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Harnessing Physical Measures for the Management of Plant Diseases

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In the era of Natural farming, there is an increasing interest in using physical methods for disease control as an alternative to fungicides for the management of seed and soil-borne pathogens and for integration in disease management programs. They usually do not leave residues or pollute the environment. As early as 1832, Sinclair suggested that hot air treatment in an oven might control smuts of oats and barley. Gardeners in Scotland while treating the bulbs of different ornamental plants first employed hot water therapy. However, the credit for conclusively demonstrating the therapeutic nature of heat must go to Jensen, who successfully employed hot water treatment for controlling loose smut of cereal grains and suggested that moisture played some role other than heat transfer. This method was followed in Demark and later adopted in the US on the recommendation of Swingle in 1892 (Sharvelle, 1979).

Physical Methods for Seed-Borne Pathogens

Some of the seed-treating procedure does not involve the use of fungicides, physical agents like hot water, hot air or steam is used to eliminate the seed-borne infection. These methods are successfully used in controlling certain internally seed-borne diseases like loose smut of wheat and systemically infected diseases caused by bacteria, virus and phytoplasma. The following physical methods are employed for the reduction and/or elimination of primary inoculums that may be present in seed or planting material:

Hot Water Treatment: Hot water treatment is widely used for the control of seed-borne pathogens, especially bacteria and viruses. A list some important seed-borne diseases, claimed to have been controlled by hot water treatment is given in Table 1, 2 and 3.

Table 1: Control of seed-borne pathogens by hot water treatment to seeds (Chaube and Singh 1990)

Crop	Disease	Causal Organism	Treatment
Brassica spp.	Black rot	*X. campestris* pv. *campestris*	50 °C for 20 or 30 min
Cyamopsis tetragonoloba	Blight	*X. campestris* pv. *cyamopsidis*	50 °C for 10 min
Cucumis sativus	Seeding blight	*Pseudomonas syringae* pv. *lachrymans*	50 °C and 75% RH for 3 days
Lactuca sativa, Arachis hypogea	Leaf spot, Testa nematode	*X. campestris* pv. *vitians Aphelenchoides arachidis*	70 °C for 1 to 4 days 60 °C for 5 min after soaking for 15 min in cool water
Pennisetum typhoides	Downy mildew	*Sclerospora graminicola*	55 °C for 10 min

Solanum tuberosum	Potato phyllody	*Phytoplasma*	50 °C for 10 min
Oryza sativa	Udbatta	*Ephelis oryzae*	54 °C for 10 min
	White tip	*Aphelenchoides besseyi*	51-53 °C for 15 in after dipping for 1 day in cool water
Carthamus tinctorius	Leaf spots	*Alternaria* spp.	50 °C for 30 min
Dipsacus spp.	Stem nematode	*Ditylenchus dipsaci*	50 °C for 1 hr or 48.8 °C for 2 hr
Nicotiana tabacum	Hollow stalk	*Erwinia carotovora* pv. *carotovora*	50 °C for 12 min
Lycopersicon esculentum	Black speak	*Pseudomonas syringae* pv. *tomato*	52 °C for 1 hr

Table 2: Control of seed-borne diseases by hot water treatment to sugarcane cutting (Chaube and Singh 1990)

Disease	Pathogen	Treatment
Downy mildew	*Perenpsclerospora sacchari*	54 °C for 1 hr, dried at room temperature of 1 day and again treated in 52 °C for 1 hr
Grassy shoot	*Phytoplasma*	54 °C for 2 hr
Leaf scald	*Xanthomonas albilineans*	Soaking in cold water for 1 day and then treating the cutting at 50 °C for 2-3 hr
Mosaic	Virus (Potato Virus Y group)	20 min treatment each day or 3 successive days at 52 °C and 57.3 °C, respectively
Ratoon stunting	*Clavibacter xyli* sub sp. *xyli*	50 °C for 3 hr
Red rot	*Colletotrichum falcatum* (*Physalospora tucumanensis*)	54 °C for 8 hr
Smut	*Ustilago scitaminea*	54 to 60 °C for 10 min
Spike	*Virus*	52 °C for 1 hr
White leaf	*Phytoplasma*	54 °C for 40 min
Wilt	*Fusarium moniliforme*	50 °C for 2 hr

Table 3: Time and temperature recommendations for hot water treatment for denematizing planting stocks (Reddy, 1983)

Nematode	Planting Stock	Time (Min)	Temperature (°C)
Aphelenchoides ritzemabosi	Chrysanthemum stools	15	47.8
		30	43.0
Aphelenchoides fragariae	Easter lily bulbs	60	44.0
Ditylenchus dipsaci	Narcissus bulbs	240	43.0
Ditylenchus destructor	Irish bulbs	180	43.0

Meloidogyne spp.	Cherry root stocks	5-10	50-51.0
	Sweet potatoes	65	45.7
	Peach root stocks	5-10	50-51.1
	Tuberose tubers	60	49.0
	Grape rooted	10	50.0
	Cuttings	30	47.8
	Begonia	30	48.0
	Tubers	60	45.0
	Caladium tubers	30	50.0
	Yam tubers	30	51.0
	Ginger rhizomes	10	55.0
	Strawberry roots	5	52.8
	Rose roots	60	45.5

Hot Air Treatment: Hot air treatment is less injurious to seed and easy to operate but also less effective than hot water treatment. It has been used against several diseases of sugarcane. Singh (1973) claimed complete control of red rot in varieties Co 527, CoS 510, Bo 3 and Bo 32 by hot air treatment of 54 ºC for 8 hours. It is used for treating sugarcane stalks on a commercial scale in Louisiana (Steiband and Forbes, 1958) to control Ratoon- stunting Disease (RSD). It is employed for treating canes that are soft and succulent. Lauden (1953) working in the Mainland, US, reported that hot air treatment at 54ºC for 8 hours effectively eliminates RSD pathogen without impairing the germination of buds. After 3 years, Steiband and Chilton (1956) confirmed Lauden's findings using thermocouples. Similarly, grassy shoot disease of sugarcane has been controlled by hot air at 54ºC for 8 hours (Singh, 1968).

Steam and Aerated Steam: The use of aerated steam is safer than hot water and more effective than hot air in controlling seed-borne infections. The heating capacity of water vapor is about half that of water and 2.5 times that of temperature control and no damage to the seed coat of legumes. Besides its use in controlling sugarcane diseases, it has also been used against citrus greening (Cheema *et al.*, 1982). The most frequent application of steam and aerated steam has been in greenhouses where steam also provides heat during cold seasons. As a gas, it moves readily through soil, in contrast to the slow, inefficient movement of water. Steam raises temperatures efficiently. As gaseous water molecules (steam) condense into a liquid they release much more latent heat than that given out as warm water cools (540 cal/g relative to 1 cal/g). Aerated steam provides an opportunity to treat soil at temperatures lower than those possible with pure steam.

Moist Hot Air Treatment: This method is effectively used in sugarcane to eliminate grassy shoot disease. Initially, the sets are exposed to hot air at 54 ºC for 8 hours, then exposed to aerated steam at 50 ºC for 1 hour and finally to moist hot air at 54 ºC for 2 hours.

Solar Heat Treatment: The simplest treatment has been devised in India to eliminate the pathogen of loose smut of wheat. Previously the hot water treatment was followed to eliminate loose smut. As the thermal death point of the fungus and the embryo are very close, extensive care should be taken to avoid killing of the embryo. Luthra (1953) devised a method to eliminate the deep-seated infection of *Ustilago nuda*. The method is popularly known as solar heat or solar energy treatment.

Luthra's solar energy treatment: The seeds are soaked in cold water for 4 hours in the forenoon on a bright summer day followed by spreading and drying the seeds in hot sun for four hours in the afternoon. Then, the seeds are again treated with carboxin or Carbendazim at 2 gm/kg and stored. This method is highly useful for treating large qualities of the seed lots.

Physical Methods for Soil-Borne Pathogens

It is well known that soil harbors a large number of plant pathogens and the primary sources of many plant pathogens happens to be in soil where dead organic matter supports active or dormant stages of pathogens. I addition, seed treatment does not afford sufficient protection against seedlings diseases and a treatment of soil around the seed is necessary to protect them. Soil treatment is largely curative in nature as it mainly aims at killing the pathogens in soil and making the soil 'safe' for the growth of the plant. Some of the commonly followed physical methods for soil-borne pathogens are discussed:

Soil Solarization: In this management tactic, the solar energy is preserved with the help of a transparent polyethylene sheet to increase soil temperature (10-15 °C above normal temperature) enough to kill most of the soil-borne pathogens and weeds (Khulbe, 2000, Akhtar, *et al.*, 2008). Soil solarization with transparent polyethylene sheet mulch (25µm) for 40 days was found effective for the control of collar and root rot of strawberries caused by *Sclerotium rolfsii* (Bhardwaj *et al.*, 2004). Fungal diseases such as damping-off, root rots, stem rots, fruit rots, wilts and blights caused by *Pythium* spp., *Phytophthora* spp., *Fusarium* spp., *S. rolfsii*, *R. solani*, *Sclerotinia sclerotoirum*, *T. basicola* and *Verticillium* spp. have been successfully managed by soil Solarization. Nematode diseases such as *Ditylenchus dipsci*, *Globodera rostochiensis*, *Heterodera* spp., and *Meloidogyne* spp. have been successfully managed by soil solarization. Bacterial canker of tomato (*Clavibacter michiganensis* subsp. *michiganensis*) is successfully managed by soil solarization for 1-2 months (Akhtar *et al.*, 2008).

Steam Sterilization: Steam is passed through perforated pipes at a depth of 15 cm to sterilize the upper layers of soil. It is mostly practiced under glass house and green house conditions.

Hot Air Sterilization: Hot air is also passed through pipelines to sterilize the soil in the nursery areas.

Hot Water Treatment: It is mainly done in pot culture studies to kill the fungi and nematodes. The pots containing soil are immersed in boiling water at 980C for 5 minutes or drenching boiling water @ 20 liters/sq.m.

Other Physical Methods

Refrigeration: It is an accepted fact that the low temperature at or slightly above the freezing point checks the growth and activities of all such pathogens that cause a variety of post-harvest diseases of vegetables and fruits. Therefore, most perishable fruits are transported and stored in refrigerated vehicles and stores. 'Cool Chains', refrigerated space from field to consumer's table is becoming very popular. Regular refrigeration is sometimes preceded by a quick hydro-cooling or air-cooling to remove the excess heat carried in them from the field to prevent the development of new or latent infections.

Radiation: Electromagnetic radiations such as ultraviolet (UV) light, X-rays and Y-rays, as particulate radiations have been studied about management of post-harvest diseases of horticultural crops. Findings of experiments revealed that y-rays controlled post-harvest fungal infections in peaches, strawberries and tomatoes but doses of radiation required to kill pathogens, were found injurious to host tissues. More efforts and required in this area as radiation can be very effective in inactivating pathogens in larger stores or handling bulk material that cannot be heated for sterilization. Some plant pathogenic fungi (*Alternaria, Botrytis, Stemphylium*) sporulate only when they receive light in the ultraviolet range (below 360 nm). It has been possible to control diseases on greenhouse vegetables caused by species of these fungi by covering or constructing the greenhouse with a special UV-absorbing vinyl film that blocks the transmission of light wavelengths below 390 nm.

Drying Stored Grains and Fruits: In the presence of sufficient moisture, a variety of microflora already accompanying harvested grains nuts, etc. cause decay. Such decay,

however, can be avoided if seeds and nuts are harvested when properly mature and then allowed to dry in the air or are exposed to the sun. Maize downy mildew pathogen is seed-borne. If the maize seeds are properly sun-dried, the inoculum gets inactivated. Hot air can be used until the desired moisture is reached (about 12% moisture) before storage. Subsequently, they are stored under conditions of ventilation, which do not allow a build-up of moisture. Fleshy fruits (peaches, strawberries) should be harvested later in the day, after the dew is gone, to ensure that the fruits do not carry surface moisture during storage and transit, which could lead to decay by microorganisms.

Burning: Controlled burning may alter the environment and after plant disease response, providing both a temperature effect and a means of destroying the pathogen (Zentmyer and Bald, 1977). Parameter and Uhrenholt (1975) introduced a new aspect of burning by demonstrating that smoke may kill several plant pathogens in tissues. According to Hardison (1976, 1980), burning is the single most important practice in grass seed production in the Pacific Northwest. It was initiated to control the blind seed disease of perennial ryegrass caused by *Gloeotinia temulenta*. It also effectively controlled *Claviceps purpurea* (ergot of rye), *Anguina agrostis* (seed nematode) and silver top. Fire can be applied to cereals in which inoculum can be destroyed after harvest or pasture grasses which can periodically be freed from inoculum before they make new growth. It has also been realized that the increasing success of non-tillage in some crops and the resultant problems of debris management can make burning an attractive and effective proposition. Diseases that have been successfully managed by burning or flaming crops residue are given in the Table 4.

Table 4: Disease Controlled by Fire and Flame (Hardison, 1976; Palti, 1981)

Sr. No.	Pathogen	Disease
1.	*Anguina* sp.	Seed nematode of *Lolium rigidum*
2.	*Angullalina tumifaciens*	Leaf gall nematode of *Cynodon transvalensis*
3.	*Claviceps paspali*	Ergot of *Paspalum dilatatum*
4.	*Cuscuta* sp.	Parasite of lucern
5.	*Drechsler poae*	Leaf mould of *Poa pratensis*
6.	*Gerlachia nivalis*	Snow mould of wheat and barley
7.	*Godronia cassandrae,Phleospora idahoensis*	Canker of *Vaccinium* sp., Stress eye spot of *Festuca rubra*
8.	*Pseudocercosporella herpotrichoides*	Eye spot of wheat
9.	*Puccinia asparagi*	Asparagus rust
10.	*Puccinia gramins*	Stem rust of *Poa pratensis*
11.	*Rhynchosporium secalis, Septoria avenae*	Eye blotch of barley
12.	*Septoria avenae*	Leaf blotch of oat
13.	*Selenophoma bromigera*	Leaf spot of *Bromus inertis*
14.	*Verticillium dahliae*	Wilt of potato and peppermint
15.	*Anguina agrostis*	Seed nematode of *Festuca rubra*
16.	*Corticium sasaki*	Sheath blight of rice
17.	*Claviceps purpurea*	Ergot of *Lolium perenne*
18.	*Diaporthe vaccinii*	Die back of low bush blueberry
19.	*Gaeumannomyces graminis*	Tale-all of wheat

20.	*Glueotinia temulenta*	Blind seed of *Lolium perenne*
21.	*Leptosphaeri* sp., *Pleiochaeta setosa*	Leaf blight of sugarcane Brown spot of lupin
22.	*Puccinia menthae*	Rust of peppermint
23.	*Puccinia poaenemoralis*	Leaf rust of *Poa pratensis*
24.	*Puccinia striformis*	Stripe rust of *Poa pratensis*
25.	*Sclerotium oryzae*	Stem rot of rice
26.	*Septoria nodorum, Septoria tritici*	Leaf blotch of wheat
27.	*Urocystis agroopyri*	Flag smut of wheat

Flooding: Flooding fields and orchards to reduce or eliminate soil-borne inoculum of plant pathogens is an ancient practice. According to Kelman and Cook (1977), flooding has been recognized to be one of the key factors for the low incidence of soil-borne disease in Chinese agriculture. In lower Yangtze and South China, the plots where vegetables are grown, are pre-cultivated with one or two crops of rice or spinach, water chestnut, water bamboo or lotus (Willian, 1979) for the control of soil-borne pests.

Table 5: Plant disease control by flooding (Stover, 1955; Roteim and Palti, 1969; Tarr, 1972; Palti, 1981)

Sr. No.	Pathogen	Disease
1.	*Alternaria porri* f. sp. *solani*	Alternaria blight of tomato and potato
2.	*Aphelenchoides besseyi*	White tip of rice
3.	*Meloidogyne* sp.	Root knot of celery
4.	*Phytophthora parasitica* var. *nicotianae*	Black shank of tobacco
5.	*Radopholus similes*	Burrowing nematode of banana
6.	*Trichodorus* sp.	Stubby root nematode of celery
7.	*Verticillum dahliae*	Wilt of cotton
8.	*Alternaria dauci*	Blight of carrot
9.	*F. oxysporum* f. sp. *cubense*	Wilt of banana
10.	*Orobanche* spp.	Phanerogamic plant parasite of several crops
11.	*Pyrenophora teres*	Canker and blight of barley
12.	*Sclerotinia sclerotiorum*	White mold of vegetables
13.	*Tylenchorhynchus* sp.	Stunt nematode of celery

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