Status and Problems of

Fertilizer-Pesticide Mixtures

Mixtures of fertilizer and pesticides are popular with farmers and are expected to become even more popular, despite complexities of preparing and regulating them

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INCORPORATION OF PESTICIDAL CHEMICALS in fertilizers, for the dual purpose of pest control and crop nutrition, has received attention by research workers for at least 25 years (*43–45*), but commercial production of such combinations was on a very limited scale before World War II. With the subsequent development of new types of highly potent organic pesticides, however, interest was intensified in the possibilities of including such chemicals in fertilizers as a convenient and economical means for their application in the control of certain pests.

Impetus was given to this interest by the development and marketing of herbicidal mixed fertilizers containing 2,4-D (*35*, *41*, *44*) and by the results of the early experiments in the Southeast (*58*)—especially in Florida (*29*, *34*), Louisiana (*24*), North Carolina (*27*), South Carolina (*59*, *60*), and Virginia (*15*)—with mixtures of fertilizers and insecticides (mostly chlorinated organic compounds) for control of soil-borne insects. Studies of fertilizer-insecticide mixtures for soil application were extended shortly thereafter to other parts of the country, particularly the Middle West (*13*, *38*, *39*, *55*). Also, experimental use has been made of fertilizer-nematocide mixtures (*6*).

In addition to this work, which has dealt mostly with mixtures of solid materials, nitrogen fertilization of some fruit crops, notably apples, has been combined with pest control by adding urea to foliage sprays (*21*). Research is in progress on the control of weeds in certain field crops by adding herbicides to top-dressing applications of liquid nitrogen fertilizers (*36*). With the growing interest in the use of liquid mixed fertilizers (*2*, *37*), one may expect that inclusion of pesticides in such mixtures will also come into practice.

As is so often the case with new de-

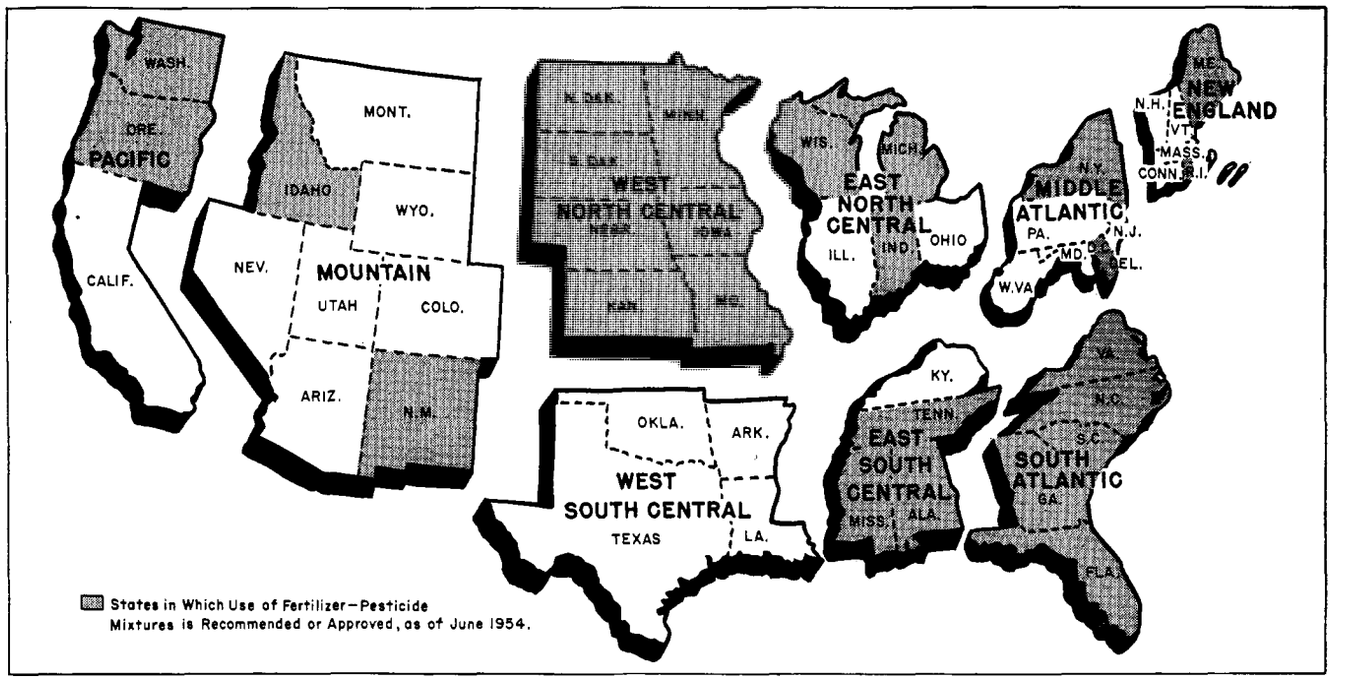

Figure 1

velopments, the comercialization of fertilizer-pesticide mixtures has outrun the research thereon, with the result that there is much diversity of opinion as to their merit and practical feasibility (*1*, *4*, *8*, *17*, *18*, *19*, *25*, *32*, *33*, *35*, *38*, *51*, *56*, *57*). Owing largely, no doubt, to the paucity of experimental data with respect to specific conditions in the different areas, the recommendations of the state agencies vary widely from state to state and sometimes between agencies in the same state. Laws, regulations, and control practices, as they apply to fertilizer-pesticide mixtures, differ considerably among the states. Many fertilizer manufacturers, including farmer cooperatives, have been reluctant to manufacture the mixtures, because of the numerous unsolved problems involved therein. Even so, considerable quantities of such mixtures have been used recently in some parts of the country, and the rapidity with which the practice is extending into other areas justifies the expectation that the demand will assume still larger proportions. It is important, therefore, that much greater emphasis be placed on research and study in this field in order that the spheres of economic and practical usefulness of fertilizer-pesticide mixtures may be defined more clearly.

This paper reviews the present status of fertilizer-pesticide mixtures and discusses some of the problems in their manufacture and use, with special reference to combinations of solid materials for the control of soil insects.

Recommendations of State Agencies

Data on the number of states in which the use of fertilizer-pesticide mixtures of one kind or another is recommended or approved by one or more agencies or agency departments in the individual States, including experiment stations, extension services, and boards of agriculture, are summarized by regions in Figure 1. The information was compiled from correspondence with the various organizations and from the results of a questionnaire submitted to fertilizer and pesticide control officials in the spring of 1954 by Rodney C. Berry, State Chemist of Virginia (*5*). As a whole, the recommendation embraces nearly all the types of mixtures that have come into use, but they relate mostly to solid products containing compounds for the control of soil insects.

As of June 1954, use of one or more kinds of fertilizer-pesticide mixtures was recommended or approved in 26 states distributed in all but one of the state regions. Although definite information is lacking to the writer, it is believed that such mixtures are also sanctioned in Puerto Rico. Fertilizer-pesticide mixtures have official sanction in all the South Atlantic and West North Central States and in all but one each of the East South Central and Pacific States, but in none of the West South Central States. It should be noted, however, that sanction of the mixtures in the 26 States has generally been accompanied by many reservations on the part of the agricultural officials, even in most of the States where considerable quantities are used. The reservations result chiefly, no doubt, from the paucity of experimental data upon which to base sound conclusions as to the merits and demerits of the mixtures under the specific conditions of their use.

Inadequacy of experimental data, together with a lack of farmer demand, has also been a principal factor in the recommendations, or the lack thereof, in most of the states where fertilizer-pesticide mixtures are not sanctioned. With a few exceptions, the situation in these states is simply that no stand has been taken either for or against their use.

State recommendations for fertilizer-pesticide combinations relate chiefly to solid products containing compounds for control of soil insects. In a few instances, the recommendations include other combinations, such as liquid mixtures containing insecticides, both solid and liquid mixtures for herbicidal purposes, and addition of urea to pesticidal sprays.

In the descending order of frequency on the state basis, the principal compounds recommended for inclusion in fertilizers to control soil insects are aldrin, heptachlor, chlordan and dieldrin, and DDT. For these compounds as a whole the recommendations cover more than 25 kinds of insects on upward of 35 crops (Table I). Since some of the recommendations are tentative, or are essentially preliminary suggestions based on limited experimental work, manufacturers planning to market fertilizer-pesticide mixtures should check with state officials—as well as with federal officials in the case of interstate shipment—to make sure that the intended uses of the mixtures should be effective without leaving objectionable residues on the crops or in the soil and that the products and their labeling are acceptable for registration.

It appears that control of wireworm and rootworm infestations of corn land is a major objective of the recommenda-

Table I. Summary of State Recommendations, Approvals, or Permissibility as to Insecticides for Inclusion in Fertilizers to Control Soil Insects (June 1954)

Insecticide[a]	Application Rate (Lb./Acre)	Insects	Crops
Aldrin	0.5–6	Ants, billbugs, cabbage maggot, carrot rust fly, corn rootworms, crickets, flea beetles, mole crickets, onion maggot, seed-corn beetle, seed-corn maggot, sweet potato weevil, western spotted cucumber beetle, white-fringed beetle, white grubs, wireworms	Beans, broccoli, cabbage, carrot, cauliflower, celery, corn, cucumber, eggplant, escarole, flowers, lawns, lettuce, melons, onion, pastures, peanut, pepper, potatoes, radish, small grains, squash, strawberry, sugar cane, tobacco, tomato, turf
Chlordan	0.5–10[b]	Ants, army worms, chinch bug, corn rootworms, crickets, cutworms, elongated flea beetle, lesser corn-stalk borer, mole crickets, seed-corn maggot, sweet potato weevil, webworms, white-fringed beetle, white grubs, wireworms	Beans, broccoli, cabbage, cauliflower, celery, corn, cotton, cucumber, eggplant, lawns, lettuce, melons, ornamentals, pastures, peanut, pepper, potatoes, squash, strawberry, sugar cane, tobacco, tomato, turf
DDT	1–25	Army worms (in pastures); European chafer; insects of lawns, turf, and ornamentals; sweet clover weevil, white-fringed beetle; wireworms	Lawns, noncultivated crops, ornamentals, pastures, potatoes, sweet clover, turf, unspecified
Dieldrin	0.5–6	Ants, army worms, cabbage maggot, carrot rust fly, chinch bug, corn rootworms, cutworms, flea beetles, green beetle, mole crickets, onion maggot, western spotted cucumber beetle, white-fringed beetle, white grubs, wireworms	Cabbage, carrot, cucumber, corn, gladiolus, lawns, noncultivated crops, onion, pastures, radish, small grains, strawberry, sweet potato
Heptachlor	0.5–6	Ants, cabbage maggot, carrot rust fly, corn rootworms, crickets, cutworms, flea beetles, lesser corn-stalk borer, onion maggot, mole crickets, seed-corn beetle, seed-corn maggot, sweet potato weevil, western spotted cucumber beetle, white-fringed beetle, white grubs, wireworms	Beans, broccoli, cabbage, cantaloupe, carrot, cauliflower, celery, corn, cucumber, eggplant, lawns, lettuce, onion, ornamentals, pastures, peanut, pepper, potatoes, radish, small grains, squash, strawberry, sugar cane, tomato, tobacco, turf, watermelon

[a] In one state fertilizers containing either BHC or lindane are approved for use on lawns and golf courses only. Fertilizers containing toxaphene are approved in two states.
[b] In one state 22 pounds of chlordan per acre, mixed with 650 pounds of 8–6–2 fertilizer, is recommended for control of ants, grubs, and other pests in lawns and golf greens.

tions in several states. The recommended rates of application range from 0.5 to 6 pounds per acre for aldrin, dieldrin, and heptachlor, 0.5 to 22 pounds for chlordan, and 1 to 25 pounds for DDT, depending on the state, the kind of soil, insect, and crop, and the method of application (row or broadcast, surface or worked in), among other things. In North Carolina (*48*), for example, the recommended rates of aldrin for control of the white-fringed beetle on cultivated crops are 0.75 to 1.5 pounds per acre with row treatments and 4 pounds with broadcast applications worked into the soil.

Consumption

On the basis of information supplied by State agronomists, entomologists, and control officials and by fertilizer manufacturers, it is estimated that the consumption of fertilizer-pesticide mixtures in the year ended June 30, 1953, ranged from 100 tons in the West South Central region to 60,000 tons in the South Atlantic region and totaled 87,000 tons for the United States and Territories (Table II). It should be emphasized that these estimates are based on very fragmentary information, but it is believed that for the most part the figures are well on the low side. It appears that the consumption increased considerably in 1953–54, with the largest gain in the North Central region and particularly in the western part of that region.

The South Atlantic region accounted for 69% of the total consumption in 1952–53, and about 90% of the consumption in that region was in North Carolina and South Carolina, the latter being the first State to use extensive quantities of fertilizer-pesticide mixtures. It is said (*7*) that approximately 100,000 acres of corn in South Carolina were treated at the rate of 1 pound of chlordan in 400 pounds of fertilizer per acre for control of wireworms and the southern corn rootworm, and that approximately 5000 acres of Irish potatoes were treated at the rate of 1 to 2 pounds of chlordan in 1 ton of fertilizer per acre for control of wireworms.

The consumption in the Pacific region (11,100 tons, mostly in Oregon) was second to that in the South Atlantic region. The consumption in Puerto Rico (8626 tons, 4.11% of the total consumption of mixed fertilizers) accounted for nearly all of the use of fertilizer-pesticide mixtures in the Territories. Puerto Rico is one of the few political units of the United States for which specific information on the use of such mixtures is available.

Table II. Estimated Consumption Fertilizer-Pesticide Mixtures in U. S. and Territories (Year Ended June 30, 1953)

Region	Fertilizer-Pesticide Mixtures (Short Tons)	All Mixed Fertilizers, (1,000 Short Tons)
New England	400	394
Middle Atlantic[a]	1,000	1,814
South Atlantic	60,000	5,152
East North Central	2,500	3,715
West North Central	2,000	1,229
East South Central	200	2,059
West South Central	100	721
Mountain	1,100	71
Pacific	11,100	299
Territories	8,700	268
Total	87,000	15,722

[a] Including District of Columbia.

On the basis of the data in Table II, the consumption of fertilizer-pesticide mixtures in the United States and Territories in 1952–53 amounted to only 0.55% of the total consumption of mixed fertilizers. Among the continental regions, the proportion ranged from 0.01% in the East South Central States to 1.1% in the South Atlantic, 1.5% in the Mountain, and 3.7% in the Pacific States.

Fertilizer-pesticide mixtures of one kind or another were registered in 1952–53 with the control officials of 23 States and Puerto Rico by a gross total of some 95 companies. The gross total of companies that actually marketed such mixtures in these States in 1952–53 was undoubtedly much higher than this figure, because many of the States either did not require any fertilizer-pesticide mixtures to be specifically registered as such or else exempted from registration such mixtures as were prepared on a custom basis. Furthermore, it is known that fertilizer-pesticide mixtures were marketed, sometimes in considerable quantity, in a number of States where no registrations were recorded. The bulk of the registrations were for mixtures containing compounds for control of soil insects, but in a

few States they were confined to specialty products containing a herbicide, usually 2,4-D.

Information on the registration of fertilizer-pesticide mixtures with state control officials in 1953–54 is lacking to the writer. It is of interest to note, however, that as of July 1954 some 200 to 250 mixtures were registered with the Plant Pest Control Branch, Agricultural Research Administration, U. S. Department of Agriculture, for interstate shipment by approximately 25 companies. For such shipment, each change in the kind or quantity of pesticide or in the kind or grade of fertilizer is considered as a separate product and requires a separate registration.

In 1952–53, chlordan was the principal pesticide added to fertilizers in several of the regions, notably the South Atlantic States. Aldrin was the chief pesticidal constituent of the mixtures in the North Central and Pacific regions. With the rapidly expanding interest in fertilizer-insecticide mixtures for application to corn land in the North Central States it appears that the consumption of aldrin in combination with fertilizer may increase at a faster rate than that of other pesticides now used in this way.

Production

On the basis of information obtained from state officials and in a partial survey of the fertilizer industry, it appears that during 1953–54 solid fertilizer-insecticide mixtures of various kinds were manufactured in 33 States and Puerto Rico by at least 113 companies or approximately 13% of all companies that manufacture mixed fertilizers in the United States and Territories. The West South Central States was the only region for which no evidence of the manufacture of such mixtures was obtained. As reported by individual companies, the quantities of technical aldrin, chlordan, or DDT added per ton of mixture and the kinds of fertilizers involved are summarized in Table III. Mixtures containing dieldrin and heptachlor are not included in this tabulation because of the limited information available thereon.

The quantity of an insecticide incorporated in a fertilizer depends largely on the rate per acre at which the fertilizer is to be applied, and this depends, in turn, on the level of soil fertility, the plant nutrient concentration of the fertilizer, and the manner of applying the fertilizer. Other factors include the kind of insect to be controlled, the degree of infestation, the kind of crop, and the physical character of the soil. Thus, the quantities of aldrin included in fertilizers range from 1 to 30 pounds per ton, chlordan 0.25 to 66 pounds, and DDT 1.5 to 40 pounds.

For aldrin a commonly used quantity in the North Central region is 10 pounds per ton added to corn fertilizer to control wireworms and the northern corn rootworm. Additions of 8 pounds per ton are made in the South Atlantic region for control of the southern corn rootworm attacking peanuts. In some other parts of the country, as much as 25 pounds of aldrin per ton are added to control potato and strawberry pests, and at least one company adds 30 pounds of this compound per ton of potassium sulfate for application to tobacco.

In one instance, an 8–6–2 fertilizer carries about 66 pounds of chlordan for control of insects and other pests in lawns and golf courses as recommended by a state official. It appears that additions of DDT usually do not exceed 20 pounds per ton.

Addition of insecticides to fertilizers is usually to mixtures containing two or more of the primary plant nutrients (N, P_2O_5, and K_2O), but in a few instances additions to straight materials—such as ammonium sulfate, superphosphate, potassium sulfate, and gypsum—are made. The mixed fertilizers cover a very wide range of formulations and grades, potentially including all possible formulations of the grades marketed in the United States and Territories—some 1700 in 1952–53, for example (*53*).

As reported by 32 companies, insecticides were incorporated in at least 48 grades of mixed fertilizers in 1953–54 (Table III). Of these grades, 71% contained all three of the primary nutrients, 17% contained N and P_2O_5 only, and 12% contained P_2O_5 and K_2O only. The total plant nutrient content ranged from 16 to 46%. In 10% of the grades the nutrient content was less than 20%, whereas 44% of the mixtures contained more than 30% of nutrients. With mixtures containing aldrin, for example, the total plant nutrient content of the grades ranged from 20 to 32% in the South Atlantic region, 25 to 45% in the North Central region, and 20 to 46% in other parts of the country.

Several forms of the different kinds of insecticides have been used, or are available, for mixing with fertilizers (*8, 19, 20, 25, 38*). These include both dustless and nondustless powders, granular products with a particle-size range of 30 to 60 mesh, solutions in low-viscosity solvents, and emulsion concentrates. In current practice the powdered products appear to be the most widely used, for example, powders containing 20% of aldrin, 25 to 40% of chlordan, or 50% of DDT. The trend is said, however, to be in favor of granular insecticides (*25*). With the rapidly expanding manufacture of granular fertilizers, it may be expected that increasing use will be made of solutions of the insecticides in low-viscosity solvents for spray application to the fertilizer granules. Seldom, if ever, does a fertilizer-insecticide mixture contain more than one kind of insecticide.

Table III. Summary of Use of Aldrin, Chlordan, and DDT in Mixtures with Solid Fertilizers in Continental U. S.

Insecticide			
Kind	*Lb./ton*	*Kind of Fertilizer*	*Region*
Aldrin	1–8	0–8–24, 0–10–10, 0–10–20, 0–14–14, 2–12–12, 4–8–8, 4–10–6, 5–10–5	South Atlantic
	10–20	3–12–12, 4–16–8, 4–16–16, 4–24–12, 5–10–10, 5–15–10, 5–20–20, 8–16–16	East North Central
	10–20	0–20–20, 3–12–12, 4–16–8, 4–16–16, 5–20–10, 5–20–20, 6–24–0, 6–24–12, 8–24–8, 8–32–0, 10–10–10, 10–20–0, 10–20–8, 10–20–10, 11–11–11, 12–12–12, 12–24–0, 13–13–8, 14–14–0, 15–15–0, 15–15–15, 16–10–0, 16–20–0, normal superphosphate, triple superphosphate	West North Central
	5–30	4–12–8, 4–12–12, 5–10–5, 5–10–10, 6–20–20, 8–16–16, 10–16–8, ammonium sulfate, potassium sulfate, normal superphosphate, gypsum	Others
Chlordan	0.25–10	2–12–12, 3–9–6, 3–9–9, 3–12–12, 4–7–5, 4–8–6, 4–8–8, 4–10–6, 4–12–12, 5–7–5, 5–10–5, 5–10–10, 6–6–6, 6–8–4	South Atlantic
	[a]	4–12–12, 5–10–5, 5–10–10, 8–6–2, 8–16–16, 10–10–10, 12–12–12, normal superphosphate	Others
DDT	1.5–40	0–12–20, 0–14–14, 3–9–9, 4–8–6, 4–8–8, 4–10–7, 4–12–12, 6–8–4, 6–8–8, 6–20–20	United States[b]

[a] Includes quantities as high as 66 pounds per ton of 8–6–2 fertilizer used in one state for control of insects and other pests in lawns and golf courses.
[b] Chiefly the South Atlantic region.

In the manufacture of fertilizer-insecticide mixtures it is the usual practice to add the insecticide to the cured fertilizer in a separate operation just before the mixture is bagged or loaded for shipment. This is commonly done in the same kind of mixing equipment used for preparing the fertilizer itself, but with a several fold increase in the mixing time. In this way the danger of loss of the insecticide by mechanical means or by chemical reaction with the fertilizer constituents is lessened, its more uniform distribution in the mixture is favored, and the possibility of over-all contamination of the plant equipment and facilities by the insecticide is reduced. Currently, most plants that prepare fertilizer-insecticide mixtures do so only at the specific request of individual customers, and they do not carry such mixtures in stock.

Price of Insecticides Mixed with Fertilizers

According to information supplied by a number of companies (Table IV) the price of insecticides (basis 100% technical grade) when mixed with fertilizers ranges from $2.00 to $3.25 per pound for aldrin, $1.00 to $1.88 for chlordan, and 50 to 70 cents for DDT. In some cases, no charge is made for mixing the insecticide and fertilizer, while in others the charge ranges from $1.00 to $10 per ton of mixture. Some of the prices include the dealer's profit while others do not. Certain manufacturers indicate that their present prices do not fully cover all the costs of handling, storing, and mixing the insecticide. Furthermore, it should be recognized that still higher charges for the inclusion of insecticides and other pesticides in fertilizers may come about if the demand increases to such a degree as to necessitate extensive plant alterations and installation of additional equipment.

Table IV. Price of Aldrin, Chlordan, and DDT in Mixtures with Solid Fertilizers in Continental U. S.

Insecticide		
Kind	Price in fertilizer, $/lb.[a]	Region
Aldrin	$2.00–3.13	South Atlantic
	2.50–3.25[b]	East North Central
	2.00–3.20	West North Central
	2.20–2.85[c]	Others
Chlordan	1.00–1.88	South Atlantic
	[d]	Others
DDT	0.50–0.70	United States

[a] Including charge, if any, for mixing.
[b] In other cases, cost of insecticide (not stated) plus $5.00–10 per ton for mixing.
[c] In other cases, cost of insecticide (not stated) plus $1.00–7.50 per ton for mixing.
[d] Cost of insecticide only; cost of insecticide plus $1.00–7.50 per ton for mixing; and others unspecified.

In the South Atlantic region, addition of 8 pounds of aldrin per ton of fertilizer, as recommended for control of the southern corn rootworm attacking peanuts, increases the price of the fertilizer by some $22 to $25 per ton. With the recommended application of 500 pounds of fertilizer per acre, the cost of the aldrin applied therein is $5.50 to $6.25 per acre. Addition of aldrin to fertilizer for control of wireworms and the northern corn rootworn attacking corn in the North Central area is commonly at the rate of 10 pounds per ton, with an increase of $20 to $30 (usually $25) per ton in the price of the fertilizer. With applications of 0.50 to 1.0 pound of aldrin per acre, as generally recommended, the cost of the insecticide is usually no more than $3.00 per acre. The per acre costs of chlordan and DDT are often substantially lower than those of aldrin.

At the indicated costs it is not difficult to understand why the farmer is interested in using mixtures of fertilizers and insecticides, thereby saving the time, trouble, and expense of separate applications of these two highly important crop-production materials. It may happen, however, that the higher cost of the mixture, as compared with that of the fertilizer alone, will tempt some farmers to hold their fertilizer application rates to substantially lower levels than would otherwise be the case.

Problems of Fertilizer-Pesticide Mixtures

As previously pointed out the use, distribution, and preparation of fertilizer-pesticide mixtures involve numerous problems in the agronomic, entomologic, regulatory control, and manufacturing phases of the subject, many of which have been solved only partially or not at all. Since these problems have been treated in a number of papers (*1*, *4*, *8–10*, *11*, *17*, *25*, *32*, *33*, *38*, *56*, *57*) the present discussion will be limited to those that seem to merit special emphasis.

Agronomic and Entomologic Problems

Problems of the persistence and accumulation of pesticides in the soil and of their effects on plants and soil microorganisms (*1*, *14*, *23*, *26*, *28*, *31*, *38*, *40*, *50*, *54*, *56*, *57*) are similar, for the most part, whether the pesticide is applied alone or in mixture with the fertilizer. The danger of adverse effects of the pesticide on plants is greater with row or hill applications of the mixtures than with broadcast applications, whereas the opposite would seem to be true of the over-all effects on microorganisms.

From both the agronomic and entomologic standpoints, a major problem of fertilizer-pesticide mixtures—and apparently the most troublesome one—is that of mixtures to supply the desired quantities both of pesticides and of plant nutrients on the acre basis. Even with a given pesticide in a specific kind and grade of fertilizer and for control of a specific pest of a specific crop, the problem is still complicated greatly by the wide variations in soil types and fertility levels—not only in different parts of the country but also in relatively small areas and often within the boundaries of individual farms—and consequently by the differences in the quantities of fertilizer and, to a less extent, of pesticide needed per acre. Thus, the formulation of fertilizer-pesticide mixtures must be tailored to meet the requirements of the individual farmer. The requirements can usually be met with a relatively few formulations in those areas where crop and fertilizer practices, the soil fertility level, and the kind and degree of pest infestation are substantially uniform. There are many parts of the country, however, in which this situation does not prevail, so that the widely varying local conditions would necessitate a considerable number of formulations.

Whether the proper time for applying the pesticide coincides with that for applying the fertilizer depends on several factors, including the kind of pest and crop and the degree of persistence of the pesticide in the soil. Although much more work needs to be done, it appears to have been definitely established that these times coincide reasonably well in some instances, for example, starter applications of fertilizer with insecticides to control wireworms and rootworms attacking corn.

The most effective method (broadcasting, drilling, and others) of applying the pesticide may not conform with the most effective or practical method of applying the fertilizer. It will usually be necessary to resolve this problem for each kind of pest and crop, among other factors. For example, it appears to be the consensus that wireworms and rootworms attacking corn are most completely controlled by broadcasting the insecticide and working it thoroughly into the soil. On the other hand, plant nutrients for corn are generally utilized more efficiently and economically by applying the fertilizer to the row or hill. Fortunately, it has been found that satisfactory control of the corn pests can usually be effected by also applying the insecticide in this manner, so that the use of fertilizer-insecticide mixtures appears to be both agronomically and entomologically feasible in this case.

Practices in the use of fertilizer-pesticide mixtures as regards the time and method of application will undoubtedly be governed chiefly by the prevailing practices with respect to the

fertilizer rather than the pesticide. Compromises in the respective practices are permissible, of course, insofar as they do not work to the disadvantage of the farmer. It is the writer's opinion that more care needs to be exercised in the design and execution of experiments involved in studies of the efficacy of fertilizer-pesticide mixtures.

Regulatory and Control Problems

Regulation and control of the sale and distribution of fertilizer-pesticide mixtures present problems of registration, labeling, fees, packaging, inspection, sampling, analysis, and tolerances, among others (*5*, *32*). Through their respective investigators for pesticides in fertilizers, these problems are receiving the attention of the Association of American Fertilizer Control Officials and the Association of Economic Poisons Control Officials.

All the States have fertilizer control laws, and most of them have laws regulating pesticides in one way or another. There are no federal laws relating specifically to the regulation of fertilizers, but pesticides—including mixtures with fertilizers—moving in interstate commerce must be registered with the U. S. Department of Agriculture, and they must meet the requirements of the regulations under the Federal Insecticide, Fungicide, and Rodenticide Act. Thus, for interstate shipment a pesticidal fertilizer is subject not only to the federal pesticide regulations but also to both the pesticide and the fertilizer regulations in the state of its sale.

As indicated by Berry's survey (*5*), practices in the regulation and control of fertilizer-pesticide mixtures vary widely among the states. In a good many states such mixtures are registered and fees are collected under both the fertilizer and the pesticide laws, while in others this is done under only one of the laws. It appears, however, that the majority of the states have not issued regulations pertaining specifically to fertilizer-pesticide mixtures.

Bulk sales of the mixtures are not permitted in a number of states, and this is also true of so-called "buyers mixtures" or "farmers mixtures" where a farmer may have any pesticide added to his fertilizer by the manufacturer. Each of these practices is specifically permitted, however, in certain other states.

It appears that most states place no restrictions on the type of containers for fertilizer-pesticide mixtures. The use of heavy paper containers is required in some states, whereas woven bags are prohibited in others.

Many states analyze the mixtures for their pesticide content, but very few have established tolerances for deficiency or excess of pesticide. In this connection it should be noted that further work needs to be done on methods for determining pesticides in fertilizer mixtures.

Manufacturing Problems

Fertilizer manufacturers in general have not been enthusiastic over fertilizer-pesticide mixtures, but no less so perhaps, than the agronomists and entomologists. This is chiefly so, no doubt, because the preparation and distribution of such mixtures involve numerous problems (*10*, *25*, *32*, *33*, *40*), many of which have been previously encountered in the fertilizer industry to only a limited extent, or not at all, and because the vast majority of the plants are not properly equipped for this purpose. The present situation is much like that in the feed industry when drugs and antibiotics in therapeutic amounts began to be incorporated in mixed feeds. Here, too, the manufacturers—knowing that they would experience difficulties in mixing and distribution—were generally reluctant to engage in the practice. From the manufacturing standpoint, at least, the problems involved in adding pesticides to fertilizers are no less complicated than those in adding the above-mentioned substances to feeds.

Aside from the very important, often critical, matter of the multiplicity of grades and formulations with which a plant may have to deal—as well as the accompanying problems of space and equipment—the compatibility of pesticides with fertilizer materials and the stability of the mixtures, the preparation of mixtures having uniform composition, and the hazards to plant workers are among the major problems confronting the manufacturer.

Numerous studies have been made of the compatibility of pesticides with diluents used in the preparation of the commercial products (*30*, *46*) and it has been shown that, in order to ensure stable products, considerable care must be exercised in selecting the diluents. This situation might well impose serious limitations on the mixing of some pesticides with fertilizers. Although some 20 materials constitute the greater portion of the total tonnage of fertilizer consumed in the United States, many other materials are also used in varying quantities. These materials comprise a wide variety of organic and inorganic products, and they differ greatly in their physical and chemical characteristics.

To the writer's knowledge, the literature contains only meager information on the stability of pesticides in fertilizer mixtures. Thus, the work of Marth, Hardesty, and Mitchell (*42*) and of Muller (*47*) indicates that 2,4-D added to superphosphate and mixed fertilizers largely retains its potency even under rather adverse conditions of preparation and storage of the products. According to Fleck and Haller (*22*), DDT is stable in contact with several fertilizer materials and mixtures at elevated temperatures, at least for short exposures, but it is catalytically decomposed by dolomitic limestone. Aldrin, chlordan, and perhaps dieldrin and heptachlor are variously reported (*8*, *17*, *25*, *38*) to be compatible with fertilizers and to be stable in mixtures, but experimental evidence in support thereof appears to be lacking in the literature.

Obviously, the compatibility and stability of each new pesticide should be carefully investigated. Until this is done, the fertilizer manufacturer will do well either to limit his operations to pesticides of known behavior or, as usually done at present, to prepare the mixtures just prior to their shipment.

With the equipment commonly available at most fertilizer plants, the problem of uniformly blending small quantities of pesticides with fertilizers is not a simple one. Differences in particle size and bulk density of the pesticides, as compared with the other ingredients of the mixture, are among the responsible factors. In correspondence with 40 companies that prepare fertilizer-insecticide mixtures it was indicated that the majority have experienced no difficulty in uniformly mixing insecticides with fertilizers. It appears, however, that this experience is based mostly on the absence of complaints by farmers and control officials. Some 25% of the companies indicated considerable trouble.

One company reported determinations of aldrin on different batches of approximately 250 tons of three grades of mixed fertilizers formulated to contain 8 pounds of aldrin per ton added as 40 pounds of 20% material. The batches, prepared in a 1-ton mixer rotating at 12 r.p.m. for 1.5 to 2.0 minutes, were bagged directly from the mixer. In 24 determinations the quantities of aldrin found ranged from 4.6 to 10.2 and averaged 7.3 pounds per ton. In 15 of the determinations, the quantity of aldrin found was less than 8 pounds per ton. These results reflect not only lack of uniformity in the blending but also any mechanical losses during mixing and handling and inaccuracies in the analyses. They point, nevertheless, to the necessity for the exercise of much care in the preparation of the mixtures.

Unlike the preparation and handling of pesticides (*3*, *12*, *16*, *49*, *52*), the fertilizer industry *per se* is generally considered to be relatively free from possible hazards to human health. Thus, the manufacturer who mixes pesticides with fertilizers is faced with a much more serious problem of employee safety than would otherwise be the case, and he may expect an increase in the rate for his employee compensation insurance. He should adopt all the health precautions prescribed for the handling and processing of the particular pesticide with

which he is concerned. Since this would include abatement of the dust nuisance so common in fertilizer plants, it would necessitate the installation of additional equipment, probably at considerable expense. Failure to observe these precautions would be to invite trouble with a manufacturer's employees, the unions, and the health and labor officials.

It appears that manufacturers who blend pesticides with fertilizers generally provide their employees with protective devices of one kind or another, and thus far most of them seem to have experienced no serious health problems. On the other hand, health casualties have occurred in some plants, and a number of manufacturers are greatly concerned over this problem. It should be noted that up to now the tonnage of fertilizer-pesticide mixtures made by any one plant usually has been quite limited and has comprised only a very small fraction of the total production of the plant. Enhanced danger of toxic effects from the pesticide may be expected as the plant output of its mixtures is increased.

In addition to the problem of employee health, the manufacturer who adds pesticides to fertilizers broadens the sphere of his product liability (*9–11*). Thus, he becomes subject to claims arising in connection with either or both the fertilizer and the pesticidal constituents of the mixture.

In conclusion, it may be said that the demand for fertilizer-pesticide mixtures will continue, likely in increasing volume, so long as their use affords a convenient, economical, and reasonably satisfactory way of combining crop fertilization with pest control. Hence it is important that research be expanded on the many problems of their production, distribution, and utilization. Increased effort should be directed toward the development of equipment for applying the pesticide separately from but simultaneously with the fertilizer, whereby the rates of application of the two materials can be regulated independently of each other. Use of such equipment, now under development by at least one company, would eliminate a major problem of combination fertilizer-pesticide applications.

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