AERATED STEAM TREATMENT OF SEED[1]

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There has been a lot of controversy on seed-borne pathogens and there are a lot of seed merchants who get up in arms when one mentions them. They say that this doesn't happen very often, but the more one delves into the seed business the more one realizes it's a lucky thing to get a seed that has no pathogen either on it or in it.

If one is going to have plant production, the propagating material, whether it be a plant material or seeds, has to be treated against pathogens. We have found that steam-air treatment has been the most satisfactory. I am going to talk on flower and vegetable seedlings, but the same procedures would apply to tree and shrub seedlings.

The problem associated with flower and vegetable seeds is similar to those for trees and shrubs — what stands for one will hold for the other. Our first experiences as seedling (bedding plant) growers came when we were using 212°F soil sterilizing in 1956. When seeds are sown into a mix thus treated one experiences a great deal of trouble because it is nearly a biological vacuum. If you introduced a pepper or a tomato seed with *Rhizoctonia* on or in it you probably would get a complete wipe-out of your crop, whereas if you hadn't sterilized your soil you would have had some competition in the soil and you might not have a complete wipeout. You would have had *Rhizoctonia* anyway, so you couldn't have sold the box. This led us to experimenting with some form of seed treatment. In those days we used dusts and hot water. It wasn't until 1961 when steam-air treatment of seed really started that we had the results we are getting today.

Seed-borne pathogens are transmitted in several ways: in the embryo of the seed; on the seed coat itself; under the seed coat; in dust particles accompanying the seed; perhaps in fruiting bodies similar in size to the seed so that cleaning by seedsmen doesn't eliminate it. Consequently, quite often it is not the seed itself that has the pathogen; it may be some particle adhering to it or with the seed itself. I want to discuss some of the diseases

[1] I have borrowed freely from Dr Kenneth Baker's paper on Seed Pathology printed in Seed Biology Volume 2, 1972 published by Academic Press, Inc All the work we have done on seed treatments has been with the help of Dr Baker, whose invaluable help to the nursery industry is well known to most, if not all, of you here today

before we go into the actual treatment; I think you will then appreciate the types of diseases and the way in which they operate.

METHODS OF SEED INFECTION BY PATHOGENS

The pathogen accompanies the seed but is independent of it. Most, if not all pathogens may be transported with plant or other debris mixed with seed. One of these, for example is *Sclerotinia sclerotiorum*, which causes the cottony rot disease, prevalent in many crops. The sclerotia develop in or on plant parts and become mixed with the seed in threshing and are not always removed by cleaning; for example, cornflower is subject to this particular disease. The sclerotia (disease carrying body) is very similar in size to the seed and seed cleaning does not remove it. Hollyhock rust teliospores are on bits of the plant mixed with seed during threshing. Another example is bacterial canker of tomato [*Corynebacterium michiganense*]. The bacteria invade the fruit and the infected pulp mingles with the seed during the seed extraction process.

The pathogen is a passive contaminant on the exterior of the seed. In this case the pathogen may be present as sclerotia, spores, vegetative cells, nematodes, or virus particles. Snapdragon rust [*Puccinea antirrhini*] contaminates seeds in threshing. A very good example is fusarium wilt of china aster; macroconidia produced at the base of the infected stems get onto the seeds during threshing. *Rhizoctonia solani* I have mentioned on capsicum and egg plant and tomatoes; mycelium in the soil infects fruit that may be lying on the ground, comes in contact with it, decays the pulp and may form sclerotia or mycelium on the surface of the seed itself. Another one is *Corynebacterium fascians*, the bacterial fasciation disease of sweet peas and nasturtiums. Generally sweet pea seed comes from California, a very dry area when they are threshing this seed; the bacteria are in the dry dust. If you have seen harvesting there you can appreciate how dusty it is; this pathogen again gets on the seed in threshing. The tobacco mosaic virus on tomato plants is carried into the fruit pulp and remains on the seed surface after extraction.

Pathogen spreads into the seed from the fruit. Some of the most important seed-borne diseases are of this type. They are usually internally borne and difficult to control. Transmission is by vegetative cells, spores, nematodes, or virus particles. *Rhizoctonia solani* — already mentioned, is one of the chief ones of this type. The fruits are invaded by mycelium when in contact with the soil; the seeds may be wholly or partly decayed. The mycelium might spread through the mass of the pulped fruit and seeds during the fermentation process. The mycelium actually invades the seed itself prior to the separation of the seeds. A very bad one is known to most seedling growers as alternaria of zinnias [*Alternaria zinniae*]. The dew on the flowers in the seed field keeps the flower head moist and the spores in the flower head infect the seed. Zinnia seed from the United States is usually superior in this regard to that from Europe, where they have wetter conditions and Alternaria in zinnia seeds is much more prevalent. Another one in this field is *Phoma lingam*, which causes black leg of cabbage; spores from plant lesions infect the seed pod and penetrate the seed on which the fungus may produce its pycnidia. *Botrytis cinerea* you all know very well. I don't know any nursery in the world that has not had *Botrytis* in one form or another. The spores of this pathogen are common in the flower seed growing areas and, under moist conditions, petals are infected and the mycelium spreads down into the seed itself.

The pathogen penetrates the seed through the vascular system of the plant itself. There are relatively few pathogens known to infect seeds through the vascular elements and most of them are in the vascular elements of the seed coat. The most common is *Xanthomonas campestris* that causes black rot of cabbage, and *Santhomonas incanae* that causes the bacterial blight of stock. The bacteria are systemic; they move up through the water-conducting tissues of the plant and into the actual seed pod itself.

The pathogen actively and directly penetrates the seed is the last one I will use as an example. Most common is *Septoria* and the worst one is *Septoria apiicola* — cause of late blight of celery. The pycnidia form on infected seedlings, and spores are spread by water as the plant grows. Seeds are infected directly and may develop pycnidia in the seed coat.

There are other instances of both diseases and hosts too numerous to mention here, but I think you can appreciate that these are only a few of the many very serious pathogens that are seed-borne with which we have to contend. Seedling growers throughout the world are familiar with the serious problem we have with these diseases, and they ask what they can do to combat them. Others of importance are *Septoria* on phlox, *Alternaria* on pansy, *Pseudomonas* on polyanthus. Seedling growers know this last one — it is a nasty seed-borne pathogen on polyanthus and primula generally. It is probably more common in the warmer than the colder states of Australia. I have seen it in all states, but it is probably held down by the colder conditions in Tasmania and Melbourne. Where we have warm summers and wet winters you can get a very serious outbreak of this disease. Another bad one is *Phoma betae* in silver beet. This is a nasty disease which turns seedlings black. Just when the seedlings are ready to go out, the weather changes and the healthy seedlings look like they have been hit with a blow torch.

Many of these disease pathogens are currently carried on seed of trees and shrubs, including our native ones as well. The same type of treatment that I am suggesting for flower and vegetable seedlings would also be applicable for trees and shrubs.

METHODS OF SEED TREATMENT

In 1888 in Denmark the first hot water treatment of seed took place for the control of loose smuts of oats and barley. From then on, hot water treatment has been used on a wide front. There are a lot of things seed producers can do that would reduce seed-borne pathogens such as growing their crops differently, by water control, by treating seed before planting, and by better harvesting. I think it is only in the last 10 to 20 years that large seed houses in the United States have really appreciated some of the problems in their methods and I am very pleased to say that quite a lot of them have tightened up their methods of seed collection and treatment in the field itself. I think the important controls of seed-borne pathogens should be carried out there. Some of the European countries and Japan, however, have not appreciated some of the problems associated with seed-borne pathogens. It is important that they do, however, for the loss in the nurseries can be of major importance.

Chemical treatments. These are, of course, advocated by the chemical firms as the best methods. I personally have not found chemical treatments satisfactory for a commercial seedling operation because they don't really do the job 100% and I think if you can't get that type of control then it is of little use. You must remember that we, as nurserymen, are upsetting the balance of nature and if we do, have to have a very good control of diseases. If you have 100 seedlings in a 12 x 12 flat you are really asking for trouble; you have to use every preventive method you can. Chemical treatments also give problems with your technical staff. If you are using any mechanical means of sowing seeds, as a lot of nurseries are now doing throughout the world, they find that chemical treatments have an irritating and a very dangerous effect on personnel; we found very early in the piece that we were not able to coat any of our seeds with fungicides. After a few minutes the staff just refused to sow because of respiratory irritation.

The hot water method. This presents a lot of problems but it also has important assets as well. It is a very good means of controlling seedling seed-borne pathogens and is still carried out today. It has a physical effect on the seed itself. If you put peas into hot water and heat them at 125°F for 30 minutes you might get pea soup. However, seeds of plants like cabbage, pepper, tomato and others can quite successfully be treated with hot water. However, the physical effect is very bad and it also has a leaching effect on the seed itself. However, there are many plants whose seeds cannot be so treated. If you put seeds of stocks, alyssum or flax through hot water, you will get a mucilaginous mess at the end. It is very difficult to dry it again or to separate it and sow individual seeds. There is another method that has recently been recommended; that is, the thiram soak method, where one uses about 10 ppm thiram for a 24 hour soak. This has proven very successful in the Brassica family, but it has limitations. Hard seeds, such as in bean, which do not soak well, are not satisfactory; it has been found that this method with ornamental flower seeds, as nemesia, phlox, marigolds, celosia, salvia, dianthus, lobelia, is very injurious; it will damage the seed. Methyl bromide has been used in certain instances for control of nematodes in onion, clover, etc.; that method has its advantages and is still used.

Steam-air treatment. As already mentioned the hot-water methods have several disadvantages. With the advent of steam-air it was possible to overcome these and still maintain the moist heat necessary to kill the pathogens at temperatures which do not kill the seed. The low moisture content of steam-air does not physically damage the seed and makes drying and cooling simple. This factor made the treatment of difficult seeds like Mathiola and Cineraria no different than that of cabbages, etc., the mucilaginous effect being completely eradicated.

Steam-air then has all the advantages of hot water without any of the problems that method has — all seeds can be steam-air treated.

Our original steam-air seed treatment equipment was in fact an adaptation of the vault method of steaming seedling flats. It consisted of an efficient venturi, the steam being passed through a simple dryer before entering same. An accurate thermometer was placed in the mixing chamber. The steam-air entered at the base of the box, a perforated plate forming the top of the plenum. From the top of the plenum to the top of the hinged lid of the box was approximately 18". The sloping lid permitted the condensation to run off. The box also had a drain hole in the base as well as baffles to ensure that the steam-air covered the entire floor area and so rose in an even volume through the perforated plate. The seed for treatment was placed in standard sieves with varying hole sizes, the hole size chosen being as large as possible without allowing the seed to come through. The steam-air temperature adjustment was simply achieved by increasing or decreasing the amount of air sucked in by the venturi. For cooling, a centrifugal blower was mounted beneath the box and on completion of the steam-air treatment the steam was cut off and the blower started and blown into the plenum, care being taken to ensure that the cooling and drying air was not too high a velocity to blow the seeds from the trays. Heating treatment was for 30 minutes, with cooling and drying approximately 15 minutes. Temperature of the seeds was read through thermisters. The treatment box was made from 9-ply marine plywood, giving reasonable insulating quality. The important thing to remember in this method is to carefully cover areas that were not covered by the seed sieves. This then forced the steam-air to go through the seed in the sieves. The depth of seeds in the sieves was also important, a thin layer being essential.

Several nurseries used this method and still do with quite good results; the temperature is usually maintained at 130°F and 135°F for pepper, tomato, brassicas, etc., the whole operation being a prophylactic treatment. Several plants such as delphiniums, marigolds, and verbena, however, reduced germination to such an extent that treatment was suspended on marigold and verbena, but we persisted with delphiniums because of high disease factors.

In 1969 we, with the help of Dr. Kenneth Baker, built a unit that would give a greater degree of control and accuracy. It is essential to be able to control the temperatures to within 1/2°F and to use a blower rather than the compressor required by Dr. Baker's laboratory model, as it was considered that compressors would not be available in nurseries.

The treater (Bakeriser) is built around a centrifugal blower which has a twofold purpose — to supply air for the steam-air and for cooling and drying. An electric modulating valve was used to bring the steam into the air stream through a solenoid valve. The steam pressure was reduced through a pressure regulating valve to a constant 10 lbs. per square inch; the steam is also dried in a steam dryer. The treating chamber is made from polypropylene and is cylindrical with several walls to give the steam-air a swirling effect which also drops excess moisture to the base of the treating chamber. The three large treating sieves are mounted on each other on a base plate that is hydraulically lifted into position, forming the base of the cylinder, with the sieves then sitting in the centre. For small quantities of seed each of the sieves holds 6 smaller units giving an overall capacity of 18 different varieties. Temperatures are read from 6 thermister probes on a meter.

The unit works very well and has been in use since 1969. However, the disadvantages are several; namely, the unit still requires constant vigilance and takes a little time to stabilize, the modulating valve is a little slow in operating, as well as several other minor problems. A new model is being built at Falg Nurseries, South Australia, by Mr. Gavin Welton. This unit is completely automatic with extremely accurate temperature control and with safeguards against malfunctions. The prototype is now completed and the first batch to be manufactured will commence shortly; the price of this unit will be in the range of 3,000 to 3,500 Australian dollars.

With this unit, with its accurate control characteristics, temperatures for specific pathogens, such as the *Pseudomonas* on primula and polyanthus can be experimented with, as this disease and *Alternaria* on pansy and zinnia needs higher temperatures, perhaps for shorter periods, 140°F for ten minutes, etc. Work on these types of diseases is urgently required.

Our own treatments of 130°F and 135°F have been most successful for the control of rusts — *Septoria*, *Rhizoctonia*, and similar pathogens. In the near future it is hoped that, with the aid of University and Department of Agriculture Pathologists, together with the latest equipment, research on the more difficult seedborne diseases and germination effects will be undertaken.