Concepts and Classifications of Seed Treatments

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The term "seed treatment" has traditionally been associated with, if not limited to, fungicides. The pesticide control officials define fungi as small, non-green plants such as bacteria, mildews, molds, rusts, smuts and yeasts; and a fungicide is defined as a substance or mixture of substances intended to prevent, destroy, repel or mitigate any fungus. As recently as 15 years ago seed treatments were almost entirely fungicides. The Farm Chemicals Handbook for 1962, however, describes 3 antibiotics, 1 bird repellent, 4 fungicidal fumigants, 4 growth substances, 12 insecticidal fumigants, 17 insecticides, 20 mercurials, 1 mercury-insecticide combination, and 17 non-mercurial fungicides.

Definition of Seed Treatment

In the first deliberation of a group attempting to prepare a uniform state seed law, we tried to define seed treatment in terms of substances designed by plant pathologists for disease control. By 1950 seed treatments were regarded as those substances or processes effectively applied to seeds for the control of plant disease organisms or insect pests.

The control officials' conception of seed treatments has changed radically since 1950 because they are not limited to fungicides and insecticides. They include any and all pesticides that are applied to seeds. The Federal Seed Act recognizes this fact in the definition: "the term 'treated' means given an application of a substance or subjected to a process designed to reduce, control or repel disease organisms, insects or other pests which attack seeds or seedlings growing therefrom". The other pests may include bacteria, birds, herbs (weeds) and rodents.

Present Definition of Seed Treatment

The idea that seed treatments are limited to pesticides is contrary to fact. Are not colchicine, gibberellins, hormones, legume inoculants, radioactive isotopes, radiofrequency waves, sulfuric acid and other seedcoat softeners and X-rays to be regarded as seed treatments? If they have been applied to seeds, the answer is "Yes".

The laws of one state - New York - contain a definition that truly covers all seed treatments. It reads "the term 'treated' means that the seed has received an effective application of an approved substance or method designed to control or repel plant disease organisms, insects or other pests; or has received some other treatment to improve its planting value".

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The revised (1961) Recommended Uniform State Seed Law includes a clear, concise definition reading: "The term 'treated' means that the seed has received an application of a substance, or that the seed has been subjected to a process for which a claim is made". Unfortunately certain substances and effects of processes may be lost or dissipated during storage so the control official cannot prove, or even determine what had been applied to the suspect seed lot.

Classifications of Seed Treatments

In a discussion at the 1960 Short Course, seed treatments were separated into two general groups on the basis of mode of action - disinfection and protection. Although applied to fungicides only, insecticides might also be placed in these two broad classes.

The 1960 discussion also touched upon other groupings based upon accomplishment, application and chemical composition. These and other logical classifications are presented in the following paragraphs.

1. **By legal definition** a seed treatment is whatever a certain state or federal seed law legislates it to be. Laws in all states cover fungicides and insecticides. Other pesticides, growth regulators and legume inoculants are included in certain states. Unfortunately laws and regulations may be more concerned with the harmful, rather than the beneficial, nature of seed treatments.

2. **By what they do or by the organisms to be controlled** seed treatments are classified as (a) adjuvants, diluents or stickers, (b) bactericides, (c) fungicides, (d) growth regulators, (e) insecticides, (f) legume inoculants, and (g) animal or bird repellents and rodenticides. This classification is too advanced and realistic for control officials. The Pesticide Handbook by D. E. H. Frear, however, groups some 8,000 product listings in a similar manner.

3. **By composition or form of energy** we could classify seed treatments as:
   
a. **Antibiotics and gibberellins** which are materials of microbial origin - extracted from molds or other microbes.
   
b. **Biologic material** such as the legume inoculant bacteria. It is possible that *Bacillus thuringiensis*, a microbial insecticide, could be effective as a seed treatment.
   
c. **Chemicals or chemical formulations** such as (1) acids and alkanes used to erode seedcoats, (2) cyclodiene insecticides such as aldrin, dieldrin and heptachlor, (3) metallic inorganic compounds such as copper carbonate and mercuric bichloride, (4) metallic and pure organics such as the halogenated insecticides - DDT, lindane, etc.; mercurials used in treating small grains; thiocarbamates - ferbam and thiram; quinones - chloranil and dichlone; organic phosphate insecticides - malathion and phorate; and others containing nitrogen or sulfur - captan, PCNB, etc., (5) crude anthraquinones or bird repellents,
(6) insecticidal fumigants—ethylene dichloride, methyl bromide, etc., and
(7) trace elements such as molybdenum.

d. Heat as hot air and hot water.
e. Physiologic effects such as cold water soak to eliminate loose smut.
f. Radiofrequency waves used to hasten germination of hardseeded legumes.
g. X-rays to induce cellular changes.

4. By form or method of application treatments are: (a) dusts usually consisting of an inert diluent carrying 0.8 to 75 percent of the actual toxicant, (b) slurries consisting of wettable powders and water. They are currently preferred to dusts since the toxicant is not as liable to bother workmen, (c) liquids, usually consisting of a toxic material dissolved or suspended in a diluent. The organic mercurials are commonly formulated as ready-mix and concentrated liquids, (d) gases as used in the fumigation of grain to kill insects or to eliminate oat smuts. The pesticide may be obtained as a liquid—formaldehyde, methyl bromide, etc., but volatilizes to reach the seeds as a gas, and (e) electrical, molecular or thermal energy which kills pests or effects changes not accomplished by dusts, slurries, liquids or gases.

5. By degree of toxicity three groups are recognized in seed laws but commercial products are toxicologically classed as 1 or practically non-toxic such as aluminum oxide or legume inoculants to 6 or super toxic for organic phosphate insecticides such as Ethion and phorate.

Control officials regard seed treatments as non-toxic within stated limits—legume inoculants, malathion, pyrethrins, etc.; possibly harmful—captan, dichlone, thiram, etc.; and highly toxic—aldrin, mercurials, phorate, etc. This classification is a compromise between accuracy and convenience and does not necessarily relate to the toxicity of the treated seed. Grains carrying the recommended dosages of a mercurial may actually be less poisonous than seeds treated with a non-mercurial.

6. The mode or site of action is the usual classification of seed treatments. It is related to what happens and where and when it happens.

a. Disinfestation is the destruction, inactivation, or removal of bacteria, fungi, insects or nematodes that are present on the outside of the seed without having entered or established host relationship with the seed. The treating of wheat to control stinking smut, the killing of superficial insect and nematode eggs, and the mechanical removal of ergots and sclerotia is disinfestation or decontamination. At least 100 chemicals are effective in controlling stinking smut of wheat.

b. Disinfection is the arresting or eradicating of infections or
actual host contacts of an organism with a seed through use of a substance or process. The volatile mercurials will reduce or control infections that are not deep-seated such as the smut of oats, scab of wheat and seedling blight of barley. PCNB will inhibit seed rots of beans and peas, while thiram will disinfect Diplodia rot from corn seed. A pyridine derivative has reduced Ascochyta infection of pea seed.

The deep-seated (loose) smuts of barley and wheat are controlled only by energy or physiologic processes such as the hot water, cold water and salt-cold water soaks. Hot water will also reduce infections of blackleg and black rot in cabbage and seedling rot in certain flower seeds.

The application of a disinfectant or disinfectant has often been recommended only when a disease organism is known to be present. The fallacy of this advice is that a few seeds may actually be infected although several hundred others were found to be disease or insect free. Only one diseased seed may introduce a disease into a previously clean area or field. The partial loss of one crop may be more costly than treating expenses for 10 years.

With increased emphasis on quality not just quantity of food, it is important to eliminate diseases not merely to reduce them. Although treatments should usually be applied in amounts that will not injure seeds, some injury is justified if the quality of the crop is improved.

The application of a pesticide in the form of a gas - fumigation - is the simplest means of eliminating insects but is not adapted to control of diseases. Ethylene oxide, for example, will kill many disease borne fungi but seed germination is reduced.

Until a good fumigant of disease organisms is developed as a satisfactory treatment each seed should receive its approximately equal share of the liquid or solid treating material. Although volatilization or fume action does redistribute a chemical - usually formaldehyde or an organic mercurial - to seeds not initially contacted the most effective and least injurious disinfection is accomplished by an originally uniform distribution of toxicant. Mercurials of the dicyandiamide and hydroxyquinolate groups were proved by biologic and radioactive tests to pass from one seed to another in the vapor stage.

c. Protection is the establishing of a barrier between seeds and organisms, that may attack them later. The organic mercurials, at proper dosage rates, not only disinfect seeds but also protect them. Thiram not only reduces dry rot infections in corn seed but also prevents organisms in the soil from destroying the germinating seed. PCNB is excellent in both its disinfecting and protecting action against the Botrytis, Rhizoctonia and Sclerotinia fungi. Malathion, pyrethrins and piperonyl butoxide protect seeds from storage insects while aldrin, DDT, dieldrin and heptachlor will repel soil-borne insects. The fungicide hexachlorobenzene or HCB is popular for the single purpose of killing stinking smut spores on wheat seed. But HCB, if applied in massive dosages, is also a protectant of wheat seed against dwarf bunt spores.
in the soil.

Uniformity of coverage is necessary when non-volatile protectant pesticides are applied to seeds. Each seed must receive its fair share of the treatment. A slurry application usually covers the seed lot uniformly but portions of the pesticide may slough off during handling. Increasing the total amount of material whether dust or slurry usually results in better coverage. But heavy dosages cause packaging, planting and diverting-to-feed difficulties.

The condition of the seed affects its susceptibility to disease and hence the need for protection. Pericarp breaks in corn permit fungi to reach the stored food and the germ. Thin pericarps and high sugar contents of sweet corn are also advantageous to decay fungi. Old and low vigor seeds of many kinds germinate slowly and are susceptible to disease fungi for a comparatively long time. A higher than usual dosage rate will partially compensate for seed damage, old age, low vigor or genetical weakness.

Systemic pesticides - chemicals which are absorbed by the seed but move into the seedling - protect for a relatively long period. Certain antibiotics are translocated into seedling growths and reduce fungus infections. A new chemical containing both nitrogen and sulfur protects pea seedlings from attacks by damping-off fungi. Di-syston placed on, or with, seeds will repel insects which contact the seedling.

Laboratory germination tests are more accurate when a protectant fungicide is placed on the seeds. Common mold fungi and bacteria thrive in the moist atmosphere of the germinator and may weaken seeds or destroy seedlings. Seedlings of beans, melons and peas are especially susceptible to laboratory bacteria and molds. A single corn or wheat seed infected with the scab fungus supplies enough inoculum to destroy an entire test of 100 seeds. These troubles are overcome by either spacing the seeds two inches apart or by placing a fungicide on the closely spaced ones. The former method may add $1.00 but the latter only $0.05 to the usual cost of a bean or corn test.

In comparison of 30 materials the organic mercurials were superior to other formulations in protecting corn and small grains from scab. Preparations containing pyridine or thiram were satisfactory.

Inoculation is the placing of selected strains of the Rhizobium bacteria on legume seeds. Traditionally a farmer applied the inoculant immediately before planting. But preinoculants which are protected by humus, sugar or the seeds themselves will survive for several months under ordinary storage conditions. Under adverse conditions - dry, hot or chemically-permeated storages - the bacteria may die before the seed is planted. According to a recent report pathogenic fungi may accompany the bacteria and infect the legume seedlings.
Detection and Measurement of Seed Treatments

High quality seed is not obtained by merely adding a known amount of a material to a certain volume of seed. Some form of quality control is needed to insure that the material is effective, that the dosage rate is correct, and that the coverage is uniform. The detection method may be simple or complicated, inexpensive or costly, rapid or slow, qualitative or quantitative but it should be informative. State and Federal seed control laboratories are increasing their capabilities to detect and measure treatments and may challenge doubtful label statements.

The visual observation of dry seeds is certainly the simplest and most rapid test. If the dosage rate of a solid material is at least 1 ounce per bushel of seed it can be detected and measured approximately. A standard sample should be prepared and used as a comparison. Uniformity of coverage can be determined at 10X magnification and the dosage rate measured at 50X.

Specific chemicals and especially proprietary formulations may be revealed and measured but not identified positively. Chloranil and dichlone are exceptions; their distinctive colors are not easily altered or masked. The green color of the liquid Morven is also diagnostic. The organic mercurials are present in minute amounts and are not detectable visually. At 50X magnification, however, the mercury-inert dust formulations present at greater than 1/2 ounce/bushel rate can be observed for uniformity of coverage. A red dye if part of a liquid formulation indicates but does not prove that a mercurial is present. The pattern of application is easily and accurately determined at 20 to 50X magnification. Neither the percentage of red-dyed surface nor the brightness of color reveals the amount of mercury originally or finally present. Through fume action some mercury has left the originally-treated seed to be redeposited on other seeds or to be lost.

Preinoculants are readily observed and recognized but the number and viability of the bacteria cannot be easily determined.

Other sensate tests of dry seeds indicate the presence of pesticides and supplement other means of detection. Several organic fungicides, especially captan and the cyclodiene insecticides, possess characteristic odors. Solid particles of thiram are irritating to mucous membranes. Chloranil reduces the friction between thumb and fingers.

Chemical tests are known for every toxicant ingredient in seed treatments. The capability of the seed control laboratory, however, may extend only to a color test for certain mercurial formulations, captan and thiram. The cyclodiene insecticides - aldrin dieldrin, etc., - and the mercurials when present as pesticide residues on food are being detected by chemical tests in
several state and federal laboratories. It would be possible, but difficult, to adapt these tests to suspect treated seeds. One difficulty is that of removing all of the material from seeds. Another is that a seed may contain an allegedly highly-toxic element such as mercury as a natural constituent.

Biologic assaying of suspect treated seeds requires only a sensitive living organism as the reacting or measuring material. The method is truly functional; the treatment is detected and/or measured by its capability to perform not by its mere presence.

The macrobiological assay of a mercurial on oat seeds depends upon a naturally occurring fungus, *Alternaria tenuis*. This fungus does not vegetate on treated seed. Hence its presence on germinating seeds proves that they are not treated. *A. tenuis* is a contaminant of all oats produced in New York, Ontario, and Virginia. The fungus always vegetates on germinating seeds grown in the areas unless a chemical treatment is present.

Mercurials also control oat smuts so their presence in a growing crop proves that the seed was not treated. The same deduction applies to covered smut of barley and to stinking smut of wheat. The field or growing-on method of determining seed treatment in grains is one of the oldest macrobiologic tests. Unfortunately since the seeds may not be smut infested a disease-free crop does not necessarily prove that they were treated.

The cold test of corn is actually a specialized macrobiologic assay. The suspect lot is planted in contaminated (*Pythium* and *Fusarium* spp.) soil and held at 10° C. for 7 days. The seedling production is counted after a warm phase of 4 days at 20° C. A similar test is performed with a portion of the suspect lot after it has been overtreated with the claimed material. The germination difference between the original and the overtreated sublot indicates the ineffectiveness of the original treatment.

The macrobiologic test is applicable to any seed if it is planted in soil contaminated with a seed-decay fungus. Beans, melons and peas are simpler than corn seed to test since a preliminary cold phase is not required.

The microbiologic assay for fungicides involves the placing of suspect seeds on agar plates spored with a sensitive fungus. For convenience a heavily-sporulating rapidly-germinating fungus is used rather than a seed-decaying species. Spores of the fungus - *Glomerella cingulata* or *Myrothecium verrucaria* - are dispersed in cooling agar which is immediately poured into Petri dishes or clean plastic boxes. The seeds are pressed into the firm agar. After 30 to 40 hours at 25° C. the size of the clean fungus-free zone around each seed is recorded. The zone is caused by failure of the fungus spores to germinate in the presence of a fungicide diffusing from the seeds into the agar.

The microbiologic test is simple, inexpensive and rapid. But more importantly it is a test for uniformity of coverage as well as for total amount of fungi-
The microbiologic assay for insecticides requires a culturable insect - brine shrimp, fruitfly or mosquito - of known sensitivity to the seed treatment. At present the assay is used by pesticide residue laboratories but could be adapted to seed testing. The treatment is usually removed from the seeds by extraction in a solvent and then resuspended in water which is offered to the insect. As with the microbiologic assays for fungicides those for insecticides are quantitative rather than qualitative. The amount of an unknown insecticide is calculated from comparison with a standard using an LD50 - lethal dose to 50% of population - as the reference point.

The test for legume inoculants is also biologic in that the preinoculant present on seeds is evaluated by its ability to form nodules. The suspect as well as control and standard-treated seeds are placed in sand cultures maintained free of all foreign bacteria. The nodule formation on plants developing from the suspect seeds is compared with that on the plants grown from the untreated and standard-treated ones. It is a macrobiologic assay and is intermediate between laboratory and field tests in cost and time involved.

The evaluation of seed-treating materials is logically a task for plant and seed pathologists. They receive formulations that have shown promise in the manufacturers' tests and compare them with accepted treatments. In New York State every candidate fungicide is placed in numerous laboratory and field tests to determine its fungitoxicity, phytotoxicity, physical effect on seeds and acceptability to workers.

The formulation is also subjected to those macro- and micro-biologic tests that are currently used to assay treated seeds. A new treatment may not be detected or measured by present methods. The protectant fungicide Dexon, for example, on bean, corn, pea or wheat seed performs excellently in macrobiologic tests. It is almost inert, however, in a microbiologic test used to measure other treatments.

Lists of seed treatments have been prepared for the convenience of analysts, control officials, researchers and seedsmen. An excellent but incomplete list was published in the Proceedings of the 1961 Short Course for Seedsmen. A more nearly complete list of 361 entries has been released by seed pathologists of Cornell University, Geneva, New York.

The items are identified by number and trade name arranged alphabetically. The trade name was usually synthesized or coined by a manufacturer and is registered as proprietary name. Their use on labels is permitted in several states.

A column headed Use or type consists of abbreviations or groups of substance or processes used to treat seeds.

(Editors Note: Please see Dr. Crosier's list which follows).