damage occurs and the character of the damage, as previously described, will provide an estimate of toxicity of equivalent weights of the standard and the new herbicides.

Attention is called to the convenience and economy in the use of *Lemna minor* for estimating the phytocidal action of chemicals where a large number of tests are needed and where cost and availability of chemicals are important considerations. This plant may be useful as physiological test material in assaying the potency of commercial preparations of weed killers, particularly those containing organic poisons not easily determined by conventional methods of chemical analysis. Results of toxicity tests on duckweed should be directly applicable to practical problems in the control of aquatic plants.

References

1. BEAL, J. M. *Bot. Gaz.*, 1944, **105**, 471.
2. FROMM, F. *Science*, 1943, **98**, 391.
3. HAMNER, C. L., and TUKEY, H. B. *Science*, 1944, **100**, 154.
4. HESSENLAND, M., FROMM, F., and SAALMANN, L. *Angew. Chem.*, 1933, **46**, 577.
5. MITCHELL, J. W., and HAMNER, C. L. *Bot. Gaz.*, 1944, **105**, 474.
6. OFFORD, H. R., and D'URBAL, R. P. *J. agric. Res.*, 1931, **43**, 791.

Tributyl Phosphate as a Solvent for Preparing Concentrated and Oil-miscible Solutions of 2,4-Dichlorophenoxyacetic Acid and Similar Substances[1]

W. B. ENNIS, JR., LT., H. E. THOMPSON, LT. (j.g.), and H. H. SMITH, LT., USNR

Camp Detrick, Frederick, Maryland

Concentrated solutions of many difficultly-soluble growth-regulating compounds for use in oil solutions may be prepared by the use of tributyl phosphate.

During the past few years much attention has been given to the use of 2,4-dichlorophenoxyacetic acid as a plant growth regulator and weed killer. For practical use in sprays, this compound, and others of a similar nature, must be used with a diluent or carrier. This acid is only slightly soluble in water, and attempts to dissolve it directly in inexpensive mineral oils, such as kerosene and fuel oil, have been unsuccessful. In an effort to find a suitable co-solvent of 2,4-dichlorophenoxyacetic acid for use in mineral oils, over 50 of the more common organic solvents were tested, and of these only tributyl phosphate proved satisfactory. The others were found to be unsuitable either by reason of insufficient solvent power, immiscibility with oil, or undesirable volatility. The co-solvent ability of tributyl phosphate in this combination is a critical property of this compound, since closely related substances such as triethyl phosphate and tricresyl phosphate are unsatisfactory.

At ordinary temperatures tributyl phosphate will dissolve up to about 36 per cent, by weight, of 2,4-dichlorophenoxyacetic acid. A range of from 5 to 36 per cent of the compound dissolved in tributyl phosphate was found convenient and useful for subsequent dilution with mineral oils. Best results have been obtained with solutions in which the ultimate concentration of 2,4-dichlorophenoxyacetic acid was from 0.5 to 5.0 per cent by weight after dilution of the tributyl phosphate solution with kerosene or low-grade fuel oil.

The solutions of 2,4-dichlorophenoxyacetic acid and tributyl phosphate are stable at ordinary temperatures, have no heat of solution when dissolved in mineral oils, and are miscible with them in all proportions. In addition, tributyl phosphate causes local burning of plant tissues at points of direct contact, which, for herbicidal purposes, may be desirable. There is evidence that greater inhibition, per unit weight of compound, is produced in some broad-leaved plants when 2,4-dichlorophenoxyacetic acid is applied in oil solutions containing tributyl phosphate than when the acid is applied in the form of aqueous solutions. It is not known whether the increased inhibitory effectiveness of such solutions is due to the contact injury produced by tributyl phosphate.

Tributyl phosphate also has been found to be capable of dissolving large amounts of 2,4,5-trichlorophenoxyacetic acid, para-chlorophenoxyacetic acid, 2-methyl-4-chlorophenoxyacetic acid and other substituted phenoxyacetic acids. In general, 2,4-dichlorophenoxyacetic acid can be replaced with equivalent amounts of one of the three compounds named above. This solvent likewise is useful in preparing concentrated solutions of mixtures of such compounds for use as such or in oil solutions.

[1] Studies conducted at Camp Detrick from January to September 1945, under the direction of Dr. A. G. Norman.

Treatment of Muck and Manure with 2,4-Dichlorophenoxyacetic Acid to Inhibit Germination of Weed Seeds[1]

C. L. HAMNER, J. E. MOULTON, and H. B. TUKEY

Department of Horticulture, Michigan State College, East Lansing

Herbicidal sprays containing 2,4-dichlorophenoxyacetic acid have been used to destroy noxious plants (*2, 3*). Aqueous sprays at 1,000 ppm are selective in

[1] Journal Article 787 (N.S.) from the Michigan Agricultural Experiment Station, accepted for publication December 1945.

action, apparently not seriously affecting most grasses. Seeds of many plants, including grasses, can be destroyed by treatment with 2,4-dichlorophenoxyacetic acid. Concentrations as low as 1 ppm have a marked effect on germination and growth (*1*), and concentrations at 10 ppm will inhibit the germination of seeds of many plants. Although grass seeds are killed readily by 2,4-dichlorophenoxyacetic acid, high concentrations are required.

Muck soils and composted manure are frequently heavily infested with weed seeds. This suggests treatment of muck and manure to reduce the weed population. The importance of weed control is accentuated by the garden and truck crops commonly grown in muck and which require much hand weeding.

Muck soil in the vicinity of East Lansing, Michigan, was collected for treatment. The muck was placed in metal flats, and treatments were prepared at 1, 10, and 100 parts of 2,4-dichlorophenoxyacetic acid to 1,000 parts of muck. The 2,4-dichlorophenoxyacetic acid was applied to the muck in solution, a water-soluble preparation being used which contained 70 per cent of 2,4-dichlorophenoxyacetic acid obtained from the Dow Chemical Company. The concentrations were such as to give .01, .1, and 1 gram of 2,4-dichlorophenoxyacetic acid per square foot. After treatment, the muck flats were kept in a warm greenhouse at 60° to 80° F.

Two weeks after treatment, such weeds as lamb's-quarters (*Chenopodium album* L.), sow thistle (*Sonchus arvensis* L.), purslane (*Portulaca oleracea* L.), foxtail (*Setaria lutescens* Hub.), and redroot (*Amaranthus retroflexus* L.) began to appear in the untreated flats and to a much lesser degree in the flats containing 1 ppm of 2,4-dichlorophenoxyacetic acid. No weeds appeared in any of the flats treated at either 10 or 100 ppm of the chemical.

In order to test the residual effect in the soil, four weeks after treatment, bean and pea seeds were planted in the flats that had been treated at 10 and 100 ppm of 2,4-dichlorophenoxyacetic acid. The seeds germinated, and the plants grew normally.

In trials with 2,4-dichlorophenoxyacetic acid on manure, seeds of rape, rye grass, field pea, brome grass, meadow fescue, creeping bent grass, orchard grass, hairy vetch, and alsike clover were added to the manure in large numbers to insure their presence. The manure was then divided into three lots. One lot was treated at 10 ppm with 2,4-dichlorophenoxyacetic acid, a second was treated at 100 ppm and a third was left untreated as a check. The manure was then mixed with sand, the final mixture being about one part of manure to two parts of sand. The mixture was placed in metal flats and kept moist in a warm greenhouse. After three days, seeds in the control lot began to germinate, and after two weeks the surface of the mixture was covered with plant growth. The germination of seeds in the treated flats at 10 and 100 ppm was greatly inhibited, only a few of the grasses appearing in the 10 ppm flat.

Treatment with 2,4-dichlorophenoxyacetic acid is suggested as a method of controlling weed seed in manure and muck soils and where these materials are used in top dressings of lawns and golf courses. This treatment may also be of special value in conditioning nursery, tobacco, and other seed beds before planting.

References

1. Hamner, C. L., and Moulton, J. E. (To be published.)
2. Hamner, C. L., and Tukey, H. B. *Science*, 1944, **100**, 154–155.
3. Hamner, C. L., and Tukey, H. B. *Bot. Gaz.*, 1945, **106**, 232–245.

Herbicidal Action of 2,4-Dichlorophenoxyacetic Acid on the Water Hyacinth, *Eichornia crassipes*

E. M. Hildebrand
Food Machinery Corporation, Dunedin, Florida

The water hyacinth, *Eichornia crassipes*, is a native of Japan and was carried about 70 years ago to South America, where it became widespread in fresh-water streams and lakes. At the International Cotton Exposition, held in New Orleans in 1884 (*1*), the Japanese government representatives gave away as souvenirs water hyacinths they had imported from Venezuela, where this pest had practically "taken over" the lower Orinoco. Very shortly thereafter the plant was introduced into Florida. Because it propagates prodigiously by both seeds and offshoots and matures two and sometimes three crops in a single season it presents a real problem in Florida and other subtropical regions, clogging the waterways, drainage ditches, and lakes.

Hildebrand and Palmiter (*3*) successfully employed the ammonium sulfamate herbicide for combating the *Prunus virginiana* wild host of the yellow-red virus disease of peach. Gowandloch (*1*) reviewed the various methods (chemical control, control by flame thrower, mechanical control, biological control) that have thus far been tried for water hyacinth control. He tested ammonium sulfamate and sulfamic acid for eradicating the water hyacinth and found that these killed only the plant parts above water.

Zimmerman and Hitchcock (*6*) developed some of the growth substances that may be toxic to plants in concentrations greater than that used to secure desirable responses such as rooting. Some of the more potent of these compounds are the substituted phenoxy