R_f values for the acid and ester of 2,4,5-T were 0.78 and 0.87, respectively.

2,4,5-T and 50% to the unknown metabolites. The extracts of green tissues of silver beardgrass, little bluestem, and dallisgrass harvested 1 hr after treatment with acid of 2,4-D or acid of 2,4,5-T yielded only the acids of 2,4-D or 2,4,5-T. Tissues harvested 1 week after treatment contained both the acid and unknown metabolites. The metabolites of 2,4,5-T had R_f values ranging from 0.10 to 0.30, and those of 2,4-D had R_f values ranging from 0.07 to 0.25.

ACKNOWLEDGMENT

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HERBICIDES IN SOILS¹T. J. SHEETS AND L. I. DANIELSON²

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INTRODUCTION

Many herbicides are applied directly to the soil surface as selective pre-emergence sprays and as nonselective soil sterilants. Other chemicals are applied subsurface or are thoroughly mixed with the soil after surface application. Residues remaining on leaves after foliar applications are carried to the soil in rainwater or fall to the soil when injured leaves abscise and fall. Therefore at least part of all herbicidal sprays eventually reach the soil.

Soils vary greatly in composition and reactivity. Many complex and ever-changing processes occur continuously in most soils. Soils are composed of mineral matter, organic matter, water, and air. The mineral fraction varies in amounts of sand, silt, and clay, and in types and amounts of clay minerals. The hydration and base saturation of the clay minerals also vary. The organic-matter fraction consists of decaying plant and animal residues and active soil flora and fauna. The organic and mineral colloids present in the soil contribute directly and indirectly to the extremely active nature of soil systems.

This mixture of mineral and organic matter is permeated by pore spaces of various sizes. These spaces are filled with water and air in a more or less reciprocal relation. The soil water contains many soluble compounds and serves as an essential medium for many physical and chemical processes. The soil atmosphere is composed of oxygen, carbon dioxide, nitrogen, and several minor gases. The composition of the soil atmosphere varies, particularly the oxygen and carbon dioxide contents. The complexity and variation of soil systems make the study of the fate of herbicides therein complicated and time consuming.

METHODS OF ASSAYING HERBICIDE RESIDUES IN SOILS

In most investigations on the persistence of herbicide in soils, researchers determine the presence of the active entity of the herbicide by growing sensitive plants. The influence of time on herbicidal residues has been measured by the growth of successive crops of test plants. This method, which has been used in both field and greenhouse experiments, is qualitative only.

Quantitative bioassays have been developed for some herbicides. Holstun and Loomis (35) measured the elongation of young shoots of germinated millet seeds to determine the concentration of the sodium salt of 2,2-dichloropropionic acid [dalapon] in soils. Burschel and Freed (11) used heights and weights of seedling oats to determine the concentrations of isopropyl N-phenylcarbamate [IPC], isopropyl N-(3-chlorophenyl) carbamate [CIPC], and 3-amino-1,2,4-triazole [amitrole] in soils. Rahn and Baynard (45) used weight of oat seedlings to assay quantitatively 3-(p-chlorophenyl)-1,1-dimethylurea [monuron] in soils. Biological assays developed for solutions and vapors of herbicides could be adapted for use with soils (7, 46, 55).

Some herbicides have been extracted from soils and their concentrations determined by physical or chemical methods. Methods are available for monuron, amitrole, CIPC, and pentachlorophenol [PCP] (10, 11, 30, 62). Whiteside and Alexander (61) followed the breakdown of several chlorinated phenoxy aliphatic acid herbicides in solutions inoculated with soil by the disappearance of the specific ultraviolet absorption.

A physical or chemical assay may be most suitable in one situation and a biological assay in another. Both types of analyses are useful in some cases. Rahn and Baynard (45) reported that the chemical method for the determination of monuron in soils was accurate if the assay was made within a few weeks after application. If soils were chemically assayed more than 1 month after treatment, values for monuron concentration were greater than those obtained by bioassay. Rahn and Baynard (45) suggested that this apparent disagreement could be explained since the chemical assay for monuron was based on p-chloroaniline, a nonphytotoxic, hydrolytic product of monuron.

¹ A contribution from the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Mississippi Agricultural Experiment Station.

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FACTORS ALTERING HERBICIDES IN SOILS

Factors affecting the movement and persistence of herbicides in soils have been reviewed by several workers (1, 8, 25, 26, 32, 41, 43). Leaching, fixation by soil colloids, chemical and microbial decomposition, and volatilization were stressed in one or more of these papers. In this discussion microbial action, volatilization, adsorption, leaching chemical reaction, photodecomposition, and absorption by plants will be considered for their significance in the performance and fate of soil-applied herbicides.

Microbial action.—Most organic herbicides subjected to appropriate tests have been inactivated more rapidly in soil under conditions favoring growth and proliferation of soil microorganisms. Absorption by microorganisms is one of the major pathways by which organic herbicides are detoxified. Perhaps 2-(2,4-dichlorophenoxy) propionic acid [2-(2,4-DP)], 2,4,5-trichlorophenoxyacetic acid [2,4,5-T], 2-(2,4,5-trichlorophenoxy) propionic acid [silvex], and 4-(2,4,5-trichlorophenoxy) butyric acid [4-(2,4,5-TB)] are exceptions (7, 61). Optimum oxygen, moisture, temperature, and nutrients favor microbial activity and also herbicidal detoxication. Numbers of soil microorganisms capable of inactivating 2,4-dichlorophenoxy acid [2,4-D] apparently increase when 2,4-D is present in the soil (8, 42, 43, 61). Thus repeat applications of 2,4-D were less persistent in soil and therefore may be less effective herbicidally than the initial application. With the phenylureas and *s*-triazines such an increase in microbial activity apparently does not occur, because soils appear to exhibit about the same capacity for inactivation for long periods. Therefore it seems that with the phenylureas and the *s*-triazines the action of soil microorganisms utilize them but not selectively or preferentially. Another explanation of this effect is that inactivation of these chemicals is catalyzed by heat-sensitive substances occurring in the soil as products of microbial activity and that the herbicides are not utilized directly by microorganisms as energy sources.

Bacteria, *Bacterium globiforme* and *Flavobacterium aquatile*, which were capable of inactivating 2,4-D were isolated from soil and grown in pure culture (6, 8, 36). Evans and Smith (27) isolated a small, Gram-negative, motile soil organism which grew freely in a mineral-salt medium containing *p*-chlorophenoxyacetic acid as the only organic-carbon source. They separated 2-hydroxy-4-chlorophenoxyacetic acid and 4-chlorocatechol from the culture. The same investigators isolated a Gram-negative, motile rod which grew on a mineral-salt, 2,4-D medium. From this culture they separated a phenolic acid and presented evidence to suggest that the compound was 6-hydroxy-2,4-dichlorophenoxy-acetic acid. They hypothesized that hydroxylation of the ring was followed by ring cleavage.

Whiteside and Alexander (61) presented evidence suggesting that 4-(2,4-dichlorophenoxy)butyric acid [4-(2,4-DB)] was converted to 2,4-D by microorganisms in the soil and that a microflora capable of quickly inactivating both 2,4-D and 4-(2,4-DB) was present in soils which had received 4-(2,4-DB) previously.

Hill, *et al.* (33) reported that a soil bacterium of the *Pseudomonas* group was capable of oxidizing monuron particularly in the presence of yeast extract.

One group of herbicides, the esters of chlorophenoxy alcohols, becomes herbicidally active only on contact with the soil. In warm, moist soil sodium, 2,4-dichlorophenoxyethyl sulfate [sesone] is hydrolyzed to 2,4-dichlorophenoxy-ethanol in the presence of either microorganisms or acids (12, 13). The hydrolysis by microorganisms was attributed to acids secreted during their metabolism. The ethanol product is oxidized in the soil to 2,4-D, the active entity.

In experiments conducted by the senior author, 2-chloro-4,6-bis(diethylamino)-*s*-triazine [chlorazine] mixed in the soil became more toxic to seedling oats with time. This trend reversed after several months, the time depending on the soil type and concentration, and thereafter the herbicidal activity of cultures containing chlorazine decreased with time. The increase in toxicity could not be accounted for completely as a response to growing conditions in the greenhouse. Autoclaving the soil prior to treatment retarded the rate of onset of increased toxicity. If one ethyl group was lost from either or both of the amino substitutions, compounds much more toxic than chlorazine would be formed. Perhaps formation of one of these compounds did occur in the soil.

The rates of inactivation of IPC, CIPC, and aminrole in the soil depended on the initial concentration of the herbicides; and the inactivation of these

herbicides appeared to follow a first-order reaction (11). The rate of disappearance of monuron from soil was proportional to the concentration (33). Hill, *et al.* (33) concluded that although soil moisture and temperature often altered the rates of inactivation of monuron and 3-(3,4-dichlorophenyl)-1,1-dimethylurea [diuron], the first-order equation was probably applicable under usual field conditions. When monuron and diuron were applied at rates of 1 and 2 pounds per acre in more humid regions of the United States, major parts of the herbicides were inactivated each year. Accumulation from applications on the same soil 2 years in succession was negligible. Rahn and Baynard (45) found that monuron applied at 3.6 pounds per acre in two applications for 3 years in succession did not persist from one year to the next. When applied at 6.4 pounds per acre, monuron toxicity persisted from one year to the next, but no accumulation occurred. Research conducted in the arid Southwest during the last 7 years indicated that monuron and diuron did not accumulate significantly from successive annual applications at rates used for selective weed control in cotton. Some carryover often occurred, and the amount of carryover appeared to be related to weather conditions.

Current research indicates that the solvent used in the application of an herbicide may have a profound influence on the persistence of herbicidal activity (13). Ethyl N,N-di-n-propylthiocarbamate [EPTC] was applied in several solvents and incorporated into the soil. At weekly intervals up to 6 weeks after treatment, the soils were assayed by the use of oat plants as indicators of toxicity. When the commercial formulation of EPTC was applied in water, growth of oat plants seeded 6 weeks after treatment were markedly inhibited on flats which received 1 and 2 lb./A. The persistence of technical EPTC applied in acetone was comparable to that of the commercial formulation applied in water. However the rate of inactivation of technical EPTC applied in kerosene was much more rapid than that of the commercial formulation applied in water. Four weeks after treatment the 2 lb./A rate of technical EPTC applied in kerosene did not inhibit growth of oats.

Persistence of several groups of herbicides in the soil is related to halogenation of the benzene ring. This relation was demonstrated for certain chlorinated phenoxyacetic acids, carbamates, and phenylureas (21, 22, 23, 50). The results of Alexander and Aleem (3) indicated that resistance of chlorinated phenoxyalkyl carboxylic acid herbicides or their derivatives to microbial degradation was governed by the position of the halogen rather than by the number of halogens on the ring and that the linkage of aliphatic side chain also influenced susceptibility to microbial breakdown.

Volatilization.—All compounds are volatile to some degree. Volatility of some herbicides is very low and of little significance. However, measurable loss of others occurs from soil surfaces by vaporizations.

The volatilities of formulations of the same basic herbicide structure may be quite different. The isopropyl ester of 2,4-D is more volatile than the octadecyl ester, which in turn is more volatile than the sodium salt (39). Many other esters and salts of 2,4-D exhibit various rates of vaporization.

Vapors of soil-applied herbicides have caused severe injury to treated crop plants in some instances. Vapors of 4,6-dinitro-*o*-sec-butylphenol [DNBP] after preemergence applications caused extensive injury to cotton in the Mississippi Delta in 1952 (25, 26, 34). DNBP injury was associated with high temperatures. Hollingsworth and Ennis (34) found that vapor injury to young cotton plants increased as soil moisture increased.

DNBP injury to cotton was reduced by application of lime and other basic materials to the treated soil surface (9, 19). Upon addition of a base, the phenol-phenate equilibrium was probably shifted to the phenate, which is less volatile than the phenol (9).

Volatilization of the carbamates has been related to their effectiveness as preemergence herbicides. IPC and CIPC volatilized rapidly from tinfoil and glass surfaces at high temperatures (4). IPC volatilized more rapidly than CIPC, particularly at temperatures of 60° to 85° F. The most volatile carbamates were found to be most phytotoxic (38); however, loss by volatility following preemergence application reduced the concentration of the more volatile compounds to nonherbicidal levels more rapidly than the less phytotoxic, less volatile compounds.

Many herbicides are formulated on granular carriers to reduce loss by volatility and leaching after application to the soil surface. The vapor and contact activities of CIPC-impregnated granular carriers were investigated by

Danielson (17). The vapor activity of CIPC was related to the physical structure and adsorptive capacity of the granular carriers. When the physical structure of attapulgite granules was changed by moistening with water, vapor activity increased. Carriers that did not change in physical structure on contact with water exhibited unchanged or reduced vapor activity. Danielson proposed the use of impervious granular carriers to obtain immediate short-term activity of CIPC and more adsorptive carriers for long-term activity.

Adsorption.—The activity of most herbicides varies with soil composition. Since many herbicides are adsorbed by colloidal particles and since the amounts of mineral and organic colloids vary among soils, much of the variation in herbicidal activity is attributed to differences in the adsorptive capacity.

The adsorption of six growth-regulator herbicides by several ion-exchange resins was demonstrated by Weaver (59). Weaver (60) and Smith and Ennis (53) used activated charcoal as a soil amendment to protect germination seeds from 2,4-D applied to the soil surface.

In a greenhouse experiment the initial toxicity of 2,4-D was greater in sandy soils than in most clay soils (16). A butylester of 2,4-D was fixed in a clay-sand mixture more strongly than a triethanolamine salt form (2). Both amine and polypropylene ester formulations of 2,4-D were adsorbed by montmorillonite, illite, and kaolinite clays (32). The adsorption of 2,4-D increased as the cation-exchange capacity and specific surface increased.

CIPC was adsorbed by activated charcoal and certain other materials (17). In laboratory and greenhouse experiments EPTC was adsorbed least by those soils in which it was most phytotoxic (5).

Sherburne and Freed (51) demonstrated adsorption of monuron by activated charcoal, sawdust, straw, and soil. The amount of monuron adsorbed by soils was correlated with organic matter and clay content. Studies by Hill (32) showed that the clay content, type of clay, and organic matter of soils influenced the amount of monuron adsorbed. Adsorption increased as clay content or organic matter increased. Approximately 150 p.p.m. was required on a bentonite clay to give 1 p.p.m. in the soil solution whereas less than 1 p.p.m. was required on a kaolinitic clay to give 1 p.p.m. in solution.

The herbicidal activity of the phenylureas was correlated inversely with soil organic matter, total clay, and cation-exchange capacity (47, 56). Multiple regression analyses suggested that soil organic matter was most important in toxicity reduction of monuron, diuron, 3-phenyl-1, 1,1-dimethylurea [fenuron], and 3-(3,4-dichlorophenyl)-1-methylurea [DMU].

Variations in the effective dosage ranges among several soils suggested greatest adsorption of diuron and DMU and least adsorption of monuron and fenuron (47). Coggins and Crafts (15) showed that clay suspended in solutions of the phenylurea herbicides reduced the toxicity to barley. The toxicity of 1-*n*-butyl-3-(3,4-dichlorophenyl)-1-methylurea [neburon] was altered most, and alteration of toxicities of DMU, diuron, monuron, and fenuron followed. In general, water solubility and adsorption were inversely related. In a recent report Leopold, *et al.* (37) demonstrated an inverse relation between solubility of several chlorinated phenoxyacetic acids and their adsorption on charcoal.

In an aqueous medium 2-chloro-4,6-bis(ethylamino)-*s*-triazine [simazine] was adsorbed to a cation exchanger and to activated charcoal but not to an anion exchanger (48). Soil toxicity tests with the *s*-triazines suggested considerable variation in soil adsorption of these compounds. The effect of soil organic matter, clay content, cation-exchange capacity, and pH on the phytotoxicity of simazine was investigated in detail. Soil organic matter appeared to alter the initial toxicity of simazine in soils most.

In soil systems adsorbed herbicides are probably gradually desorbed as leaching, chemical and biological degradation, and absorption by plants reduce the concentration in the soil solution. However, the adsorption-desorption relations of herbicide molecules in soils and the importance of these phenomena in the movement of herbicides in soils have not been adequately investigated.

Leaching.—The movement of herbicides in soils depends on or is influenced by several factors. Upchurch and Pierce (57, 58) indicated that at least two steps are involved in the movement of an herbicide downward in soil: (a) Entrance of the herbicide into solution and (b) adsorption of the herbicide to soil particles. Entrance into solution could occur from solid particles of the

herbicide or from colloidal particles with adsorbed herbicide molecules. These two processes, solution and adsorption, may be affected by several variables.

The solubilities of herbicides and of salts of herbicides that may form in the soil are important properties affecting leaching (32, 41, 43). Minarik (41) discussed the leachability of 2,4-D and its salts. He pointed out that the calcium, magnesium, potassium, sodium, and ammonium salts of 2,4-D are more soluble in water than the acid, whereas salts of heavy metals such as iron and copper are less soluble than the acid. The equilibrium status of the several forms of 2,4-D in the soil probably affects the leaching rate of 2,4-D. However, Smith and Ennis (53) did not measure a difference in the movement of the acid, the triethanolamine salt, and the sodium salt of 2,4-D in soils. Hill (52) concluded that the lower water solubility of diuron compared to monuron resulted in slower movement of diuron than monuron in soils. Diuron is adsorbed more strongly than monuron and differences in adsorption probably contribute to differential leaching of these two compounds.

An herbicide that is strongly fixed in soils should leach less readily than one that is not so tenaciously fixed (2). The adsorptive capacity of soil is influenced by soil organic matter and the amounts and types of clay minerals. The adsorption process is influenced by temperature and the nature of the solvent. The adsorptive characteristics of a compound are influenced by pH of the solution. Since these factors influence adsorption, they must influence movement of herbicides in soils. The organic matter content and soil texture are known to influence leaching (20, 24, 25, 26, 32, 35, 44, 47, 52, 53, 58).

The leachability of DNBP appeared to be influenced by pH. Dowler, *et al.* (24) concluded that movement of DNBP in soils was as much a function of soil type and soil reaction as of the amount of rainfall. In experiments by Upchurch and Pierce (58) soil temperatures of 50° to 45° C. had little effect on the monuron leached from the upper 2-inch layer of soil columns. However, greater amounts of monuron were retained by the 2- to 8-inch layer at 25°, 35°, and 45° C. than at 5° and 15° C.

That the amount of rainfall or of water applied as irrigation influences the movement of herbicides has been demonstrated by many research workers. Sherburne, *et al.* (52) compared the movement of monuron in soil columns to the movement of compounds in chromatography and concluded that the depth of the highest concentration of the herbicide in soil columns was a function of the amount of water added to the soil surface. Upchurch and Pierce (57) studied the effect of amount, intensity, and frequency of simulated rainfall on the leaching of monuron. The greater the amount of simulated rain the greater the movement of monuron. Rainfall intensities of 1/16 to 4 inches per application had little influence on the amount of monuron retained in the top 2-inch layer. In the 2- to 8-inch zone greater accumulation of monuron occurred with low intensities than with high. A greater movement of monuron from the upper soil layers occurred as frequency of rainfall increased. Approximately half of the frequency effect was attributed to evaporation of water from the surface of soil columns that received less frequent applications. These workers concluded that of the three variables studied, the amount of rainfall would be most directly correlated with the distribution of herbicides in soil profiles under field conditions although they maintained that intensity and frequency might also be of practical importance.

The effect of the amount of monuron applied on the amount moved by simulated rainfall was also investigated by Upchurch and Pierce (58). Monuron was applied to surfaces of soil columns at rates of 0.5, 1, 2, 4, 8, 16, 32, 64, 128, and 256 lb./A, and the applications were followed by 4 inches of simulated rainfall. The lowest percent retention (34 percent) in the 0- to 2-inch layer was found in columns treated with 32 lb./A. Retention by the 2-inch layer was increasingly greater as the rate increased and decreased from 32 lb./A. These workers suggested that the increasing percent retention when the rate of application was increased from 32 to 256 lb./A was attributable to the low solubility of monuron.

Molecular size may also be a factor in the movement of herbicides in soils (15, 44).

The exact pattern of movement of an herbicide in a particular soil would be impossible to predict presently. However, relative rates of movement can be predicted for many herbicides.

Chemical reaction.—The formation of salts of 2,4-D and DNBP and a possible reaction scheme for inactivation of 2,4-D in soils have been discussed.

Relatively little is known of the chemical reactions that most herbicides undergo in soils. Hydrolysis, oxidation, and formation of complexes are known reactions for certain herbicides.

Amitrole forms stable complexes with cobalt, copper, nickel, iron, and magnesium. Sund (54) suggested that complexing with metal ions in the soil solution was one mechanism by which amitrole was detoxified.

The 2-chloroacetamides, for example 2-chloro-N,N-diallylacetamide [CDA], can be hydrolyzed in the soil (31). The chlorine atom and the amide linkage are sites on the molecule where hydrolysis may occur. Regardless of the site where hydrolysis begins, the end products are glycolic acid and secondary amines.

The dithiocarbamates, for example 2-chloroallyl diethyldithiocarbamate [CDEC], can be broken down in the soil by oxidation and hydrolysis (31). If hydrolysis of CDEC precedes oxidation, allyl alcohol is an intermediate; whereas if oxidation precedes hydrolysis, 2-(diethyldithiocarbamyl)acetic acid is an intermediate. The two reactions can occur separately or concurrently in the soil. End products of breakdown are formic acid, glycolic acid, carbon disulfide, and secondary amines for both reaction pathways. The breakdown products may undergo further reaction in the soil.

Freed, *et al.* (29) suggested that EPTC was hydrolyzed in water; and according to the reaction scheme which they proposed, a secondary amine, carbon dioxide, and ethylmercaptan were end products.

Soil treated with 3,5-dimethyltetrahydro-1,3,5,2 *H*-thiadiazine-2-thione [DMTT] evolves formaldehyde, which is thought to be the first product of DMTT breakdown in the soil. (40). Methylaminomethylthiocarbamate forms next and activation continues by forming monoethylamine, methyl isothiocyanate, and hydrogen sulfide. Monoethylamine and hydrogen sulfide react with formaldehyde and form methylaminoethanol, dimethylaminomethane, and 1,3,5-trithiocyclohexane. Eventually this reaction proceeds to carbon dioxide, ammonia, sulfur dioxide, and water. The methyl isothiocyanate and water react to give carbon dioxide, hydrogen sulfide, and methylamine; and the methylamine degrades into carbon dioxide and ammonia.

Monuron is thought to be hydrolyzed slowly in the soil to *p*-chloroaniline (45).

In the presence of moisture tris-(2,4-dichlorophenoxyethyl)phosphite {2,4-DEP} is slowly hydrolyzed step-wise to form one mole of phosphorous acid and three moles of 2,4-dichlorophenoxyethanol (28).

The reactions which herbicides and agricultural pesticides in general undergo in soils and the products formed are important with respect to residues in soils. Weed research scientists should emphasize this phase of herbicide research.

Photodecomposition.—Less is known about the direct effect of light on the breakdown of herbicides than other factors suspected of being involved. However, photodecomposition of monuron was demonstrated by Hill, *et al.* (33). When a solution containing 89.3 p.p.m. of monuron sealed in quartz tubes was exposed for 48 days to sunlight, an 83-percent loss of monuron occurred. Hill, *et al.* (33) concluded that in dry areas of the Western United States monuron may be inactivated by ultraviolet irradiation. They suggested that this factor would account for disappearance of only a small part of the herbicide in humid regions where frequent rains move it into soils.

Neburon, diuron, monuron, fenuron, and DMU were applied as alcohol solutions to filter paper (14). After the paper dried, it was exposed to ultraviolet light for several hours. The herbicides were not visible prior to exposure, but in white light they were readily visible after exposure as light tan spots. The compounds were apparently changed during exposure.

The effects of shade, moisture, and position in the soil on the residual activity of monuron, diuron, and simazine were investigated in cooperation with the California Agricultural Experiment Station. The activity of monuron and diuron disappeared more rapidly from soil exposed to the sun from shaded soil. The activity of monuron and simazine disappeared more rapidly from moist soil than from dry soil. Monuron, diuron, and simazine were not affected to the same degree by these variables. Soil temperature was measured but not controlled in this experiment, and soil temperatures varied considerably among the treatments during the day. Temperature markedly influences vapor pressure and chemical reactions. Therefore the difference in the rate of disappearance in shaded soil and soil exposed to the sun cannot be attributed unquestionably to light inactivation.

Absorption by plants.—Herbicides are absorbed by plant roots and are usually translocated to the aerial parts. Within the plant the herbicide molecules are subjected to various physical and chemical processes. Crop plants may be removed from the land or they may be returned to the soil along with weed growth. Most plant roots remain in the soil. Therefore a portion of herbicides absorbed by plants and the metabolic products of herbicides in plant tissues may eventually be returned to the soil.

It has been stressed previously that soils reduce the initial effectiveness of herbicides and that the degree of effect varied among soil types and herbicides. Unpublished data showed that at least four times as much simazine was required in a clay loam soil as in solution culture to produce the same weight reductions of seedling oats. In another experiment the dry-weight increase of oat tops following simazine treatment through the roots was reduced 50 percent by 7.2 mg. of the herbicide (C^{14} expressed as simazine) per gram of dry tissue at harvest 9 days after initial exposure (49). The amount of simazine (C^{14} expressed as simazine) required in seedling oat plants to reduce plant weight was less than 2 percent of that present in 400 ml. of the 0.05 p.p.m. by weight culture solution initially. Although the conditions of this experiment were markedly different from those which occur in the field, plants probably absorb only a small fraction of the total amount of an herbicide applied to the soil.

CONCLUSIONS

Although considerable progress has been made, much additional information is needed on the fate of herbicides in soil. Weed research scientists need to know more about the persistence of herbicides in soils under varying environmental conditions so that they can establish safe rotational practices. Mammalian toxicity of some soil degradation products should be determined, because these products can also be absorbed by plants. Information on adsorption-desorption relationships; on the interrelationships of adsorption, volatility, solubility, and leaching of herbicides; on the nature and extent of microbial and chemical inactivation; on the importance of photodecomposition; and on the influence of various environmental factors on these processes is essential to an understanding of the behavior of herbicides in soils.

Weed scientists should determine the component or components of the soil from which dosage requirements of soil-applied herbicides can be predicted. Some of this information is available (48, 56), but more is necessary. Eventually specific recommendations of rates, times, and methods of application of herbicides may be based on weather forecasts and analyses of soil samples from farmers' fields (25).

One of the most urgent needs for research on the fate of herbicides in soils is methods of isolation and identification of herbicides and breakdown products. Biological and chemical assays must be improved and new ones derived. Radioactive isotopes have been used very little to study the decomposition of soil-applied herbicides. Soil samples could be treated with different lots of an herbicide with each lot tagged with C^{14} at different positions in the molecule. By known analytical techniques the unchanged herbicide and many reaction products could be separated and identified. Radioisotopes should be most useful tools in future research of this nature.

As new herbicides are developed, their behavior in soils in response to variable soil characteristics, weather conditions, and cultural practices must be investigated concurrently with some of the more fundamental aspects prior to recommendations for use by farmers.

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Senator HART. Do you have any comparable information about dioxin?

Dr. BAYLEY. The answer at this point is no.

Senator HART. Are any tests being run?

Dr. BAYLEY. Not yet. One of the problems we had here is developing the methodology for testing these in products. As soon as this is settled, we will be able to expand our efforts and find this information.

Senator HART. And you hope you will find that it has not been building up in our bodies every day?

Dr. BAYLEY. We sincerely do yes, sir. But that will not bias our results, I assure you.

Senator HART. Perhaps Dr. Byerly might help us with this. I am told by my notes here that dioxins are chlorinated hydrocarbons and that these tend to be stable, and more significantly, in view of the fact that other dioxins are known to be absorbed and retained in the tissue of animals, isn't it likely that there is a build-up in the human of the dioxins found in 2,4,5?

Dr. BYERLY. I will give you an opinion first. You stated since they are chlorinated hydrocarbons, they therefore would be persistent. This does not necessarily follow. There is a very wide range from almost complete persistence, if you like, long-time persistence, to a very short-time persistence on the part of some other chlorinated hydrocarbons.

With respect to these which are in the family of chlorinated hydrocarbons, of which 2,4,5-T is a member, the time of disappearance substantiated by empirical evidence, it is a matter of a few months. With respect to the dioxins themselves, Dr. Bayley answered you quite frankly, we do not have the information. We will seek it when the methods are complete.

Senator HART. In your report you state that you agree that more rigorous tests on teratogenicity should be imposed before registration. If you favor such test as a requirement for registration, isn't there an inconsistency in allowing 2,4,5-T, which is a pesticide with suspected teratogenicity to be allowed to continue in a registered status pending the outcome of the tests? In other words, should you not deregister it now and then if the tests prove negative, register it?

Dr. BAYLEY. The basis on which we would take such action would have to be on the consideration that we believe a hazard now exists. Based on the information which has been provided to us from the Department of Health, Education, and Welfare, and on our own analyses of the levels of the contaminant we do not believe such a hazard exists at this time.

Senator HARR. You cite the content of four lots of 3,4,5-T in terms of the content of, as you put it, TCDD. How many more producers of that product are there?

Dr. BYERLY. There are only three primary producers, sir. There are many formulators.

Senator HARR. Is a formulator engaged in a process which changes the generic business?

Dr. BYERLY. No.

Senator HARR. Almost the total of production is from three sources, right?

Dr. BYERLY. Primary production. I understand the check has been made and the importation is very small.

Senator HARR. After you have registered the product, how frequently do you check up on the amounts of dioxins in the products that are being produced?

Dr. BAYLEY. Mr. Chairman, one of the requests which we are making of the Congress this year is to strengthen our law so that we can have plant inspection and insist on quality control within these particular plants. We have asked the Congress to help strengthen our activity in this area. It is not adequate at the present time. We very definitely need legislation to improve it.

Senator HARR. Is that sort of a way to say that you do not check the dioxins?

Dr. BAYLEY. This is the first time. One of the reasons, of course, is that the methodology has only been newly developed. The results presented here were developed through check procedures with our laboratories, the Food and Drug Administration, and the industry group to see that our methodology was technically correct. So we are just getting started.

Senator HARR. You will include in your budget request moneys to provide what?

Dr. BAYLEY. The President's budget includes an increase of approximately \$2.4 million for the pesticide regulatory division. This is between 50- and 100-percent increase in the funding for that organization.

Senator HARR. Do you believe that with that sum you would be in a position to have plant inspections on a regular basis? Would you be able to have an enforcement staff which would be able to move in the event a violation was discovered? Is this the sort of thing that you visualize?

Dr. BAYLEY. Yes. We based that estimate in our budget request on what we currently thought was necessary to do this.

Now, we all recognize that the problems of concern about chemicals are expanding, and I would not want to suggest that is the final request that we would make in order to improve our operations. We put those in believing they currently were adequate from the standpoint of the enforcement and registration procedures.

Senator HARR. Is the table which shows the amount of dioxin of this particular type—is there a test and do you have facility and personnel to attempt to identify the existence of any of the other seven possible dioxins?

Dr. BYERLY. This, sir, is in the process of development in cooperation with the Department of Health, Education, and Welfare and

industry. These methods are in the process of development. For some of them the methods are quite adequate; for others, the methods have to be developed.

Senator HART. For some you feel you can?

Dr. BYERLY. Yes, sir.

Senator HART. In that case you do.

Dr. BYERLY. We will.

Senator HART. Hinged on the money problem?

Dr. BYERLY. No, it depends primarily on the development of the competence of personnel. This is the thing that has to grow. We have to have a cadre of people who are highly competent. These are most sensitive methods and we cannot just create people who can handle them overnight.

Senator HART. In the testimony of the first two witnesses, and I do not recall whether it was that of Mr. Wellford or Mr. Turner, it is my impression there was a reference to a chick embryo study. Do you recall the comment they made?

Dr. BYERLY. Mr. Chairman, I do not recall the specific comment. There is a chick embryo test. It is highly sensitive. I would point out that it has, as a screening test, possibilities. Again, its sensitivity would make me want to suggest that we be very careful with respect into whose hands the tests were put.

With respect to the teratogenicity, with respect to the chick embryo, the application in this test is hardly like the application either to the skin or in the food of a mammal. So a direct comparison of the effects in the chick embryo with rats and mice, the traditional ones, would require a great deal of review.

Dr. BAYLEY. It would really require a correlated study to ascertain the relationship.

Dr. BYERLY. It would indeed.

Senator HART. I think just from what we have heard this morning, everyone on this subcommittee will be eager to assist you in obtaining the additional moneys, whether it is 2.4 million or more to insure the development just as rapidly as possible of the technical data on which to base tests and the human hands to administer them.

Let me get into this burden of proof again—we sort of dismissed it—very briefly.

The basic conclusion of your testimony is you have not found that registered uses of 2,4,5-T without a finite tolerance on food crops constitutes a hazard requiring cancellation or suspension of such registered use.

Dr. BAYLEY. That is correct.

Senator HART. And yet this morning we have heard testimony that preliminary tests suggest that 2,4,5-T when contaminated by dioxin comparable to that found in currently produced 2,4,5-T is teratogenic in three species; that the MRAK Commission or a panel advisory to it said that the teratogenic effects in one or more such species should be grounds for immediate restriction of pesticide use; that residues of 2,4,5-T are now found on approximately one out of every 200 food samples analyzed by FDA; that we can't be sure of the amounts of tetradoxin in 2,4,5-T now being sold, nor do we

have as yet clear ideas on the amount of other dioxins in the pesticide, some of which may be more potent than tetra; that no evidence suggests that these dioxins are not persistent or cumulative in human tissue, and that some evidence which would indicate perhaps they are.

If you accept that as a premise, in view of all of this, would you say that you are sure that registration of 2,4,5-T for use directly on food crops does not constitute a hazard to man?

Dr. BAYLEY. I would say that the information we have does not give us indication that it is a hazard to man in accordance with the registered uses.

I think we have to recognize that—and I am sure the committee and we are in agreement—these are all economic poisons, and the purpose of registration is to provide for their use in such a way that they are not a hazard. That is the basis on which we make our judgment.

Senator HART. Your position is that they do not constitute a hazard?

Dr. BAYLEY. Yes, sir. And our position is based not only on our own data but that provided to us from the medical authorities of the Department of Health, Education, and Welfare, and to add, 20 years of safe use.

Senator HART. The first two witnesses described the difficulty of finding the brand name on a deformed infant.

There are lots of birth defects. How can anyone say over 20 years that this has not been a factor in some of these private tragedies.

Dr. BAYLEY. I do not in any way want to be facetious, but I think we have to recognize that one of the compounds closely related to this contaminant is lysol, a rather common household disinfectant, and I hear no suggestion that we take this off the market. We in the Department of Agriculture recognize that there is a large group of chlorophenols that we are going to have to examine to find out whether there is a real hazard or not. I am not here to raise a scare, but I think we recognize that in dealing with these compounds we must have evidence that they are a hazard or we will be dealing with emotional conjecture based on inference from various scattered data.

Senator HART. To make clear what is meant, what is your position with respect to lysol?

Dr. BAYLEY. We have no reason to take action at this time.

Senator HART. Do you have in process studies or evaluations to see whether you modify that?

Dr. BAYLEY. Within our capability, for example, we have already moved out to ascertain the dioxin content of 17 other pesticides in this area, and we recognize that this is a field in which we want to make intensive study.

I do not single out this particular product as one which I would consider as more hazardous than any of the rest, but merely as an example of the total problem that we have in meeting these pesticide issues.

It seems to me that from the standpoint of protecting the public health, the important thing for us to do is to take those which, based

on scientific data appear to have the greatest potential hazard and put our resources on evaluating these as we go ahead.

This is true of the mercurials. We are looking very closely at all of these compounds. I think we must recognize that we are going to have to do this on a priority basis as we go. We are giving attention to 2,4,5-T, but we need to have the appropriate facts as we proceed.

Mr. BICKWIT. I think what has come out here is that really it all boils down to a question of burden of proof.

While you say there is no evidence that 2,4,5-T is hazardous, I would have to dispute that. Assuming that you are right, that there is no evidence that it is hazardous, and yet it cannot be shown that it is not hazardous; on what do you base your inaction?

Dr. BAYLEY. Let's recognize first of all that these are economic poisons. We should all agree to that to start with. And when I use the word "hazardous" I use it in terms of sufficiently hazardous to take action. This is bound to be a judgment based on scientific—including medical scientific data. If there is a disagreement between us, then it is in this judgment, not in anything else.

Mr. BICKWIT. I recognize my inability to make adequate scientific judgments and, as a result, defer to those who I regard are capable of making such judgments.

The panel which reported to the Mark Commission has recommended whenever teratogenic effects of a given pesticide are shown in one or more mammalian species, that immediate steps should be taken to restrict the use of that pesticide.

Are you rejecting that advice?

Dr. BAYLEY. No. The use of this pesticide is already restricted because of the registered uses.

Mr. BICKWIT. I suspect that the thrust of their statement would require that it be further restricted but perhaps we would have some difficulty pursuing what the exact intention of their statement was.

You say that you must believe that a hazard exists before you can take a pesticide off the market and that in the case of 2,4,5-T you do not believe that a hazard exists.

Dr. BAYLEY. We do not believe that a hazard exists which would authorize us to take it off the market, yes.

Mr. BICKWIT. Are you sure that a hazard does not exist?

Dr. BAYLEY. One can never be absolutely sure that a hazard does not exist, even if we are talking about table salt.

In fact, we know that table salt is hazardous if taken improperly, and we don't even register it.

Mr. BICKWIT. There is a distinction from table salt in this case, and that is that there has been evidence that suggests, and to my mind rather strongly suggests, that there is a hazard here.

Dr. BAYLEY. I do not see the difference that you are trying to point out.

Mr. BICKWIT. You do not think that the studies that have been done by FDA, by NIEHS, although preliminary, establish that there is any greater hazard than the hazard of table salt?

Dr. BAYLEY. No; I did not say that.

Mr. BICKWIT. I misunderstood you.

Dr. BAYLEY. I did not say that. But again I come back to the point that we are dealing with economic poisons. There are hazards

in the use of all of them. The decision that has to be made is are the hazards sufficiently great to take action at this particular time. That is the difference.

Mr. BICKWIT. You do say issues involving human health should have priority over all other issues.

Dr. BAYLEY. Yes, sir.

Mr. BICKWIT. What I am not clear on is whether you have to actively believe there is a hazard before you take a pesticide off the market.

Is that a legal requirement?

Dr. BAYLEY. I don't know what you mean by actively believe.

Mr. BICKWIT. I conceive of relative states of mind as being belief, state of suspension, and state of disbelief.

Do you think you have to be on the belief side of state of suspension in order to take a pesticide off the market?

If you are in a state of suspension, would that authorize you legally to take it off the market?

Dr. BAYLEY. The information provided to us has not shown that there is sufficient hazard for us to take action, and the information provided to us from the Department of Health, Education, and Welfare is the information primarily that we have used.

Mr. BICKWIT. And you do not feel that if you are not sure one way or the other that that would authorize you to take it off the market?

Dr. BAYLEY. The data that we have at this time are not adequate to show us that there is a hazard, and the data to the contrary are sufficiently adequate to suggest that there is no hazard as 2,4,5-T is presently registered.

Mr. BICKWIT. I guess what it all does boil down to are two differences between us: one, in evaluation of the evidence—

Dr. BAYLEY. Yes, sir; and these types of judgments are inherent to the decisions being made.

Mr. BICKWIT. (continuing). And, two, differences in feelings about burden of proof?

Dr. BAYLEY. And we believe that the relationships between the departments have been fully utilized in working out this type of a basis of position.

Mr. BICKWIT. At least we have emphasized what the differences are.

Senator Baker earlier asked whether any studies have been run to weigh the benefits of poisons as against the detriments.

Have any actually been run?

Dr. BAYLEY. Are you talking about specific compounds or about all of them?

Mr. BICKWIT. All of them.

Dr. BAYLEY. Are there any data on it, Dr. Byerly?

Dr. BYERLY. There is one study done by Velmar Davis.

Whether it would be suspended without the suspension of other phenoxy herbicides or whether only it would be suspended makes a substantial difference.

If all of them were suspended, it might amount to more than \$100 million of added cost. If other phenoxy's remained available to us, it would only be a fraction of that amount.

Let me emphasize that this kind of study is very treacherous in drawing any conclusion at all, because if you make a substantial difference in the amount produced or the quality produced, that which remains may sell at a higher price, and this again brings in a matter of value judgments.

What we can say, I think, with respect to all herbicides and all pesticides in general, is that if we had to do without them and had available the hoes and the people to do the hoeing and the other things to produce our same crop, you would add a cost of production of more than \$2 billion a year.

Let me emphasize, however, that our primary concern is not the economic cost in the aggregate.

Important as this may be, our primary concern, as Mr. Bayley has said, is that we shall control pests and we shall do it safely and without hazard to human health or the public welfare.

Mr. BICKWIT. We have emphasized that we have some differences in evaluation of the evidence. I am trying to discern what evidence would convince you that this pesticide was in fact hazardous.

The one thing that you have said about what would convince you is that you specify that should the teratogenic nature of 2,4,5-T be confirmed, registration for use on food crops will be canceled.

My understanding, correct me if I am wrong, is that the four studies cited earlier; although all preliminary, demonstrate that 2,4,5-T is teratogenic.

Dr. BYERLY. We do not accept that statement.

Mr. BICKWIT. In what way do you not accept it?

Dr. BYERLY. I think the statement that Dr. Bayley read is correct, that all of the evidence known to me is compatible with the hypothesis that these results were due to contaminant dioxin or the interaction of that dioxin and 2,4,5-T.

Mr. BICKWIT. The evidence which I have read shows that 2,4,5-T when contaminated with dioxin in amounts similar to or less than those in currently produced 2,4,5-T does produce teratogenic effects.

Now, I am on the basis of that evidence, unwilling to say it is because of the dioxin or the 2,4,5-T or the relationship between the two. Are you?

Dr. BYERLY. I believe that our previous dialogue indicated that these are preliminary results, so preliminary, sir, that I have not seen the published figures nor have I seen all of the figures to which you allude in the record.

Mr. BICKWIT. I agree they are preliminary. What I am asking you is if they are confirmed, will you deregister 2,4,5-T for use on food products?

Dr. BYERLY. This depends upon the dosage at which they are effective.

Mr. BICKWIT. You will have to modify your statement then.

Dr. BYERLY. In what way?

Mr. BICKWIT. Well, you have said that should the teratogenic nature of 2,4,5-T be confirmed, you would deregister the pesticide.

Dr. BYERLY. I do not modify the statement. I said if 2,4,5-T.

Mr. BICKWIT. What does it matter whether pure 2,4,5-T is teratogenic if there is no such product as pure 2,4,5-T on the market? I

assumed that by your reference to "2,4,5-T," you meant pure 2,4,5-T as currently produced on the market.

Dr. BAYLEY. I think you ought to recognize that he was answering your question precisely.

Dr. BYERLY. I believe good manufacturing practice can restrict the amount of contaminant dioxin in the product. I believe it should be done; I believe it is now being done and that it will be done.

Mr. BICKWIT. Then, I take it that your statement was not in reference to the teratogenic nature of 2,4,5-T when contaminated with any dioxin whatsoever?

Dr. BAYLEY. No.

Mr. BICKWIT. Have we ever produced 2,4,5-T without any dioxin whatsoever?

Dr. BYERLY. This is not a statement that can be answered absolutely, but it can be answered within the limits of the method in Dr. Bayley's statement. It indicates there was one in which there was no detectable amount of dioxin.

Mr. BICKWIT. Would you be willing to say that if the teratogenic nature of 2,4,5-T with the amount of dioxin that is contained in currently produced 2,4,5-T is found to be teratogenic that you would deregister it for food use?

Dr. BYERLY. I would be willing to say, sir, if the 2,4,5-T with no detectable amount of dioxin, of tetrachlorodibenzo paradiioxin, would prove to be teratogenic, I would recommend to the Department that actions to cancel uses on food crops be taken.

Mr. BICKWIT. Yet, what is really relevant here is the effect of currently produced 2,4,5-T. Why then are you basing your decision on the effects of 2,4,5-T in a form that we do not know it commercially?

Dr. BYERLY. I think you are misconstruing my reply. Again, pending the fact that neither you nor I have before us published figures which would sustain your statement that all four of these things do in fact show teratogenic effects, if we accept what you say may be true, but it has not been published nor publicly disclosed, then let me say further that so far as I know, the dosage at the current level of 150 milligrams per kilo is equivalent to the amount of the dioxin therein contained at one part per million which would be expected to give a teratogenic effect if there were no 2,4,5-T present, and 150 milligrams per kilo is astronomically higher than any amount to which any person would normally be exposed in the normal course of usage.

Mr. BICKWIT. How long is the usage to which you refer?

Dr. BYERLY. I did not make a limit.

Mr. BICKWIT. In one's lifetime?

Dr. BYERLY. In a lifetime.

Mr. BICKWIT. You are willing to say this is more dioxin than one is likely to be exposed to in his entire lifetime?

Dr. BYERLY. That is my opinion.

Mr. BICKWIT. You will have to admit it is not based on much.

Dr. BYERLY. You are forcing me into the realm of conjecture and I do not choose to go into that very far. We do not have the empirical evidence on which to state whether or not it is degradable. We have no evidence, sir, that it is not degradable.

Mr. BICKWIT. Here we are again; we do not know whether it is or is not.

Dr. BYERLY. We intend to find out.

Dr. BAYLEY. Mr. Chairman, this dialogue is the same type of dialogue that we have with industry people who come in and want to know exactly what evidence we have to have in order to assure them that they have provided us with sufficient proof. These judgments are not so simple that you can conjecture ahead of time of seeing the data exactly what position you are going to take. It is characteristic of them: it is inherent to them. And I suggest this is characteristic not only when we are dealing with industry but when we are also concerned about the public health.

Senator HART. Gentlemen, did you have anything you would like to add?

Dr. BAYLEY. We do not, sir. We would be glad to enclose the additional statements for the record that we have discussed.

Senator HART. Thank you very much.

I had hoped we could continue through the lunch hour, but I am stuck with a Policy Committee lunch.

(The statement follows:)

STATEMENT BY NED D. BAYLEY, DIRECTOR OF SCIENCE AND EDUCATION,
U. S. DEPARTMENT OF AGRICULTURE

MR. CHAIRMAN: I am Ned Bayley, Director of Science and Education, Office of the Secretary, USDA. I have with me T. C. Byerly, Assistant Director of Science and Education.

We are pleased to be here to comment on the current state of knowledge with respect to the herbicide 2,4,5-T. We will be glad to respond to questions relevant to its usage as fully as information available to us enables us to do so.

The herbicide 2,4,5-T has been recognized as the most effective herbicide registered for use for control of certain weeds and brush species for more than 20 years. About four-fifths of the domestic use of 2,4,5-T is for nonfarm use, the largest such use being for control of brush on rights-of-way. It is also used extensively to control brush on forest lands and certain weeds in turf. 2,4,5-T has been used in the production of fruit crops, cereal grains, and sugarcane. It is the most effective herbicide for control of brush on several million acres of rangeland in the Southwestern United States.

2,4,5-T is degraded in the environment within a few months after application so that residues do not persist from one season to the next. Residues on foods are unusual. Among 5300 food samples analyzed by FDA for 2,4,6-T during the past four years, 25 were reported to contain trace amounts; i.e., amounts less than the 0.1 ppm limit of accuracy of present analytical procedures for foods. Two samples showed residues of 0.19 ppm and 0.29 ppm, respectively.

No finite tolerance has been established for 2,4,5-T in food. In the absence of such tolerances, any detectable amount of 2,4,5-T in food would make such food subject to seizure if found in the channels of interstate commerce. From the data cited above, it is apparent that contamination of food with 2,4,5-T is very infrequent and then only at very low levels.

There is current concern over the continued use of 2,4,5-T arising from the report of a research study completed under contract by the National Cancer Institute by Bionetics Inc. This study was based on a commercial lot of 2,4,5-T acquired for the study in 1963. It was fed to pregnant mice and rats. Many of the developing young had birth defects.

A review of the data from this study was conducted by the National Cancer Institute in 1968. The Agency's findings were published in a report, "Studies on 2,4,5-T," announced on October 29, 1969, a consolidated series of notices being taken by these agencies with respect to the use of 2,4,5-T.

Among them was the announcement that "The Department of Agriculture will cancel registrations of 2,4,5-T for use on food crops effective January 1,

1970, unless by that time the Food and Drug Administration has found a basis for establishing a safe legal tolerance in and on foods."

USDA was informed in January that the lot of 2,4,5-T used in the Bionetics study contained significant amounts of a highly toxic contaminant, tetrachloro-dibenzo paradioxin. The Department was further informed that lots of 2,4,5-T of current and recent manufacture were reported to contain less than 1 ppm of this contaminant in contrast to the 27 ppm reported for the lot used in the Bionetics study.

Extensive studies are under way to determine whether 2,4,5-T is itself teratogenic. Preliminary reports are consistent with the hypothesis that the teratogenic results reported in the Bionetics study were due to the contaminant dioxins or to interactions of such contaminants with the 2,4,5-T rather than to 2,4,5-T per se.

The Department announced on February 6 that it would undertake examination of 2,4,5-T and 17 related compounds registered for pesticidal use to determine whether or not they are contaminated with dioxins. Preliminary results on 2,4,5-T show that those lots examined of current manufacture and those now in channels of trade gave the following results:

TABLE 1.—AMOUNTS OF TCDD FOUND IN COMMERCIAL 2,4,5-T BY TWO METHODS

Sample	Manufacturer	Lot	Grade ¹	Collected	TCDD Content p.p.m. ²	
					USDA	FDA
2,4,5-T	Dow	120110	TG	2/70	trace	0.07
2,4,5-T	Monsanto	07-020	TG	2/70	1.1	2.9
2,4,5-T	Hercules	X-17394-21-5	TG	2/70	N.D. ³	N.D.
2,4,5-T ⁴	Dow	MM-120449	TG	2/70	.48	.47-.52

¹ TG—Technical grade.

² TCDD Refers to the 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD).

³ N.D.—Levels of TCDD are below the limits of detection or below 0.05 p.p.m.

⁴ Sample supplied by Dow as a reference check and reported to contain about 0.5 p.p.m. TCDD.

These data are preliminary and are obtained from first drafts of methods developed by chemists in the Crops Research Division (USDA) and in the Pesticide Chemistry and Toxicology Division (FDA). The dioxin values refer only to the 2,3,7,8-tetrachloro-dibenzo-p-dioxins (TCDD) and do not indicate levels of other halogenated dioxins (containing 5, 6, 7, or 8 chlorines) in the 2,4,5-T samples.

In view of all the information now available, we have not found that registered use of 2,4,5-T without a finite tolerance on food crops constitutes a hazard requiring cancellation or suspension of such registered uses.

There has been and is concern over the ecological effects of 2,4,5-T used as a defoliant in Viet Nam. Dr. Fred Tschirley, Assistant Chief of our Crops Protection Research Branch, has reported the results of his examination of areas treated in Viet Nam. He has reported no evidence of irreversible ecological damage. Allegations that defoliation will lead to extensive laterization of Vietnamese soils, that Mangrove areas will not recover, that fish production in wetland areas will be reduced were not verified.

Dr. Tschirley also headed a team of scientists who investigated allegations of injury to humans and animals due to herbicide treatment for control of Chapparal by the Forest Service on the Tonto National Forest near Globe, Arizona. They found that apparent damage consisted of damage to susceptible plants near the treated area from drift of the herbicides used. The alleged injuries to a duck and a goat were found to be groundless. Human illnesses were those expected in a normal population with the possible exception of one man with skin irritation on his eyelids. Clinical chemistry on specimens obtained during the investigation is in process.

Senator HARR: I think in fairness to all we should recess to resume

(Whereupon, at 2:15 p.m., the subcommittee was recessed, to reconvene at 2:15 p.m., this same day.)