"spacers" for orienting the compound in some biological system. A few experiments were carried out using the American cockroach, *Periplaneta americana* (L.), as a test animal and applying measured dosages of the thienyl compound exteriorly and by intra-abdominal injection. Tobias, *et al.* (*3*) determined the LD_{50} of DDT applied to *P. americana* in acetone as 10 μg/gm in 120 hrs. For DDT injected intra-abdominally the figure was 5–8 μg/gm. Using identical technics and amounts of acetone per insect, we obtained no response in 120 hrs from the application of 125 μg/gm of 2,2-*bis*-(2-chlorothienyl)-1,1,1-trichloroethane on the dorsum of the thorax near the point of attachment of the wings, nor from the intra-abdominal injection of 125 μg/gm of the compound between the third and fourth abdominal sternites. Thus, DDT is much more effective to this insect both by contact and by injection than is its thienyl-isoster, and the failure of the latter to produce symptoms at equivalent dosage cannot be due to poor penetration into the insect.

TABLE 2

COMPARATIVE EFFECTIVENESS OF DDT, CHLORDAN, AND γ-HEXACHLOROCYCLOHEXANE TO GERMAN COCKROACH AND RED HARVESTER ANT

Insect	Toxicant as residue (μg/cm²)	Per cent mortality in 120 hrs		
		DDT	γ-Hexachlorocyclohexane (m.p., 112° C)	Chlordan (b.p., 175°/2 mm)
B. germanica	1,300	50	...	...
	13	0	100	100
	1.3	..	90	70
	0.13	..	10	10
		Per cent mortality in 48 hrs		
P. barbatus	500	0		
	13	..	90	65
	1.3	..	45	30
	0.13	..	10	15

Yeager and Munson (*5*) studied the site of action of DDT in *P. americana* and found evidence that DDT acted at a site common to the insect leg and body, viz., the myoneural junctions of nerve fibers. A significant portion of their evidence was the action of DDT in causing tremors and convulsions when applied to severed insect legs. The application of the thienyl-isoster to the severed legs of *P. americana* at a dose of 100 μg/leg resulted in unmistakable DDT-like, repeated, and spasmodic contractions of three-fourths of the legs treated. The duration and intensity of the movement was, however, much less than that produced by similar applications of DDT at 10 μg/leg. This appears to demonstrate that 2,2-*bis*-(2-chlorothienyl)-1,1,1-trichloroethane affects insect nerves in a manner similar, if not identical, to the action of DDT, but that the intensity of action is much less than one-tenth that of DDT.

It may be concluded that 2,2-*bis*-(2-chlorothienyl)-1,1,1-trichloroethane is considerably less potent insecticidally than DDT, except when tested against insects highly resistant to DDT. However, qualitatively it resembles DDT in its mode of action and appears to affect the same locus in the insect nervous system. This is evidence, therefore, that the phenyl rings are not essential in producing the biochemical effects of the DDT-type molecule.

References

1. METCALF, R. L., and GUNTHER, F. A. *J. Amer. chem. Soc.*, 1947, **69**, 2579.
2. SCHOMAKER, V., and PAULING, L. *J. Amer. chem. Soc.*, 1939, **61**, 1769.
3. TOBIAS, J., KOLLROS, J., and SAVIT, J. *J. Pharm. exp. Therap.*, 1946, **86**, 287–293.
4. TRUITT, P., MATTISON, M., and RICHARDSON, E. *J. Amer. chem. Soc.*, 1948, **70**, 79.
5. YEAGER, J. F., and MUNSON, S. C. *Science*, 1945, **102**, 305–307.

A Theory of Herbicidal Action

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Because there are many herbicides and many mechanisms involved in their action, generalization concerning them is hazardous. However, the contact sprays and soil sterilants are so dependent upon uptake by the plant that the mechanism of absorption is paramount to their effectiveness.

A theory proposing that nonpolar compounds can pass through the cuticle of leaves readily, whereas polar compounds enter with difficulty, has been published (*3*). Evidence is presented that nonpolar phenols in water, or in oil, are more toxic than their salts in water. Because such compounds (dinitrocresol, dinitrobutyl and amyl-phenols, pentachlorophenol, etc.) are more soluble in oil than in water, they are used to prepare either fortified oils or fortified oil emulsion sprays. Salts of these compounds in water are selective because, by differential wetting, they will kill broad-leafed weeds with no injury to grain, flax, etc. Lowering the polarity of the toxicants of such solutions by addition of acid salts (activation) or by using the ammonium salts increases their toxicity. Active absorption of the phenol molecules explains this increased toxicity where complete conversion to undissociated parent molecules is not accomplished.

Early testing confirmed this mechanism for 2,4-D compounds (*5*). The esters were more toxic than the ammonium salt, which exceeded the sodium salt. Many published results substantiate this relation. Early herbicides such as iron sulfate, sulfuric acid, sodium arsenite, and sodium chlorate entered plants because of their high concentration or corrosive action. Modern herbicides, such as dinitro- and chlorophenols, phenoxy compounds, and carbamates, are used at low concentrations; their entry from sprays into the plant depends upon their com-

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patibility with the plant cuticle. Some will act in the dust form, where solubility in cuticle is not complicated by the presence of water.

The cuticle does not form a perfect covering, especially on young leaves. Only xerophytes like cactus have nonpervious cuticle; young leaves of mesophytic plants lose considerable water through the cuticle. This is why arsenic and chlorate from 1 or 2% solutions penetrate young leaves and also why the sodium salt of 2,4-D is so effective on young plants.

Roots are specialized for absorption of ions. Recent tests in Puerto Rico prove that sodium pentachlorophenate as a pre-emergence treatment through the soil is more effective than pentachlorophenol. The sodium salt is effective as a selective soil sterilant against weeds in robust crops such as corn or sugar cane. Pentachlorophenol in oil emulsion is more useful as a pre-emergence contact spray in onions and carrots. The sodium salt in the topsoil injured these fragile plants; pentachlorophenol was noninjurious (*2*).

Salts of 2,4-D are more readily absorbed from soil than the esters; the salts caused crippling of oats and corn to a much greater extent than esters. On the other hand, 2,4-D acid, its sodium salt, and its methyl ester caused equal toxicity to oats, sunflowers, and peas in California soils compared on an acid-equivalent basis (*4*). Apparently the acid is sufficiently soluble to cause normal toxicity to the highly sensitive roots; the ester hydrolizes to an equivalent concentration. No leaching occurred from the cultures.

There are two possible pre-emergence methods: (1) pre-emergence contact spray to kill weed seedlings that have grown since preparation of the seed bed; (2) selective sterilization of the soil to kill weeds with little or no harm to the crop. Pre-emergence contact sprays can be used safely provided a nonpolar or water-insoluble toxicant is employed. Sodium cresylate and pentachlorophenate have proved harmful to seedlings of lettuce, onions, and carrots when a light shower occurred soon after application. Corn, cotton, and soybeans may not be injured.

Successful selective soil sterilization depends on profound differences between the crop and weed in susceptibility, root location, or some other factor. Certain corn varieties allow treatment with enough 2,4-D to kill grass seedlings without injury to the crop (*1*). Sodium pentachlorophenate was used successfully in corn and sugar cane in Puerto Rico. Leonard (*6*) found ammonium dinitrobutylphenylate effective in cotton in Mississippi. Current use of 2,4-D in cane proves that the pure acid applied dry is more effective under humid conditions than the sodium salt applied in solution. Solubility as related to solution rate and loss by leaching is probably the critical factor. The salt was effective for two weeks, but with over 3″ of rain it was leached out, whereas the acid remained effective for over a month. To use pre-emergence treatments successfully one should understand the nature of the selectivity upon which success depends.

A valuable generalization concerning absorption of herbicides is: for penetration of the cuticle and absorption by foliage, nonpolar compounds should be used; for absorption by roots, polar compounds. Although solubility and differential wetting (dinitro selectives) may limit the usefulness of toxicants, and cost, availability, and other economic considerations may justify exceptions, the above rule provides a sound theoretical basis for predicting the herbicidal uses of various toxic materials.

References

1. Anderson, J. C., and Ahlgren, G. *Down to Earth*, 1947, **3**, 16; Anderson, J. C., and Wolf, D. E. *J. Amer. Soc. Agron.*, 1947, **39**, 341–342.
2. Crafts, A. S., and Raynor, R. N. *West. Grow. Ship.*, 1944, **25**, 10–11, 26–28.
3. Crafts, A. S., and Reiber, H. G. *Hilgardia*, 1945, **16**, 487–500.
4. Harvey, W. A. *Hilgardia*, in press.
5. Harvey, W. A., and Crafts, A. S. Results of tests on 2,4-D weed killers in California, 1945. (Unpublished.)
6. Leonard, O. A. Private conference.

Progesterone in Blood Plasma of the Ovulating Hen[1]

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The occurrence of progesterone in the avian ovary, or the presence of luteal tissue implying secretion of this hormone by the bird, has long been a debatable subject (*2*, *5*) of much interest not only in connection with avian reproduction, but also because of more general phylogenetic implications emphasized by the remarkably divergent histories of the ova of birds and mammals following ovulation. All previous attempts to identify luteal tissue or progesterone in the bird's ovary have led to either inconclusive or negative findings (see *2* and *5* for summaries). The results of tests reported here, however, demonstrate beyond reasonable doubt the presence of progesterone in the blood stream of the regularly ovulating hen, presumably still a proper representative of *Aves*.

The 10 plasma samples examined came from 3 White Leghorn hens in which the interval between successive ovulations was ca. 26.5 hrs. Timing of withdrawal of blood samples was referred to second ovulation of the clutch (Table 1), but the same samples may also be considered as having been taken between 2 consecutive ovulations, ca. 6.5 hrs elapsing between withdrawal of samples 10 and 1. The choice of relatively close intervals between times of withdrawal of samples 2–8 was predicated upon the supposition that changes in progesterone levels might most likely occur within this period.

Each plasma sample was prepared from 0.95 ml of blood plus ca. 0.05 ml of sodium citrate, centrifuged as

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