Because of the unprecedented demand for soil sterilization information, it has been necessary to make an emergency reprinting of the article from the March Bulletin.

PENNSYLVANIA FLOWER GROWERS

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Steam Sterilization of Greenhouse Soils

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I realize that technically speaking we should call the method Soil Pasteurization but the term sterilization has been in the trade so long, I'll continue with this misnomer.

WHY STERILIZE SOILS?
1. To destroy harmful disease organisms such as those causing wilt, root rot, etc.
2. To kill soil pests such as symphyllids, nematodes, grubs, etc.
3. To kill weed seeds—this is a real labor saver.
4. To eliminate the need for changing old soil—another labor saver.
5. To improve soil structure; this is a great benefit in some greenhouse soils.

DOES SOIL STERILIZATION PAY?
Killing the disease organisms and insect pests in the soil is one of the first steps in good greenhouse crop production, and is essential to prevent troubles on many crops. The loss of just one crop will often pay for many steamings so it is good insurance. Killing the weed seeds and not having to change soil both result in saving of labor. Just the destruction of weed seeds will often pay for the steaming job.

SHOULD NEW SOIL BE STEAMED?
Yes! Steam new soil as well as old soil. Many growers feel that bringing in new soil will eliminate disease problems. Often the disease which hits your cultivated crops also grows on the weeds or cultivated plants in the field. Be safe; steam new soil too. The saving through weed control will pay for a good share of the cost.

If you steam your soil and weeds start to grow, you can be sure that you did not do a good job of soil steaming.

SHOULD MANURE AND PEAT BE ADDED BEFORE STEAMING?
Yes! Add everything including fertilizer, if needed, to the soil before steaming. Sometimes we find a grower who steams the soil and then puts on a layer of manure to add some "good" organisms. He can just as easily be adding disease troubles or soil pests. This is an easy way to get symphyllids. Or you may add new disease organisms just after killing the old ones.

You may even make the trouble worse than if you hadn't steam sterilized the soil in the first place. The steaming job kills off organisms thus eliminating competition for the newly introduced disease organisms which will then grow and spread rapidly.

WHAT TEMPERATURE IS REQUIRED?
The important thing to remember is that we want to raise the soil temperature up to 180°F in the coldest part of the bench, and hold it there for at least 30 minutes.

Test the soil in many locations with a thermometer. Using a thermometer is the only way you can be sure. Dairy thermometers are O. K. but are of glass and easily broken. We like a metal dial thermometer registering up to 220°F; they are easier to read and handle.

Often growers will raise the soil temperature up to 180-190°F and then turn off the steam, leaving the cover on for half an hour. Check the soil temperature to make sure it doesn't drop too fast. After the 30 minutes, remove the cover so the soil will soon be ready for planting.

HOW LONG DOES THE JOB TAKE?
The length of time the job takes will be affected by the steam pressure, the volume of steam, the amount of soil being steamed, the temperature of the soil at the start, and the soil moisture content. If the job takes longer than 4 hours, you should figure on doing a smaller area at one time, or increasing the supply of steam.

The soil should be slightly moist, not too dry or too wet. If too dry, the weed seeds and some organisms are not so easily killed. If the soil is too wet, you have to heat a lot of water as you raise the soil temperature. Figure on having the soil just a little drier than you would like it for planting or potting.

HOW LONG SHOULD I WAIT BEFORE PLANTING?
You can plant as soon as the soil cools and is of the proper moisture content for planting. Troubles with poor plant growth after steaming are usually due to a high soluble salt content in the soil or a build up of ammonia. Various organisms grow in greenhouse soils and build up various materials in their bodies; when the soil is steamed, the organisms are killed and these nutrients become soluble. The concentration gets high and injures plant roots.

Trouble from accumulation of ammonia after steaming can be avoided by applying 2 or 3 pounds of gypsum (calcium sulphate) per 100 square feet of bench area. If you are applying superphosphate, (Continued on Next Page)
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keep in mind that about half of the superphosphate is gypsum.

Soils research has shown that occasionally manganese may become soluble and toxic after steaming of some soils.

These troubles can usually be overcome in several ways. First, you can plant soon after steaming (as soon as the soil cools) so the plants become established before the soluble salt concentration starts to build up. Along with this, water the new plants well, and keep the soil moist so the soluble salt concentration will be diluted.

Secondly, prevent a build-up by tapering off the fertilizer applications to the previous crop and giving a good leaching as the crop starts to come into flowering. In this way, the soluble salt content will be lowered so that it will not build up to a toxic level and cause plant injury. (Refer back to Bulletin No. 28, May 1953.)

STEAM THE TOOLS, TOO

Put tools such as shovels, rakes, markers, and trowels under the cover when you steam the soil. Then you'll have clean equipment to use on the clean bench. Your flower pots and flats can be similarly handled.

MECHANICS OF STEAM STERILIZATION

After putting the peat, fertilizer, manure, etc., on the soil in the bench, work up the soil so it is loose and friable; then the steam can penetrate easily.

You can then use the "Thomas surface method" or the "buried conductor method."

The Thomas Method

This is an easy labor saving method of soil sterilization. A sterilizing cover is put on the bench and hangs over the sides; there is enough slack so that the cover can billow up 5 to 6 inches from the soil lengthwise down the middle of the bench, when steam is injected. The cover is either fastened to the sides of the benches with clamps or lath, or held down by pieces of pipe or 2 x 4's or the cover seals itself against the side of the bench without fastening. Steam is injected under the cover which billows up like a balloon and the steam penetrates the soil.

Many growers do not use a conductor under the cover. Some growers use a few supports such as wire hoops, flower pots, or something similar just to keep the sterilizing cover partially off of the soil so the steam can move lengthwise of the bench easily.

Others find it advantageous especially on long benches to lay a conductor on the soil surface to carry the steam lengthwise of the bench. A porous canvas hose is excellent for this purpose. Some growers feel that if holes are drilled on the side of a metal conductor and the conductor is laid with the holes against the soil, the steam will penetrate the soil better.

In all methods the whole volume under the cover fills up with steam which then penetrates the soil.

The Thomas method works well on raised benches and is all right on ground beds if there is drain tile in the bottom of the bed, or there is good drainage in the bed. There is some question as to how far and how quickly the steam will penetrate from the surface of the soil of a ground bed; burying a conductor in the soil will help get the steam down farther in a shorter time in ground beds.

Buried Conductor Method

Burying the steam conductor is extra work, and it is a hot job getting it out again when the steam sterilization job is done. We usually figure on two lines of a conductor lengthwise of the bench about 24 inches apart in a 4 foot bench or bed or 14 inches apart in a 3/2 foot bench. The conductor will be about an inch from the bottom of a raised bench or a ground bed with a tight bottom. If the bed has no bottom, bury the conductor about 6-8 inches below the soil surface.

It is not necessary to pull the soil away from the sides of the bench to get the sides sterilized. If you do this, be sure you keep the sterilizing cover out of the depression so the steam can contact the inside of the side boards. Otherwise you will not be doing a complete job of steaming and will be throwing away money.

If you want to use the buried conductor method, you can save a lot of time and trouble by putting in a permanent installation of drainage tile which will serve as a drainage conductor when crops are in the

Collapsible canvas hose for conducting steam along the bench. Photo—courtesy, Geo. J. Ball, Inc.
soil and will serve as a steam conductor when you are sterilizing the soil.

CONDUCTORS

If you use a conductor on your bench, use something that will require a minimum of labor. For the Thomas method, the porous canvas tubing (Pikes Peak Greenhouses, Inc.) is excellent. It is easy to handle and when dry, it can be rolled up for easy storage. It is not expensive. I do not know anything about its lasting qualities but it is used widely in the Colorado area. I saw it in use at the Holton and Hunkel Co. in Milwaukee and the George J. Ball Co. in West Chicago. They like it. (See photo on page 4).

Aluminum tubing (2, 3, or 4 inches in diameter) is light, easy to handle, and durable; one man can handle 15 or 20 foot lengths easily. Its initial cost is greater than for other materials. Down spouting is O. K. but rusts quickly. Iron pipe (old boiler flue pipe or second hand pipe) is not expensive but is heavy to handle. Usually 3/16 to 1/4 inch holes spaced 10 to 12 inches apart will distribute the steam well. For the buried conductor method, holes are often drilled spirally about the tubing or pipe; some growers like the holes a foot apart on opposite sides of the conductor, and others prefer holes on one side pointing downward into the soil. Paint a red line lengthwise on the upper side of the conductor—this will make it easy for anyone to lay the conductor so the holes will be exactly the way you want them.

Agricultural tile will work all right but it is taking a lot of money out of your pocket to handle those short lengths. It is fine for permanent steam sterilization installations.

STEAM STERILIZING COVERS

There are many air tight covers on the market now. Sisalkraft paper is still being used by a few growers. It is relatively cheap initially but it not durable. Some of the newer covers are much cheaper in the long run.

Some of the covers are cheaper than others initially but do not last as long as some of the heavier more expensive ones. Preference varies as to which is the best cover. I'd like to acquaint you with some of them; there may be other good ones with which I am not familiar. I'll give you the experiences and reports that I know about. Samples of the sterilizing covers and exact costs are available.

Thin plastic covers—There are many good ones on the market. These sterilizing covers are light and easy to handle. As steam is injected and condenses under the cover, the condensate runs to the side of the bench or bed and seals itself against the sides thus eliminating the need for clamps, etc., if steam is not injected too rapidly. (See photo on page 6.) Growers' experiences with thin plastic covers vary and the results probably depend on the handling.

1. Visqueen—a polyethylene plastic sheeting which comes in rolls 10½ to 13 feet wide and 100 feet long. Weighs about 2½ ounces per square yard.

2. Fumi-cover—a vinyl plastic, sometimes called Velon which is made up 6½ to 13 feet wide and 100-150 feet long. These sheets had been made of several narrower pieces sealed together. There had been some trouble with them coming apart. About 3 1/3 ounces per square yard.

3. Jednak "Stericover"—a lightweight plastic cover developed by the Goodyear Rubber Company. Weighs approximately 7 1/3 ounces per square yard.

4. No. 1012 Plastic Sterilization Cover—a plastic which is thicker than Visqueen and Fumi-cover; weighs about 11 ounces per square yard. Have not had any experience with it. Costs about 25 cents per square foot.

Some growers report having used Visqueen and Fumi-cover as much as 35 to 50 times, and a few experiences have been even higher. In my opinion, based on the experiences of many growers, about 30 times would be a good average. These plastic covers cost 3 to 4 cents per square foot. I have had no experience with the Jednak "Stericover"; H. M. Cathy of Cornell reports using a cover 30 times with no apparent deterioration. It costs about 7½-8 cents f. o. b. Cleveland.

Some heavier covers—Some of these sterilizing covers cost more initially but have a longer life thus giving them a low unit cost.

1. Rubberized cloth—Many of the older rubber covered fabrics were long lasting but were heavy and cumbersome to handle and store.

2. Fiberthin sterilization cloth—a coated fabric, made by the U. S. Rubber Company, thin but strong; weighs about 5 ounces per square yard. Clings to the sides of the benches like Fumi-cover and Visqueen. Costs about 18 cents per square foot f. o. b. Denver. I am using a piece and have no first hand accounts on its lasting quality, but understand it is used widely in the Denver area.

3. Steriltex—a plastic coated glass fabric. Very tough and durable. Heavier than the previously mentioned covers. Has been used 150-175 times by some growers. Costs about 20 cents per

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square foot. About 9 1/3 ounces per square yard.

4. Tufedge—a neoprene (synthetic rubber) impregnated cloth. Very tough and durable. Has been used 200 times by Jim Mikkelson in Ash tabula and is still in use. Not as light as the thin plastic covers but weighs only about 9 ounces per square yard. Costs about 13½ cents per square foot.

USING THE COVERS
Get the sterilizing cover long enough and wide enough to cover the bed with some slack lengthwise down the middle and also to hang down the outside and the ends of the bench or bed.

There are several reasons for this:

1. Many of the plastic covers can be used without fastening them down with weights or clamps. Adjust the steam flow so the cover does not blow off. The condensate will seal the cover against the side of the bench. (See photo below)

2. For ground beds, you can hold the cover down by laying pieces of 2” x 4” wood or pieces of pipe on the edge of the cover in the walk.

3. The cover hanging down the outside of the bench or bed will trap heat so that the sides heat up slowly. This is especially helpful in reducing the possibility of cracks in concrete benches.

4. This heating of the sides also helps to get the inside of the bench up to the 180°F mark which will kill diseases.

Precautions With Covers

1. Don't let the covers touch the steam pipe. We wrap an extra piece around our steam injection pipe so that our good big covers are not injured.

2. In general, it is best to dry the covers before storing. With some covers it apparently makes no difference but others deteriorate if put away wet.

3. Don't let the covers lay in a hot greenhouse sun for weeks between sterilizing. There have been some reports of the thin plastic covers aging and becoming brittle when allowed to lay on a bench in summer heat.

4. Don't lay metal pipes or angle iron on plastic covers to hold them down. Use wood. Some growers have observed that the hot metal injured the plastic cover whereas wood did not. This is not true for all covers.

If you hold down any cover in this way, do not lay the wood or pipe on the cover inside of the bench. This will prevent the steam from properly heating and killing disease organisms or soil pests on the inside of the sideboards. Lay the wood or angle iron, if you use it, on the top edge of the soil board. This is absolutely essential. Many growers use clamps and strips of wood.

Wooden clip clothespins can be used to hold pieces of sterilizing cover together around supports in the middle of a bench.

Plastic cover for steaming soils. Note how the condensate seals the cover against the side board. Photo—courtesy, Geo. J. Ball, Inc.
SOURCES OF STEAM

If your heating system operates on steam, you can generate steam easily. Install permanent 2 inch outlets in your main so you can easily hook on your steam hose. Locate them so you can inject steam in the end of short benches, or in the center of long benches. The length of bench you can steam at one time depends mainly on the pressure and volume of steam available. If you have a special line of pipes to carry steam, make sure all of the pipes from the boiler to the bench are at least 2 inches in diameter to assure a good supply of steam. Some 1½ inch pipe is O.K. if you have high pressure, or if you are not carrying the steam too far.

Converting a Hot Water Boiler

If you are heating with hot water, you may be able to convert the boiler for generating steam during the summer. The principle is to drop the water table and generate steam in the upper part of the boiler if it is of the proper design. Check this carefully because if dropping the water level exposes part of the inside surface to heat on one side and no water on the other side, you will have trouble. You'll have to add a few attachments such as a few valves, a gauge glass, safety valve, automatic water feeder and alarm, etc. It is not difficult but the job must be done right. Refer back to Bulletin No. 6, June, 1951.

Some growers have installed a small steam boiler for generating steam for sterilizing soil.

Size Generator Required

In the spring 1949 issue of Under Glass it was stated that 25 H. P. is the minimum horsepower requirement for steam sterilization of 400 square feet of a bench or bed of soil 6 inches deep. This would be about 16 square feet per boiler H. P.

A. C. Newhall of the Department of Plant Pathology reported (N. Y. St. Flow. Grow. Bul. 91) that growers have been steaming 1½ to 6 cubic feet per hour per rated H. P. boiler and a general average would be 3 cubic feet, or 6 square feet of bench area per hour per H. P. This would be 24 square feet per boiler H. P. if you figured a 4 hour steaming period.

A rate of 9 square feet of bench area per boiler H. P. is the figure given by A. Laurie and D. C. Kip linger in their book, Commercial Flower Forcing, assuming that the sterilization will not take more than 4 hours.

These figures give some idea of the boiler capacity needed for steam sterilization of soil. Don't underestimate; it is better to have too much than too little.

Steam Pressure Required

You can do a good job with only 3 to 5 pounds pressure at the boiler if you have at least 2 inch pipes and are not trying to move the steam too far. As long as you have some "push" behind the steam, you can do a good job. Higher pressures will enable you to do the job faster.

Portable Steam Generators

Portable generators are available and are especially valuable for growers who have hot water systems. A relatively new development at reasonable cost is the Steam-Flo generator produced by the Rough Brothers. We had a unit at our Penn State Florist meeting last summer and it worked very well. Units are being used by several Pennsylvania growers.

It is an oil fired burner which will maintain 10 pounds pressure and has sufficient volume to do a good job on about 300 square feet of a six inch depth of soil at one time. The steam generator is on 2 rubber tired wheels and easily moved right to the greenhouse where you want to do the job. The cost is within the range satisfactory for most greenhouse operators.

Similar generators are used in eastern Pennsylvania for steaming mushroom soils and houses. The Cleaver-Brooks Company and the Homestead Valve Manufacturing Company and others have portable type boilers which are being used for steaming soils. The cost is higher than the Steam-Flo Sterilizer but the capacity is greater. The Homestead Super-duty Hypressure Jenny for instance has a 25 boiler H. P. capacity. Probably cooperative purchasing and use could be worked out. In mushroom areas, it might be possible to rent steam generators.

The small steam jennies used for cleaning tractors, etc., do not have sufficient volume to be of value to the florist.

CHECKING TEMPERATURES

The soil will not all heat up at the same rate so it is essential that the soil temperature be measured (Continued on Next Page)
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in many locations in the bench to make sure it is up to 180°. Check the corners and along the edges of the bench, especially near where the steam is injected.

Sometimes the steam flows in so fast that this part of the soil does not heat up as quickly as other parts of the bench. If some spots are not properly heated, you are not doing a good job. Various types of baffles or supplementary outlets have been used to get better distribution at the injection point.

STEAMING OF POTTING SOILS

So far we have talked mainly about bench soils. The same temperature principles hold true for potting soils. You can steam soil in a pile or in a section of a greenhouse bench and then transfer it to the potting bench. This is extra work and a good chance for contamination compared to having a steam sterilization box above the potting bench. Build a sterilization box with a top that can be opened for filling and a bottom that can be opened for dumping right onto the potting bench. Fill the box, turn on the steam, treat the soil at 180° for 30 minutes, dump the soil directly on the potting bench and it's ready for use. It can be rigged up with a hopper arrangement to dump only the soil you need at that particular time. A real labor saver for the pot plant grower.

A grower on the West Coast has a steam sterilizing box built so that when the soil is properly sterilized, the front side can be dropped forward and used as a potting bench surface. An excellent idea!

The soil for pots and flats can be steamed in a truck or trailer body by making a perforated pipe frame to fit the body.

Flats of soil can be steamed by stacking the flats with space between them so steam can circulate. Then cover the pile with a steam-sterilizing cover and inject steam under the cover.

OTHER HEAT METHODS OF STERILIZING SOILS

Flash Flame Pasteurizer
The flash-flame pasteurizer will treat about 2 cubic yards of soil per hour and would be O.K. for potting soils. For details, refer back to your PFG Bulletin 21, September 1952.

Electric Sterilizers
An electric soil sterilizer unit which can be mounted in a ½, ¾ or 1 yard sterilizing box is available from the Hardy and Dillon Company in Boston. This is similar in principle to the G. E. units which have not been available for quite some time. Plans and specifications for building one of these sterilizers are available. It is a handy unit for treating potting soils. I'd build the unit over a potting bench as you could drop a trap door and allow the soil to fall from the sterilizing box to the surface of a clean potting bench.

The L. N. Roberson Company, of Seattle 55, Washington, also manufactures yard and 1 yard electric soil sterilizers.

Hot Water
To raise the soil temperature high enough to do a good job of sterilizing, tremendous quantities of very hot water are needed. This leaves the soil very wet, and delays planting. The hot water method, therefore, is very unsatisfactory:

SUMMARY

From this discussion you can see that the soil sterilization job can be done many ways. To do a good job, you must be thorough. Make sure all of the soil temperature gets up to 180°F for at least 30 minutes and do not recontaminate it.

Your Editor, John G. Seeley