Seed Pretreatment as a Means to Achieve Pathogen Control

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Abstract Seed treatment is the first and basic technique being practiced for seed protection since long. Chemicals and biological agents are applied to protect seeds from microbial pathogens and insect pests. The application of seed treatment is being evolved to more environment-friendly compositions as the time passes. Purposes of seed treatment are to reduce the economic losses to the crop due to

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pathogens and avoid development of resistant pathogen races and reduction of pesticide residues in the product. The purpose of the seed treatment is to avoid the pathogen attack and protection of seeds and seedlings. Application of chemicals at the early stage has an advantage of effectiveness of low dosage as the pathogen is very vulnerable because the seedborne stage is the weakest part of the life cycle of microbes. On the other hand, the disadvantages include the possibility of accidental poisoning, limited dose capacity, shorter shelf life of the treated seeds, and exposure of the worker to the chemicals when treating larger quantities of seeds. Major fungal diseases including bunts, water molds, rots, and damping-off and bacterial diseases including rots and wilting are commonly controlled by applying chemicals. A few viral diseases are transmitted by the soilborne fungal pathogens that may result into a major problem at the later stages and must be controlled at early crop stage by application of seed treatment of their fungal vectors. Soilborne insects like rootworms, maggots, and wireworms are to be controlled at the sowing stage. To control these pathogens, several biological agents like *Bacillus subtilis*, *Streptomyces griseoviridis*, and *Trichoderma harzianum* are also used along with the synthetic chemicals. The chemical applications are done using carboxin, difenoconazole, fludioxonil, imazalil, mefenoxam, tebuconazole, thiabendazole, and triadimenol. The insecticides commonly used for the seed treatment are chlorpyrifos, imidacloprid, permethrin, and thiamethoxam. Several additives including colors, antifoaming agents, lubricants, carriers, and micronutrients are also used to enhance the efficiency of the seed treatment. Application of biological and chemical treatments at the early stage of the crop is playing a helpful role in maintaining the healthy crop and harvesting an improved yield.

Keywords Seed priming · Seed treatment · Fungicides · Insecticides · Seed diseases

1 Introduction

Procedures of seed treatment are in practice for thousands of years by the farmers to save their crops from pests and pathogens. At the beginning, the seed treatment was practiced excluding fungal and bacterial pathogens to improve the crop productivity. Seed treatment started with application of lime solutions and brine which got evolved to the application of formulated products. Hit and trial methods kept on altering the formulations and applications of different mixtures and solutions over time, but in the early 1800s, the application of copper sulfate was found to be more efficient than lime solutions for the control of bunt. Later in 1920, dusting of copper carbonate proved to be even more effective than copper sulfate.

The seed treatment products kept on evolving with time, and mercury-based chemicals appeared to be effective against several seedborne biological issues. Although this protective application was very effective, it was still carrying a risk of unintentional poisoning, due to which it was banned in 1970. After the World War

II, several organic fungicides were introduced in the 1980s. The process of evolution in seed treatment methods came up with biological control in 1990.

Seed treatment is defined as the application of seeds with chemical or biological material to avoid or control the pathogens or pests. Seed-treating chemicals might include insecticides, fungicides, or bactericides. Seed treatment chemicals can be applied both to the true seeds and propagative material such as bulbs, tubers, or corms. On the other hand, application of growth regulators, nitrogen-fixing bacteria, and micronutrients to the seeds is not considered to be seed treatment because they are not meant to reduce the pathogen inoculum or pest control.

Seed treatment is essentially applied to the seed to obtain a uniform and well-grown seed. Apart from this, the continuous application of the seed treatments over years has compromised the survival of soilborne pathogens, and the problem of smut or bunt is under control in wheat and barley crops. Also, it has been found effective in reducing the root rots. Although the application of chemicals to the seeds is beneficial, it also poses to be a threat for the workers in case of accidental exposure, and sometimes they contaminate the food by unnoticed mixing of treated seed with feed or food products.

2 Purpose of Seed Treatment

Purposes of seed treatment include protection of seeds and seedlings, control of seedborne pathogens, and control of pests. Seedborne disease-causing pathogens may work as infestants or may be present deep inside the seeds, hidden in the cracks of the cervices. These pathogens may be important to be controlled in three possible conditions. Firstly, these pathogens cannot survive in the soil or crop residues and need the soilborne phase to survive the fallow period between the crops. Secondly, these pathogens may survive in the soil or crop residues and behave as soilborne pathogen which adds to its capacity to cause disease. Thirdly, these soilborne pathogens may invade new soils by getting transported with the seed shipments.

Seed treatment might be efficient in controlling the seed-infesting or seed-infecting pathogens. The method to be implemented for the control of the disease is decided by the nature of the pathogen whether it is residing on or inside of the seed.

Soilborne pathogens and pests are threat to the seeds and seedlings, which may cause heavy damage to the crops. Especially, the young seedlings are not able to withstand the stress because of their tender nature and lack of food availability to recover from the damage. Apart from pathogen and pest attack, the stress may include heavy rains, cool soils, soil compaction, hard crust of soils, and postemergence herbicide application. Under the prevalence of unfavorable conditions in the soil environment, the pathogen with less virulence may turn out to be devastating and cause heavy loss to the crop.

Application of the non-systemic seed treatment chemicals can protect the seeds and seedlings from damage by making up a protective barrier on the surface of the seed and avoiding the chewing insects and soilborne pathogens. Systemic seed treatment chemical can help avoiding the damage to the roots by root rotting fungi as well as the aboveground parts of the seedlings from sucking type of pests and the aerial pathogens. The duration of the seed treatment efficacy stands for 11–14 days which is even less if the environmental conditions are warm and humid. Considering the effect of these seed treatment chemicals is not long-lasting but can help in delaying the infection and hence reducing the yield losses.

Usually, seed treatments are not the only way to control soilborne pathogenic diseases. Considering the cost-effectiveness, other methods of disease control like use of certified seeds, crop rotation, heat treatment, resistant varieties, and observing the planting date can be added to the seed treatment to devise an effective control strategy because implementation of a single control measure may not be sufficient to avoid the disease.

3 Advantages and Disadvantages of Seed Treatment

There are several advantages of seed treatment, which include the vulnerability of the pathogen as seedborne stage of the plant pathogens is the weakest phase of many plant pathogens during their life cycles that makes seed treatment an effective control measure for the disease. Due to vulnerability of the pathogen to the seed treatment chemical, the low-dose application is cheap and enough to control the disease without developing any unwanted impact on the environment. Pathogens as well as plants are also vulnerable to the diseases during seedling stages, and seed treatment is essential to be executed at this stage. Another advantage is precision targeting of the disease source as the chemical is applied directly to the seed and very little amount of the chemical is lost on untargeted sites.

Disadvantages of the seed treatment with chemicals include the accidental poisoning of animals and birds that may pick/eat the treated seeds as feed from the environment. Low-dose application often results into short-term protection of the plants from the disease. Another disadvantage is low shelf life of the seeds after treatment with the pesticides. Phytotoxicity is also a problem as the higher concentration of the seed-treating chemical is possibly not appropriate for the young seedlings and their tender tissues. If the application rate of the chemicals is not calculated and controlled, the crop may result in low germination percentage or stunting in some cases. Other than plants, human may also become affected by the seed treatment chemicals as the workers are exposed to higher doses of the chemical while treating a greater lot of the seeds.

4 Imperative Seed Diseases and Pests

Seed treatment chemical is specific to a group of pathogens or pests. To devise an effective and appropriate control strategy, it is vital to understand the life cycle and behavior of the pathogen or pest. Understanding of their behavior, time of attack, and mode of action will help in defining an appropriate defense strategy, type of seed treatment chemical, and correct time and dose of the application. Pests or the pathogens are not sometimes controlled properly because pesticides with required mode of action are not applied which don't have enough systemic activity. The failure to obtain desired results may also be attributed to the lack of overlapping of the peak periods of pest or pathogen damage and the protection. Economic constraints also hinder the process as sometimes the higher doses of the control chemicals are too expensive to be applied to larger seed quantities. In such situations, the seed treatment is better to be added up with cultural control or use of resistant varieties.

One of the largest and destructive groups of plant pathogens that affect the crop at seedling stage is fungi. Most fungi are decomposers and derive their nutrients from dead organic matter both from plant and animal sources. Some plant pathogenic fungi are not able to survive in the soil for longer period of times, while most stem and root rot fungi are able to stay viable in soils for longer duration even when crop rotation is practiced starving them by not sowing their host crops for a reasonable duration. Seed treatment techniques can be implemented to overcome several seedborne, soilborne, and foliar diseases that appear on the crops during the early stages (Maude 1996).

Very common fungal diseases include bunts, foliar disease like powdery mildew and rusts, water molds like *Pythium* (Hendrix and Campbell 1973) and *Phytophthora*, root rotting fungi like *Fusarium*, and damping-off fungi. Additionally, some bacteria are also pathogenic to crop plants during the early crop stages, but unlike the fungi they cannot move on their own; rather they depend on wind, seed, insects, farm equipment, and other ways that can facilitate them to come in contact with the host plants. They can get access to the host plant only via wounds or natural openings and cause local or systemic symptoms. Bacteria cause several symptoms like leaf spots, soft rots, leaf blights, and wilting, and some of them can be controlled by seed treatments. In beans, the most common diseases caused by bacteria are bacterial blights, halo blights, and brown leaf spots. The spot diseases initiate with small angular, light green, and water-soaked spots, which become dry and brown colored with narrow yellow margins. Halo blight lesions are encircled by a relatively wider pale green to yellow colored tissue. Pod lesions start with the same pattern as followed by leaf lesions, but as they mature, they produce sunken, irregularly shaped reddish brown blotches (Garu et al. 2004). Stewart's bacterial wilt is a common problem of sweet corn with long yellowish streaking symptoms developed parallel to the veins of the infected leaves (Pataky et al. 2000). These symptoms appear to be similar to the symptoms of drought, nutritional deficiency, or insect pest attack.

Plant viruses are spread by the insect vectors from infected to healthy plants. The most common vectors of the viruses are aphids, whiteflies, and leafhoppers. Although the viruses cannot be controlled by application of any pesticide or seed treatment chemical, their mode of transmission can be interrupted by controlling the insect vectors. Vector control is effective in the case of viruses that are transmitted in persistent manner because they cannot be transmitted instantly like those which are transmitted in nonpersistent manner. The viruses that are transmitted in persistent manner need to be accumulated in the vector and can be transmitted to the host plants for several days once they are acquired from a diseased plant. For successful transmission of the virus, the vector needs plentiful time to feed on the healthy plant that provides an opportunity for the application of the insecticide and control the vector. On the other hand, the viruses transmitted by the vector in nonpersistent manner require less feeding time for both acquisition and transmission of the virus making the application of the insecticides ineffective to control the spread of the disease.

In addition to the pathogens, insect pests can be controlled by the seed treatment applications. Under low rootworm pressure, the application of seed treatment chemicals is reliable, but under high pest pressure, the seed treatment must be aided with the soil treatment. Maggots, beetles, wireworms, and grubs are also important pests of the crops that cause damage to the underground parts of the plants. Root feeding may cause nutrient deficiency symptoms on the foliar parts of the plants. Wireworms are common pests of the vegetables, small grains, and cereal crops. Larvae of the wireworm cause damage to the crop by boring into the germinating seed or into the base of the seedling (Van Herk and Vernon 2007). The treatment is beneficial only if applied before the damage. Light pest pressure can be managed by the application of seed treatment, while high pressure can be controlled only by soil application or in severe cases replanting of the crop.

Aphids are one of the major sucking insect pests of several crops. Aphids are commonly green in color but may possess any color. Nymphs are like the adults but lesser in size. The adult aphids have needlelike mouthparts and suck the juice from the host body. They can cause damage to the plant both directly and indirectly (Dedryver et al. 2010). Direct damage is caused by the sucking of sap and injecting the plant toxin that is present in the saliva of the insect. Indirect damage to the crop is caused by transmission of viral diseases caused by *Barley yellow dwarf virus*, *Cucumber mosaic virus*, and *Watermelon mosaic virus* in several host plant species. Several seed treatment chemicals are found to be effective against the aphids and hence reducing the spread of the viruses that are vectored by this group of insects.

5 Seed Treatment Products

Seed treatment chemicals are categorized based on different attributes like active ingredients (a.i.), additives, doses, and methods of application. Different ingredients have different limitations of application that's why the seed treatment products have more than one active ingredients. The level of control of the pathogen depends on the strength and dose of the active ingredients because some pathogens require a higher dose of the chemical for the control as compared to others (Halmer 2000).

Evaluation of the seed treatment method depends on several factors like unavailability of the effective control activity of the active ingredient, less systemic activity than required, limited movement of the active ingredient with the developing root system, inability to extend the effective period so that the peak activity time and the damage period of the pathogen overlap, and disease is controlled. Another important factor is the effective dose of the chemical is expensive or is phytotoxic that limits the application of the active ingredient to control the problem. Active ingredients of the seed applications are categorized as systemic and contact. Systemic chemicals penetrate the seeds and move in the stem and reach the leaf tissues, while the contact treatment only protects the outer surface of the seed.

The seed-treating chemicals are divided into bactericides, fungicides, and insecticides based on the pathogens against which they are used. Commonly used bactericide is streptomycin, which is a broad-spectrum chemical to control halo blight pathogen of beans, soft rot, and blackleg of potato.

Fungicides are used to control the fungal seed pathogens. Few examples of the fungicides applied for the control of fungal problems include captan (a.i., ethyl mercaptan, broad-spectrum, non-systemic fungicide to control several seed decaying and rotting fungi such as *Aspergillus*, *Fusarium*, and *Penicillium*), carboxin (systemic fungicide used against smuts, seed rots, damping-off, and seedling blights and commonly used with other fungicides and insecticides), difenoconazole (systemic fungicide used against loose smut, bunt, root rots, powdery mildew, and rusts), fludioxonil (broad-spectrum, non-systemic fungicide used against decay and damping-off fungi including *Rhizoctonia*, *Fusarium*, *Aspergillus*, and *Penicillium*), imazalil (systemic fungicide, used against common and dryland root rot), mefenoxam (narrow-spectrum fungicide, systemic fungicide used against *Pythium*, *Phytophthora*, and powdery mildews), PCNB (pentachloronitrobenzene, non-systemic fungicide, used against *Rhizoctonia*, *Fusarium*, and common bunts), tebuconazole (broad-spectrum, systemic fungicide, used against some fall-season root rots and some foliar diseases), thiabendazole (broad-spectrum, systemic fungicide used against common bunt, seed decay, damping), thiram (broad-spectrum, non-systemic fungicide used against bulb, tuber decay, damping-off, and common bunts), and triadimenol (broad-spectrum, systemic fungicide used against root rots and foliar diseases).

Biological agents are also effective component of the seed treatment strategy and are composed of dormant microorganisms. Under the favorable conditions, the inocula of the biological control agents germinate, grow, and colonize the outer surface of the seed and prove protection layer against the soilborne pathogenic fungi. Biocontrol agents provide protection by releasing antibiotic agents or by competing with the pathogenic microorganisms. Biocontrol agents belong to both bacteria and fungi. Bacterial organisms include *Bacillus subtilis* and *Streptomyces griseoviridis*, and fungal agents include *Trichoderma harzianum* (Lifshitz et al. 1986; Turner and Backman 1991; Mastouri et al. 2010; Burges 2012).

Important insecticides used to control insect pests include chlorpyrifos and diazinon (non-systemic insecticide used against seed-corn maggots and beetles); imidacloprid (systemic insecticide used against aphids, bugs, beetles, leafhopper, thrips, white grubs and wireworms, and whiteflies); lindane, tefluthrin, and permethrin (non-systemic insecticide used against soilborne insects such as wireworms and maggots); and thiamethoxam (systemic insecticide effective against several chewing and sucking types of insects such as Colorado potato beetle, seed-corn maggot, Hessian fly, leafhoppers, thrips, and aphids) (Schmeer et al. 1990, Pike et al. 1993).

6 Formulation and Additives

Seed-treating chemicals are commonly formulated as dry flowable (DF), flowable (F), flowable seed treatment (FS), liquid (L), liquid suspension (LS), or wettable powder (WP). Different formulations have different advantages and disadvantages. For example, some formulations don't mix well in the tank, while others readily settle down and make aggregates. On the other hand, some formulations are available in water-soluble form and are relatively safer as they reduce the chance of exposure to the workers.

In addition to active ingredients, the seed treatment chemicals are added with a number of additives like dyes, carriers, binders and stickers, antifoam agents, lubricants (Beilfuss and Gradtke 2001), and micronutrients. Colorants and dyes improve the appearance of the chemical and help in maintaining the uniformity and standardization of the application to the seed lots. Addition of color to the treated seed also helps in detection of treated seeds with the feed or food grains. Carriers and binder are usually added to the seeds to develop the adherence of the chemical to the seed and avoiding the dusting off or cutting off the ingredient. Addition of antifoaming agents in the chemical formulations for seed treatments diminish the troublesome of the foam generation during application.

7 Storage of Treated Seeds

Pesticide-treated seed must be stored in a ventilated, clean, and dry place and should never be stored in bulk or close to the edible grains (Ashraf and Foolad 2005). The treated seeds should be stored tightly in woven bags after proper drying since undesired moisture content may deteriorate the seeds quickly. After packaging the seed must be labeled with type of seed and chemicals used to treat the lot. If the seed is stored for longer period, the germination capacity of the lot must be assessed before sale or sowing. If the seed is not good enough for further use, it should be disposed of properly, and the label of the storage should be added with appropriate information regarding the dispose-of methods (Balešević-Tubić et al. 2010).

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