make sure that the soil is not infested before planting and that the transplants are free of nematodes.

The type of cover crop used in peach orchards can have a considerable effect on the degree of attack by root knot nematodes and consequently on the growth and yield of the trees. In experimental plots in Georgia, trees on plots where root knot resistant cover crops were planted produced about six times as many peaches in four seasons as trees on control plots where cover crops highly susceptible to root knot were planted. Where no cover crops at all were used and the plots were kept free of weeds, about five times as many peaches were produced as on the control plots.

Some species of the nematode *Aphelenchoides*, which parasitize the aboveground parts of such plants as strawberries and chrysanthemums, can be controlled by repeated spraying of the plants with parathion.

Undoubtedly the simplest method of preventing nematode damage is the use of plant varieties or rootstocks which are not susceptible to attack. Examples are the Shalii, Yunnan, and S–37 peach rootstocks, which are highly resistant to attack by some of the most common species of root knot nematodes in this country, though not to all of the root knot nematode species. Some advances have been made in the development of varieties of other crops resistant to root knot and other nematodes, but progress is necessarily slow and it will be many years before satisfactory nematode-resistant varieties of all crops will be available.

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**Treating Seeds To Prevent Diseases**

R. W. Leukel

Sometimes chemicals are applied to seeds, bulbs, corms, tubers, and roots to prevent their decay after planting and to control seed-borne and soil-borne plant diseases.

To be satisfactory, a seed treatment has to be effective yet reasonably safe from seed injury in case of overdosage; economical, readily available, easily applied, and chemically stable; and not overly poisonous or disagreeable to operators or corrosive to metal.

Fungicides may be classified as seed disinfectants, disinfectants, or protectants, according to the location of the organisms to be combated.

Disinfectants inactivate organisms, such as bunt spores, that are borne on the surface of the seed.

Disinfectants are effective against those located deeper within the seed.

Protectants protect the seeds from attack by organisms that are present in the soil.

Practically all effective seed-treatment materials are disinfectants. Many are also disinfectants and protectants. The formaldehyde and hot-water treatments, however, are disinfectants and disinfectants but are not seed protectants. In fact, seeds that have been treated with formaldehyde or hot water frequently are attacked by soil-borne fungi more severely than are untreated seeds and therefore should be treated also with a protectant before planting.
TREATING SEEDS TO PREVENT DISEASES

Based on composition, fungicides may be organic or inorganic, mercurial or nonmercurial, and metallic or nonmetallic. There are organic mercurials (Ceresan) and inorganic mercurials (calomel); there are nonmercurial metallic organics (Fermate) and nonmetallic organics (Spergon); there are metallic inorganics (copper carbonate) and nonmetallic inorganics (sulfur).

Fungicidal seed treatments may be dry or wet according to the form in which the fungicide is applied to the seed.

In a dry treatment, the fungicide is applied in dust form, usually in a mechanical mixer at rates ranging from 1/2 to 4 ounces or more to the bushel.

Wet treatments once meant soaking the seed in a water solution of the fungicide for a certain period, after which the seed was allowed to drain and dry. Wet treatments now are applied mostly by the slurry method or the "quick-wet" method.

In the slurry method, the fungicide is applied to the seed as a soup-like water suspension, which is mixed with the seed in a special slurry treater. The seed requires no drying but may be bagged immediately for sowing or storage.

In the "quick-wet" method, a concentrated solution of a volatile fungicide is applied to the seed and thoroughly mixed with it. The dosage may range from 1/2 to 5 fluid ounces to a bushel. As in the slurry treatment, that adds less than 1 percent of moisture to the seed. The well-known formaldehyde spray treatment of oats is essentially a "quick-wet" treatment. So also is the method recommended for applying Panogen, Mercuran, Setrete, and several other materials.

Inorganic mercurials used for treating seed are limited practically to mercuric chloride, mercurous chloride (calomel), and mercuric oxide.

Mercuric chloride, as a 1 to 1,000 solution, may be used for treating potato seed pieces, sweetpotatoes, and rhubarb roots for planting. It is also used for seed of crucifers (plants of the mustard or cabbage family), celery, cucumber, pepper, tomato, watermelon, and certain other vegetables. Most seeds are more or less susceptible to injury by mercuric chloride.

Calomel is used on seeds of crucifers, celery, and onion. Mercuric oxide may be used as a dip treatment for sweetpotatoes (1 pound to 30 gallons of water).

Organic mercurials are more numerous and more widely used than the inorganics just mentioned. They are used on seed of small grains, legumes, grasses, cotton, beets, flax, sorghum, and some other field crops, and also on certain corms, bulbs, tubers, and roots and the seeds of some vegetables.

Ceresan, 2 percent ethyl mercury chloride, introduced in 1926, was the first organic mercurial widely used in the United States. It is applied at 2 ounces a bushel. It was followed and largely replaced in 1933 by New Improved Ceresan, 5 percent ethyl mercury phosphate, which is applied at 1/2 ounce per bushel. Both were used mostly on small grains, flax, cotton, peas, hemp, and sugar beets.

Ceresan M, 7.7 percent ethyl mercury p-toluene sulfonanilide, appeared in 1948. It largely replaced the two previous Ceresans because of several advantages over them, including its application as a slurry.

Leytosan and Agrox, 7.2 percent and 6.8 percent phenyl mercury urea, respectively, are applied to small grains, peas, rice, and sorghum at 1/2 ounce to the bushel and to flax at 11/2 ounces. They may be applied in dust or slurry form.

Mercuran, 3.5 percent mercury as methoxy ethyl mercuric acetate, is used at the rate of 1/2 ounce per bushel on small grains. It may be applied as a dust, in concentrated solution by the "quick-wet" method, or in a more dilute solution with a slurry machine.

Panogen, 2.2 percent methyl mercury dicyan diamide, is a concentrated
liquid applied at \( \frac{3}{4} \) fluid ounce per bushel to small grains, \( 1\frac{1}{2} \) fluid ounces to flax, and 4 fluid ounces per 100 pounds of segregated beet seed. It is applied in a special Panogen treater, but can be successfully applied in a slurry treater if diluted with water.

Setrete, 7 percent phenyl mercury ammonium acetate, is a concentrated liquid that may be applied as such at \( \frac{1}{2} \) ounce per bushel, or it may be diluted 1 to 9 with water and applied in a slurry treater.

Mersolite, 5 percent phenyl mercury acetate, is used as a dip treatment (1 pound to 800 gallons) for narcissus corms to combat basal rot.

Merthiolate, sodium ethyl mercury thiosalicylate, is used to prevent corm rot and yellows in gladiolus.

Sanoseed, 7.9 percent ethanol mercury chloride, and Corona P. D. 7, 5 percent mercury in a mercury bromine-phenol compound, are used as dip treatments for seed potatoes.

Semesan, 30 percent hydroxy mercuric chlorophenol (19 percent Hg), is an excellent mercurial used as a wet soak treatment for bulbs, tubers, and corms and as a dust treatment for seeds of flowers and vegetables.

Semesan Bel, a mixture of 2 percent hydroxy mercurichlorophenol and 12 percent hydroxymercurinitrophenol, is used as a dip treatment for seed potatoes.

Puratized N-5-E, 10 percent phenyl mercury triethanol ammonium lactate, is used for treating seed potatoes and lily bulbs.

L-224, an experimental mercury-zinc-chromate material, is an excellent treatment for seed corn.

Aagrano, 3.5 percent ethoxy propyl mercury bromide, is effective against cereal diseases, especially when it is applied in slurry form.

Semenon, 2 percent isopropyl methyl mercury acetate, gave excellent results in controlling diseases of small grains and sorghum. Both Aagrano and Semenon are European products. They were not available in the United States in 1953.

Nonmercurial organic fungicides have increased greatly in number since 1945. Generally they are less effective than the mercurials, but as a rule they are less injurious to seeds and less dangerous to persons using them. The organic sulfurs and quinones are prominent ingredients in these compounds and often are combined with phenol, chlorine, bromine, quinoline, zinc, iron, copper, sodium, or other materials.

Spergon, 98 percent chloranil (tetrachloro-\( \beta \)-benzoquinone), was among the first nonmetallic organics to be widely used for treating seed, especially peas and beans. It is used for vegetable seeds, corn, sorghum, peanuts, alfalfa, clover, soybeans, and some other crops. It may be applied as a dust or as a slurry.

Arasan, 50 percent thiram (tetramethylthiuram disulfide), still another early organic fungicide, is used for the same crops as Spergon. Both will also control bunt in wheat, but are not recommended for treating oats or barley.

Arasan SFX, 75 percent thiram, is the wettable form of Arasan for treating seeds by the slurry method. Tersan, also a wettable form of thiram, is used for the control of diseases of turf and lawn grass.

Phygon (formerly Phygon XL) consists of 50 percent 2,3-dichloro-1,4-napthoquinone and 50 percent talc. It is an effective seed treatment for corn, peanuts, rice, sorghum, and most vegetables. It controls bunt in wheat, but is not recommended for other small grains.

Zerlate, 70 percent ziram (zinc dimethyl dithiocarbamate), is effective as a prebedding dip for controlling black rot in sweetpotatoes. It is similar to Zincate, Methasan, Zimate, and Karbam, as all contain ziram as the active ingredient.

Fermate, 70 percent ferbam (ferric dimethyl dithiocarbamate), like Zerlate, is used as a prebedding dip for sweetpotatoes. Both materials are used also as foliage dusts or sprays.

Dow 9-B, 50 percent zinc trichloro-
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phenate, has been used to treat gladiolus bulbs and seed of cotton, corn, and sorghum.

Dithane Z-78, 65 percent zinc ethylene bisdithiocarbamate, has shown promise as a disinfectant and chemotherapeutic fungicide.

Mycon, 7.7 percent methyl arsensulfide, in extensive field tests, has been found effective in controlling those seed-borne diseases of wheat, oats, and barley that are amenable to control by fungicides.

Seedox, 50 percent 2,4,5-trichlorophenyl acetate, has been used to treat cottonseed. Mycotox is similar to Seedox. Neither is effective as a seed treatment for small grains.

Anticarie, 40 percent hexachlorobenzene, is effective as a seed treatment for the control of bunt in wheat. When applied to the soil it also prevents infection due to bunt spores in the soil. It is not recommended for treating seeds of other cereals.

Pentachloronitrobenzene (50 percent) controlled covered kernel smut in kafir and a 20-percent product controlled bunt in wheat. In Europe this chemical is reported as having controlled infection from soil-borne spores of both common bunt and dwarf bunt when it was applied to the soil at planting time at the rate of about 50 pounds an acre.

INORGANIC NONMERCURIALS are few. Copper carbonate, the first dust seed treatment to be widely used in agriculture, and basic copper sulfate are still used on wheat as bunt preventives. Copper sulfate (bluestone) solution, once a popular seed treatment for wheat, now is used for that purpose to a very limited extent.

Cuprous oxide (yellow or red) serves as a seed protectant for vegetable seeds to prevent seed decay and preemergence damping-off. It is injurious to seeds of lettuce, crucifers, and onions.

Vasco 4, a mixture of zinc oxide and zinc hydroxide, is used on seed of crucifers, spinach, and other vegetables that are sensitive to cuprous oxide.

OTHER SEED-TREATMENT MATERIALS, some effective and some experimental, may be mentioned. The hot-water treatment remains the standard method for controlling the flower-infecting loose smuts of wheat and barley. It is effective also for treating seed of crucifers, onion, tomato, and some other vegetables.

Some gases, such as chlorine, have been suggested for treating large quantities of seed, but their effectiveness has not been proved.

Hot vapor was described in 1944 as being applied to tons of seed exposed on a moving belt. Ultraviolet and infrared rays, short waves, Hertzian waves, diathermy, X-rays, and other similar devices have been tried as seed disinfectants, but none has been proved practicable. Like hot water, these materials would not act as seed protectants, and so a supplementary treatment would be necessary to guard against soil-borne fungi.

TESTING THE EFFECTIVENESS of fungicides in the control of seed-borne diseases presents two chief difficulties: Obtaining a supply of suitable seed that is sufficiently infected to furnish an adequate test for the fungicides, and obtaining environmental conditions after planting that favor infection in the plants.

In diseases like bunt of wheat, in which the causal spores are located on the surface of the seed, clean seed can be infested artificially if a supply of spores is available. But many disease organisms are located deeper within the seed in a manner that cannot be duplicated artificially. So one has to get seed from a heavily infected field, or, better still, from the seed lot that produced that crop. At times seed obtained from a heavily infected field may be infected too lightly to serve as an adequate test for seed treatment because conditions for infection may have been very unfavorable at the critical period.

We must observe certain precautions in testing fungicides for seed
treatment. The seed should be thoroughly cleaned, before treatment, to remove dust, chaff, weed seeds, and other substances, all of which take up much of the fungicide. Proper dosage is important because the seed sample used usually is relatively small and hence the amount of fungicide applied must be carefully weighed or measured. In treating cereal seeds experimentally, 500 cubic centimeters is a convenient sample. This volume, which is 1/70 of a bushel, simplifies the conversion of ounces-per-bushel to grams-per-sample. If the desired rate of application is one ounce (28.34 grams) per bushel, 1/70 of a bushel will require 1/70 of 28.34 grams, or 0.4 grams. Rates of 1/8, 2, 3, and 4 ounces per bushel are easily converted to 0.2, 0.8, 1.2 and 1.6 grams per sample, respectively. Differences in bushel weight among different seeds or seed lots then can be ignored. It also avoids the error involved in treating samples of light, chaffy seed as compared with plump, heavy seed. The light seed should receive more fungicide for each weighed bushel than the heavy seed.

When small samples of seed are treated, the capacity of the container should be such that it is only half filled by the sample. It should be first “conditioned” by treating in it a sample of seed at a rate sufficient to coat the inside with the fungicide. This seed is then discarded.

After the fungicides have been applied to the different samples, the containers should be shaken in some mechanical contrivance so that all receive the same amount of mixing. Thorough mixing is especially essential when applying the nonvolatile materials.

Between the treatment and sowing, the treated and untreated samples should be stored at a moderate temperature and preferably at a low humidity. Metal or glass containers are preferable to paper envelopes because if the envelopes are stored in contact with one another, the fumes from a volatile mercurial fungicide in one envelope will treat the seed in the adjoining envelope. If this envelope contains the untreated check sample, it will be rendered useless for that purpose.

The effects of the treatments on germination of the seed, seedling emergence, disease control, and plant growth and yield are among the details usually desired from seed-treatment experiments.

Germination tests, to study any harmful effects of the fungicides on the seed itself, may be made on wet blotters placed in incubators (in which temperature and humidity are controlled) or in steamed wet sand or soil. Relatively disease-free seed and disinfected soil should be used in the tests, because the harmful effects of a fungicide on the seed may be masked by its protective effect against seed-borne or soil-borne fungi that cause seed rot or preemergence damping-off.

The use of infested soil is essential for determining the effect of the seed-protectant qualities of treatments on emergence. That may involve the isolation and culture of soil-borne fungi, such as species of *Pythium*, *Fusarium*, *Helminthosporium*, and *Rhizoctonia*, and using the pure cultures to inoculate soil in which the treated (and untreated) seed is to be planted. Such tests may be made in the greenhouse in pots, flats, or beds. The soil should be steam fumigated before being inoculated in order to determine the effectiveness of the fungicides against each specific soil-borne fungus culture.

The effectiveness of fungicides in the control of seed-borne diseases, such as the smuts of cereals, that are not apparent in the seedling stage usually is studied in field plots. The seed should be sown at the proper date so that the soil temperature as well as moisture before emergence are conducive to infection. For the cereals, that calls for soil that is not too moist for aeration and germination of the seed-borne spores. Along with this
somewhat submedium moisture content of the soil, the temperatures considered conducive to infection by cereal diseases are: Bunt of wheat, 41° to 50° F.; barley covered smut, 50° to 68°; false loose smut of barley, 59° to 68°; the smuts of oats, about 64° to 72°; the barley stripe disease, 46° to 59°; and kernel smuts of sorghum, 75° to 86°. Periods favorable to infection cannot be predicted with certainty. Frequently, because of the absence of such conditions, significant field data are not obtained.

The effect of the seed treatment on yield should be obtained by treating and sowing relatively disease-free seed in replicated plots along with untreated seed. Increases in yield from such treated seed presumably reflect the seed-protectant qualities of the fungicide used.

CEREAL SEED TREATMENT was rather widely practiced for quite a few years before the treatment of other crop seeds was generally recommended. The reasons perhaps were that smuts could be seen in cereals and that it was discovered early that some of them could be prevented by seed treatment.

The beneficial effects of the treatment of cereal seeds may result from the elimination of seed-borne diseases, the prevention of seed rot and seedling blight, and the suppression of weeds by better and more even stands.

One of the greatest benefits lies in the elimination of some seed-borne fungi or bacteria that cause primary infection lesions from which the disease spreads to other plants. Outstanding examples are certain helminthosporium diseases of wheat, oats, and barley. This spread by secondary infection may cause heavy loss, although only a small percentage of the seed sown may have been infected. Annual seed treatment of cereal seed is now considered a wise farm practice because the use of disease-free or treated seed one year does not insure the production of disease-free seed for the next year's crop. Airborne spores from neighboring fields may contaminate the heads of grain grown from disease-free seed, so that seed from these heads, if sown untreated, may produce a diseased crop the following year.

Growers of certified seed have found it wise to guard against this source of infection, as it may disqualify their fields for certification.

Wheat is treated mostly for the control of bunt, which if only seed-borne is the most easily controlled of all the seed-borne cereal smuts. Ceresan M, Agrox, Setrete, Panogen, Leytosan, Mercuran, Aagrano, and some other organic mercurial compounds are generally most effective in bunt control, especially if infection is severe. Most are applied at less than an ounce to the bushel. Many nonmercurials also are effective—copper carbonate, basic copper sulfate, Arasan, Spergon, Phygon, Anticaric, Mycon, and several experimental materials. The mercurials by and large are preferable because they eliminate also some of the pathogens borne more deeply within the seed. Loose smut (caused by *Ustilago tritici*) is prevented only by the hot-water treatment.

Rye may be treated to prevent the spread of seed-borne diseases, like stalk smut and bunt. The treatments for wheat may be used also for rye.

Barley is treated largely for the prevention of covered smut, black or false loose smut, and stripe disease. Seed treatment also reduces the amount of primary infection from such diseases as bacterial blight, scab, net blotch, and spot blotch. The fungicides recommended are restricted largely to the organic mercurials such as Ceresan M, Panogen, Leytosan, and Agrox. The nonmercurial organics may improve stands and reduce infection by these diseases to some extent but, with a few exceptions, they seldom control them satisfactorily.

The flower-infecting loose smut (caused by *Ustilago nuda*) is controlled only by the hot-water treatment.
Seed of oats, like that of barley, is treated most frequently for the prevention of the smut diseases, which are visible at heading time. The effective treatments are restricted largely to the organic mercurials, although the formaldehyde spray treatment is widely used. It is cheap and effective but may injure the seed. Also it is not a seed protectant. The effective organic mercurials also prevent primary infection from seed-borne halo blight, fusarium blight, anthracnose, and the helminthosporium diseases; they will not prevent these diseases, however, if the causal organisms are present in the soil.

Corn, a warm-season crop, is subject to many diseases, most of which cannot be prevented by seed treatment. Disease control or prevention is largely a matter of developing disease-resistant strains and providing favorable growing conditions for the plants. The chief purpose of corn seed treatment is to prevent seed rot and seedling blight caused by seed-borne and soil-borne fungi, especially when cold, wet weather follows planting. For many years Semesan Jr. (1 percent ethyl mercury phosphate) was most widely used for the purpose, but it has been supplanted largely by the nonmercurial organics, such as Phygon and Arasan, and Dow 9-B. The experimental compound, L-224, a mercury zinc chromate, and Dithane also have proved to be effective. Mercury compounds may injure corn seeds that have been damaged near the embryo by rough handling, especially if planting is delayed after treating.

Hybrid corn seed, which constitutes about 80 percent of the corn seed planted, is treated at the seed houses before it is sold to the growers; thus the work of seed treatment of corn mostly has been taken out of the hands of individual growers.

Treatment of rice seed was not a generally recommended farm practice until about 1947. Experiments proved that the treatments increased stands, especially in the early seedings when the soil was cold and wet. Often yields also were improved. Best results were obtained with Ceresan M, Phygon, Arasan, and Spergon. Ceresan M prevented seedling blight caused by *Helminthosporium oryzae*. Dow 9-B injured the seed after long storage. Cuprocide (cuprous oxide) seemed best for seed sown in water, but it may injure presprouted seed. Rice may be fumigated with methyl bromide to combat the seed-borne rice nematode. Exposure to a concentration of 11/4 pounds of methyl bromide to 1,000 cubic feet of space for 12 to 15 hours will kill the seed-borne nematodes without injuring the seed seriously.

Sorghum, like corn, is benefited most by seed treatment when cold, wet weather follows planting. It reduces seed rot and seedling blight and prevents infection by the kernel smuts. The nonmercurial organics, such as Phygon and Arasan, have been found beneficial in improving stands and controlling smut. In varieties whose seeds have persistent glumes, however, the kernel smuts are controlled more effectively by the use of volatile organic mercurials, such as Ceresan M and Panogen.

Sugar beet seed is treated mostly to combat seed-borne infection by *Phoma betae* and *Cercospora beticola*. Seed treatment is effective in preventing preemergence damping-off, caused either by seed- or soil-borne fungi. Materials used for beet seed treatment include the organic fungicides N. I. Ceresan, Ceresan M, Panogen, Phygon, and Arasan. Inorganic mercury compounds, cuprous oxide, and various mixtures of mercurials with copper carbonate have proved effective experimentally but never have come into widespread commercial use.

Preemergence and postemergence damping-off have been successfully combatted in greenhouse experiments by applying an Arasan-fertilizer mixture to the soil so that the sugar beet seed germinated in the soil impregnated with the mixture and the seed-
lings grew through it. The Arasan was used at a rate of about 4 pounds an acre. Field experiments to control black root by Arasan-fertilizer mixtures have not given consistently favorable results.

Seed treatments for the control of damping-off caused by *Pythium* species, *Phoma betae*, and the *Rhizoctonia* species are beneficial unless soil infestation is severe or soil moisture conditions are unfavorable. Black root, caused by *Aphanomyces cochlioides*, however, is not prevented by seed treatment.

Proper soil management helps reduce the soil populations of sugar beet pathogens. Adequate drainage and heavy application of commercial fertilizers, especially phosphate, are important. Of great importance also is a rotation in which sugar beets do not immediately follow a legume sod crop but follow an early fall-plowed legume. Such handling of the legume crop is necessary because clovers, sweetclover, and alfalfa harbor the various pathogens that cause damping-off. Their sods, if spring-plowed, produce peak populations of the fungus at the period corresponding to planting time for sugar beets. If associated with proper soil management, control of excessive soil moisture by drainage, and a good fertilizer practice, seed treatments show value.

Cotton, flax, and hemp respond to seed treatment in the order named. The diseases of cotton that are reduced somewhat by seed treatment are bacterial blight or angular leaf spot (*Xanthomonas malvacearum*), anthracnose (*Colletotrichum gloeosporioides*), sore shin (*Rhizoctonia solani*), and seedling blight caused by species of *Aspergillus*, *Fusarium*, *Diplodia*, *Sclerotium*, and other fungi.

Seed of cotton is generally delinted before being treated because seed-borne infection is more easily eliminated in delinted seed. Delinting may be done mechanically by reginning or chemically by acid treatment. Mechanical delinting may injure the seed and impair its germination. Acid-delinted seed germinates better than fuzzy seed, but it rots more easily, especially in cold, wet soil. Effective seed treatments largely prevent that. Organic mercurials (such as the Ceresans) with some exceptions have generally been more effective than the nonmercurial organics (such as Spergon, Dow 9–B, Phygon, Arasan, and Seedox) in eliminating seed-borne infection. Some growers object to the use of poisonous fungicides, such as the mercurials, however, because excess treated seed may become mixed with untreated seed used for making cottonseed meal or oil. The nonmercurials are especially useful as seed protectants for acid-delinted seed.

Treatment of flaxseed is made necessary largely because seed, especially of large-seeded kinds, may be injured in threshing. Many of the fractured seeds rot after planting, particularly in heavy soils, unless they are first treated with an efficient protectant, which prevents invasion by species of *Alternaria*, *Penicillium*, *Fusarium*, and *Pythium*. Several seed-borne diseases of flax are alleviated by seed treatment. Pasmo (*Mycosphaerella linorum*), when seed-borne, causes primary infection lesions, which initiate secondary infection in other plants. Browning and stem break (*Polyspora linii*) and anthracnose (*Colletotrichum lini-colum*) also may be seed-borne.

One of the difficulties in treating flaxseed is the failure of dry fungicides to adhere to the smooth seed coat. The seed therefore requires a much heavier dosage of dusts than is applied to most other seeds. Wet treatments cause gumming of the seed because of the mucillaginous coat. The organic mercury dusts usually are applied at 1½ ounces per bushel. Nonmercurials are applied somewhat more heavily.

Seed treatment of flax may increase stands, but increased yields do not always follow unless an abundance of weeds prevents sufficient branching to compensate for the thinner stands from untreated seed.
Treatment of hempseed with New Improved Ceresan, Spergon, and Arasan was found to improve stands when planting was followed by unfavorable conditions for germination and growth.

Treatment of seeds of forage crops controls some diseases, such as certain smuts in slender wheatgrass, millet, Canada wildrye, and Sudangrass. Seed treatment sometimes has increased stands in some species of Lespedeza, Lotus, Medicago, Melilotus, and Trifolium. Other species are injured by certain treatments when the treated seed is sown in dry soil.

Seed of winter peas, mung beans, cowpeas, hop clover, hairy vetch, and alfalfa gave better germination, improved stands, and superior plants when treated with Spergon, Arasan, Phygon, or Dow g-B in extensive field and greenhouse tests in 1949. Nodulation was not inhibited by treatment when the nitrogen-fixation culture was applied to the treated seed immediately before sowing. Some investigators, however, say that legume seed should not be treated before being inoculated if it is to be sown in soil not previously cropped to legumes.

Experiments with treating soybean seeds have been more numerous and extensive than with those of almost any other legume. In general, improved stands were had after the use of Arasan, Spergon, Phygon, and Dow g-B. Organic mercurials are sometimes injurious. Increased stands due to treatment were not always followed by increased yields, probably because branching of the plants often compensates for thinner stands and because a higher percentage of the soybean flowers in a thin stand of plants will form pods.

Treatment of peanut seed is a profitable farm practice, especially when mechanically shelled seed is used. Increases in stand have ranged from 30 to 100 percent. Uninjured hand-shelled seed frequently gets no benefit from seed treatment except when unfavorable growing conditions follow planting. Arasan, Spergon, Phygon, Dow g-B, and Ceresan M are commonly recommended.

Vegetable seeds are treated primarily to prevent seed rot and damping-off. Sometimes the control of seed-borne diseases is a major aim. The materials so used include Arasan, Phygon, Spergon, Fermate, Semesan, Dow g-B, N. I. Ceresan, Ceresan M, Cuprocide, zinc oxide, zinc hydroxide, mercuric and mercurous chlorides, copper sulfate, phenothiazine, Zerlate, Dithane, and others.

Arasan and Spergon are two widely used fungicides for vegetable seeds. Arasan seems most suitable for seed of beets, chard, and spinach. Spergon seems best for legumes.

Some fungicides display differential benefit or injury toward the seed of certain crops. Cuprocide, for example, is injurious to seed of crucifers and lima beans and causes necrosis, delayed absorption, and delayed seedling growth in peas. It is especially beneficial, however, to lettuce seed, which in turn is injured somewhat by Arasan and Fermate. Zinc oxide is injurious to peas but is highly beneficial to seed of spinach and crucifers.

Potato tubers often are treated before planting. Fifteen or more diseases of potatoes may be transmitted in or on the tubers. Few of them are amenable to control by treating the tubers before planting. Scab, rhizoctonia or black scurf, and fusarium seed-piece decay respond to seed treatment if they are seed-borne. The principal treatments recommended are hot formaldehyde dip, cold formaldehyde soak, hot mercuric chloride dip, cold mercuric chloride soak, yellow oxide of mercury dip, and the hydrochloric acid-mercuric dip. Several organic mercury fungicides also are used. Among them are Semesan Bel, Sanoseed, and Corona P. D. 7, all of which are made specifically for treating potato seed pieces. Beneficial results have been obtained also from the use of Fermate, Semesan, Spergon, and Dithane.
Sweetpotatoes used for planting are treated to prevent injury due to seed-borne black rot, scurf, and stem rot and soil-infesting pathogens as species of *Pythium*, *Rhizoctonia*, and *Sclerotium*. The standard treatment is one 10-minute dip in a 1 to 1,000 mercuric chloride solution, or a dip in Semesan Bel solution (1 pound to 7½ gallons of water). Both are effective but sometimes they delay or reduce the production of sprouts. Fairly good results without injury have been had with Spargon, Phygon, Fermate, Zerlate, Tersan, and Puratized N–5–E.

Some vegetable diseases, caused by soil infestation, are partly or wholly prevented by applying fungicides to the soil, usually with the fertilizer. Clubroot of cabbage has been controlled by adding calomel to the soil along with fertilizer and hydrated lime. Onion smut has been controlled by applying sodium nitrite, calcium nitrite, potassium nitrite, or Fermate to the soil a few days before sowing. Arasan, similarly applied, controls onion smut and damping-off. Phygon, applied to the soil in fertilizer, controls damping-off in eggplant, pepper, beet, cucumber, and tomato. Different formulations of Dithane, applied to the soil, are said to be effective against red stelle in strawberries, downy mildew in lettuce, blight in peppers, bed diseases of mushrooms, and damping-off in peas. The material acts either as a soil disinfectant or as a therapeutic agent.

Treating the seeds of ornamentals is a common practice. Semesan has been widely used for this purpose. The nonmercurial organics, such as Arasan and Spargon, also are satisfactory.

Ornamentals grown from bulbs, corms, tubers, and roots also are benefited somewhat by the use of fungicides. Gladiolus corms, for example, are helped by a 15-minute dip in a solution of 1 pound of New Improved Ceresan in 50 gallons of water just before planting. The standard mercuric and mercurous chloride solutions also are used. Dipping the corms in slurries of Spargon, Fermate, or Dow 9–B after digging is beneficial.

Tulip bulbs have not responded very well to treatment. Some fungicides have lowered the yield of bulbs. Dipping bulbs in slurries of Spargon or Fermate has increased some yields. Narcissus bulbs may be dipped in a phenyl mercury acetate solution (1 pound to 800 gallons) for 5 minutes, after digging in spring and again before planting in fall, to control fusarium basal rot. Arasan SFX, Dow 9–B, and New Improved Ceresan also are beneficial.

Hormones in seed treatments have been tried often. Results have varied. Of 30 investigators whose work was reviewed, 10 reported beneficial results from the use of growth-promoting substances on seeds. Twenty failed to obtain any benefits. Apparently the conditions under which hormones may or may not be beneficial in seed treatments are not fully understood.

Growth-promoting substances are used commercially to induce root formation in cuttings, prevent fruit drop in apple orchards, induce fruit formation without pollination in some plants, and to prevent sprouting in stored potato tubers. It seems reasonable that under proper conditions the materials may improve seed germination and early growth of the seedlings. Definite and reliable recommendations cannot be made until more extensive research has been carried out.

Synergism and antagonism between different fungicides, when mixed together, has been demonstrated often enough to restrain one from mixing fungicides with one another or with insecticides without knowing how they will affect each other and the seeds on which they are to be used.

A few examples of the effects of such
mixing may be mentioned. The addition of New Improved Ceresan to DDT reduced both the fungicidal action of Ceresan and the insecticidal action of DDT. Magnesium oxide, added to copper carbonate or to Spergon, reduced the beneficial effect of those materials on emergence in wheat and on smut control in sorghum. Magnesium oxide also reduced the fungicidal efficiency of cuprous oxide and of Dow 9-B, but seemed to increase the fungicidal effectiveness of sulfur. Pyrophyllite containing 3 percent DDT when mixed with Dow 9-B reduced the control of sorghum kernel smut from 0.3 percent to 40 percent, with 60 percent infection in the check. Copper compounds in general are reduced in effectiveness when mixed with materials high in protein.

A good fungicide, prepared especially for seed treatment, usually is a well-balanced combination of active ingredients and suitable diluents, perhaps with the addition of wetting and dispensing agents, dyes, and other materials in proper proportion. The addition of other materials, such as insecticides or other fungicides, may cause chemical reactions and the formation of compounds that are ineffective as fungicides or injurious to the seed.

The labels on containers for fungicides used for dusting or spraying vegetation often mention the insecticides with which they are not to be used. Labels for seed-treatment fungicides, however, do not include such directions because, as a rule, those fungicides are not mixed with insecticides or other fungicides. That may change, however, with the growing need for combatting insects that attack seeds after they have been planted. Experiments in New York showed that Arasan SFX mixed with chlordane, lindane, or aldrin and applied to lima beans prevented both seed rot caused by fungi and seed injury due to the seed-corn maggot. Mergamma, a treatment for cereal seed, contains phenyl mercury urea for the control of certain cereal diseases and benzene hexachloride for wireworm control. The number of these insecticidal-fungicidal seed-treatment combinations doubtless will increase, but their use in combination should follow careful chemical and biological experiments.

Seed injury following treatment was common when the treatments were mostly copper sulfate solutions, formaldehyde, or mercuric chloride, especially when planting was delayed after treatment.

When copper carbonate dust began to be used to treat wheat, it was found that delayed planting after treatment caused no injury to the seed but actually protected it against rodents and insects in storage. The more volatile organic mercury treatments, however, occasionally lowered the viability of seed after storage periods of more than a few days, especially when the moisture content of the seed was high. Several factors govern the degree of such injury: The moisture content of the seed; the volatility of the fungicide and the rate at which it is applied; the length of the storage period; the temperature, humidity, and aeration during storage; the kind of seed (seed of some genera, species, or varieties are more susceptible to chemical injury than are those of others); and the condition of the seed coat (cracked, chipped, or broken seed coats are conducive to seed injury).

If seed is to be stored for a while after treatment with a volatile fungicide, its moisture content should be relatively low—13 percent or less for cereals—and a lighter rate of application used. Different portions of oats of 12 percent moisture content were treated with New Improved Ceresan at 1/2 and 1/8 ounce per bushel and either sown at once or stored for several weeks. The seed treated at the 1/2-ounce rate yielded better when sown the day after treatment. The seed that got the lighter application yielded better when
sowing was delayed for several weeks after treatment. Several experiments proved that sound seed of wheat, oats, and barley of good quality and proper moisture content, treated with one of the better organic mercury disinfectants at the recommended rate and properly stored for a year, was not injured in viability but yielded better than did untreated seed similarly stored. Occasionally in the more humid areas of the Southeast, treated seed is stored with a too-high moisture content and the poor viability is ascribed to the treatment. Subsequent tests often show that the viability of the untreated seed is equally poor.

Pretreatment of seed sold by seed dealers has been advocated for years. Some large seed houses pretreat seed of some field crops, such as cereals, flax, cotton, sugar beets, peas, corn, broomcorn, and some forage crops, either as a general practice or on a buyer's request.

Pretreatment of seeds by all dealers would mean cheaper but more general and more effective seed treatment; fewer outbreaks of preventable diseases; less waste of chemicals; less need of storing large stocks of chemicals in many places; more economical packaging, distribution, and use of seed-treatment chemicals; the use of the proper disinfectant at the proper rate for each type of seed; and many other advantages.

Some objections to general pretreatment of seed are valid enough. There is no general agreement as to what treatment is best for each kind of seed. Some buyers object to planting "poisoned" seed. Some persons might not realize that treated seed is sometimes poisonous and they might suffer injury. I think, though, that all the advantages of pretreating seed outweigh the objections.

Continued advances in seed treatment doubtless will bring new and better fungicides, better apparatus, and improved procedures into use. Fungicidal materials that promise to be more effective but less costly and less poisonous and disagreeable are sought. Slurry treaters that are more accurate and less troublesome are promised. A process that will fix the slurry fungicide to the seed and prevent its dusting off when the dried seed is handled will rid the slurry method of its chief shortcoming.

The possibility of systemic fungicides and chemotherapeutic disease prevention has been suggested and has been demonstrated in a few instances. This might eventually lead to the prevention of such Nation-wide calamities as epidemics of stem rust of cereals. Such fungicides would be applied to the soil and, when taken up by the plant, would render it resistant or fatal to the fungus attacking it. The fact that a tiny amount (3 parts per million) of selenium in soil is fatal to aphids and spider mites feeding on plants grown in the treated soil should encourage the search for fungicides equally effective against fungus infection but not poisonous to humans and animals. Such fungicides would be a tremendous advance in our war against plant diseases.

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