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Aerated Steam: A System for Heat Treating Sugarcane to Control Ratoon Stunting Disease

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AERATED STEAM: A SYSTEM FOR HEAT TREATING SUGARCANE TO CONTROL RATOO STUNTING DISEASE

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Introduction

The ability to control diseases in seeds and plants by heat is well documented. A combination of a prescribed treatment and time of exposure is used to inactivate or control ratoont stunting disease in sugarcane. Hot air and hot water are two media currently used for treating sugarcane seed pieces for a specified time and at a prescribed temperature without severly reducing the viability of the seed pieces. The hot water treatment, developed in Australia, consists of immersing seed cane in water at a temperature of 50°C for 3 hours. The hot air system developed for Louisiana utilizes a recirculating electrically heated air system with the cane seed pieces being exposed to an entering air temperature of 58°C for 8 hours.

Both the hot air and hot water treatment methods recommend the seed pieces be shucked or cleaned before treatment. A small fluctuation in the treatment temperature affects germination and the extent of disease control. Hot or cold spots within the treatment chamber also affect germination and disease control. The advantages and disadvantages of both systems contributed to the development of a system for treating sugarcane seed pieces using aerated steam.

The Aerated Steam System

Aerated steam is defined as a mixture of air and steam. A constant amount of air conditioned to a predetermined temperature with steam is recirculated until the system reaches thermal equilibrium. Circulation is continued with the addition of steam to maintain the prescribed temperature

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for a specific length of time. An aerated steam system utilizes the efficiency and uniformity of heat transfer through a moist environment as well as the flexibility of a recirculating air system. A schematic of the pilot system is shown in Figure 1. It consists of (1) a treating chamber, (2) a recirculating air system, (3) a steam generator, and (4) a method of controlling the amount of steam applied to the system. Recirculation at a rate of approximately eight times the empty volume of the treatment chamber per minute is adequate to minimize the blast effect of higher velocities and also suspend the steam within the turbulent air throughout the chamber.

Components and assembly sequence for the steam system are shown in Figure 2. The steam can be generated with a portable steam generator with a rated capacity of 100 gallons per hour. Steam from the generator is stored in an accumulator where the generator pressure pulses are cushioned. The accumulator collects condensate and other foreign materials from the steam and discharges it through a steam trap. Although the system operates at 30 psi of steam pressure, the accumulator should be rated at a minimum of 150 psi and have a capacity of approximately 50 gallons. Steam going to the system is taken from the top of the accumulator and passed through a modulating steam flow control valve. The amount of steam injected into the recirculating air system to maintain a prescribed temperature is controlled by the steam control valve. A temperature sensing element is placed near the entrance transition to monitor the temperature of the aerated steam entering the treatment chamber. The sensing element temperature is indicated by a dial thermometer on the control valve. The prescribed temperature is set by manually adjusting the spring pressure on the pilot of the steam control valve. Steam passing through the valve is distributed into the air stream through a nozzle constructed of galvanized pipe with 1/16 inch holes spaced 1 inch apart. The nozzle should be positioned horizontally across the air duct between the fan and the entrance transition with the steam emission holes facing opposite to the direction of air flow. Turbulence within the system will thoroughly mix the air and steam to provide a humid environment at the prescribed temperature for treating the seed pieces.

Research Results

Copper constantan thermocouples were used in conjunction with a 24-point continuously recording potentiometer to monitor the rate of heat transfer from the aerated steam into the cane stalks as well as to indicate the temperature equilibrium within the treatment chamber. The thermocouples were strategically placed in the center of cane stalks, attached to the outside of cane stalks, and placed at various locations throughout the cane mat within the chamber. Recording the temperature also showed the temperature variation within the system and the relative temperature of each
Figure 1. — A circuit diagram of an aerated steam system
Figure 2.—Schematic diagram of aerated steam heat treating system components

thermocouple location at a given time.

The cane stalks were stripped of trash and stacked on racks similar to those used with hot air systems. Results showed temperature equilibrium and distribution within the treatment chamber was maintained at the desired temperature, ± 1°C, with aerated steam. The temperature of all thermocouples positioned in the system was in equilibrium within 1 hour after treatment began. Similar results were obtained when the stalks were not stripped of the leaves.

After the aerated steam system was tested using an experimental treatment chamber (Figure 2) and the operation parameters established, a full-scale treatment system was designed. The unit shown in Figure 3 is capable of treating approximately 1 ton of sugarcane stalks with adhering trash and leaves. The inside dimensions of the chamber are 6 feet x 8 feet x 8 feet. The cane is stacked into a cart on removable pipes or trays. The layer thickness should be 15 inches with a 3-inch space between layers to assure circulation throughout the chamber. Aerated steam distribution within the chamber is accomplished with a fan displacing a minimum of 2,500 cubic feet of air per minute. Openings from the entrance plenum to the treatment
chamber are of various sizes to provide an even distribution of air from top to bottom, and the outlet plenum is slotted in a similar manner (see Figure 4).

During the first hour of treatment, steam must be provided at a rate sufficient to overcome heat loss and to raise the temperature of approximately 1 ton of cane with leaves from about 15°C to 53°C. The specific heat of sugarcane has been found to be 0.94 Btu/lb-°F. Based on this value the process was calculated to require 188,752 Btu to increase the temperature of a ton of cane to 53°C. The time for the treatment chamber to reach the prescribed treatment temperature is affected by the initial air-cane temperature when the aerated steam is turned on. Time-temperature data for each layer tested was recorded and analyzed to obtain a relationship between the change in temperature inside the treatment chamber and time. This relationship was plotted for each layer thickness.
Figure 4.—A cross-section of an aerated steam treatment chamber showing the construction details.
Using a general law for heating and cooling, the following temperature ratio was computed:

$$TR = \frac{T - T_i}{T_t - T_i}$$

Where:  

- $TR$ = temperature ratio  
- $T_i$ = starting temperature  
- $T_t$ = treatment temperature  
- $T$ = temperature at any time

When the temperature ratio is plotted against time, the curve takes the form:

$$TR = 1 - e^{-\frac{t}{\tau}}$$

Where:  

- $TR$ = temperature ratio  
- $t$ = time minutes  
- $\tau$ = time constant, minutes

One time constant, $\tau$, is defined as the time required for the temperature to reach 63.2 percent of $(T_t - T_i)$.

The relationship of the temperature ratio expressed as percent of $\Delta T$ and the time of exposure of sugarcane to aerated steam is shown in Figure 5. By applying aerated steam to a treatment chamber loaded with cane in 15-inch layers at ambient temperature, the time constant, $\tau$, was found to be 15 minutes. When the time the system has been operating is known, the TR or percent of $\Delta T$ can be calculated. For example, if the system has been operating for 60 minutes, substituting for $t$ and $\tau$ in the equation above, the
percent of $\Delta T$ achieved is found to be 98.2. The starting temperature has a pronounced effect on the time it takes for the cane to reach equilibrium temperature.

Steam generators are sometimes rated in terms of gallons of water converted to steam per unit of time. Heat losses in the delivery system are significant, and results using aerated steam indicate a steam generator rated at 100 gallons per hour is needed to treat a 1 ton load. By staggering the starting times, a 100 gallons per hour steam generator is capable of providing steam for two 1 ton units. The automation of the steam generator is necessary to discontinue steam generation when the amount generated exceeds the requirements of the system. A high-low pressure cutoff switch is provided to turn the steam generator on and off to maintain a steam pressure from 20 to 40 psig (pounds per square inch — gauge). The steam output is piped to the accumulator and a steam trap purges the accumulator of excess condensate. The accumulator is insulated and protected with a relief valve set at 75 psig. Steam is drawn off the top of the accumulator and piped to the flow control valve for use on demand by the treatment chamber.

The flow control valve is normally closed and pilot operated. A bulb installed in the inlet plenum monitors the temperature and actuates the pilot valve, which in turn operates the main valve. The steam is injected into the air duct through a sparger tube. The outlets of the tube should be pointed in an upwind direction for best mixing of the steam and air. A second steam trap is positioned in the system to protect the modulating valve from condensate.

Conclusions

Results using the aerated steam system for heat treating sugarcane to control ratoon stunting disease show several advantages.
1. A relatively short time is required for the system and cane to achieve temperature equilibrium.
2. It provides an environment for efficient heat transfer into sugarcane seed pieces.
3. It has a fast and easy method to vary the rate of temperature change within the treatment chamber.
4. Temperature distribution is uniform within the treatment chamber.
5. It eliminates the accumulation of trash, mud, and extraneous material in the treatment chamber.
6. It eliminates stagnant or polluted water.
7. Sugarcane can be heat treated with trash and leaves attached.
8. It is adaptable for treating and handling cane in bulk.
9. It does not adversely affect germination at the temperature-time combination needed to control ratoon stunting disease under Louisiana conditions.
Equipment Specifications

The following equipment arranged according to Figure 2 is suggested for a complete aerated steam system.

Item 1. Steam source — Steam may be supplied to the system by a quality automotive-type steam cleaner, or a steam generator. The steam capacity of the steam cleaner should be 100 gallons per hour per ton of cane treated. Generators should be selected on the basis of 5 hp of steam per ton of cane. The steam generating system should have the following specifications or the equivalent: a pump output of 100 gph (gallons per hour), non-corrosive check valves, and a thermostatic control to protect the cleaner from excessive heat in case of a water supply failure. Water should be available at a rate of 2 gallons per minute free flow with a maximum inlet pressure of 60 psi. The purchaser will specify to the retailer the type of fuel and drive desired with the unit. The unit may be oilfired with an electric motor drive. A standard 115 volt, 60 cycle, 15 amp fused electrical circuit is needed.

Item 2. Accumulation tank — The accumulation tank serves as a cushion for the steam from the generator, collects condensate, and provides a steam supply for the system when the steam generator is shut-off by the pressure control switch. For long time use, the tank should be fabricated from a non-corrosive material such as stainless steel or copper with a working pressure of 75 psi and a factor of safety of 4.

If the tank is constructed from more readily available material such as low carbon steel plate, a minimum working pressure of 150 psi is suggested. The conventional propane or ammonia tank has a working pressure of 250 psi and can be used.

The tank should bear a name plate indicating it is constructed according to Section VIII of the unfired pressure vessel code, ASME. It should be fitted with legs at least 12 inches high and have three openings in the vapor zone and one opening at the bottom. A 2-inch layer of insulation should be used to minimize heat loss and condensation.

The size of the accumulator is not critical. However, a 50-gallon tank is suggested. Install the tank with the long axis in a vertical plane to facilitate separating the condensate from the steam.

Item 3. Steam trap — Condensate from the accumulation tank can be removed through the ¾ inch Sarco 9-125 (1-125 psi) or an equivalent steam trap without losing pressure in the system.

Item 4. Pressure gauge — A pressure gauge positioned on the accumulation tank will let the operator visually observe the pressure within the system. The gauge should be a Duragauge with a 0-100 psig range dial face or the equivalent.

Item 5. Pressure relief valve — Protect the tank with a relief valve set to
discharge at not over the working pressure of the accumulator. The relief valve must be set at least 20 psi above the steam pressure in the accumulator. A ¾ M x ¾ F relief valve with a 0.750 inch seat diameter will discharge 750 pounds of steam per hour when set at 75 psi. This will protect the accumulator. A Kunkle Valve Company relief valve type 383 or the equivalent is suggested. Pipe the outlet away to a safe discharge area.

Item 6. **Pressure cutoff switch** — At the beginning of the treatment cycle the system will require the maximum output of 100 gph of steam per ton of cane. As the system approaches the treatment temperature of 53°C (127.4°F), less steam is needed. After the system reaches the treatment temperature, the pressure in the accumulation tank will increase. A pressure cut off switch is attached to the accumulation tank to cut off the steam generator and let the accumulator provide steam to the system until the pressure drops to 25 psig. At 25 psig the pressure switch will close and start the steam generator in order to maintain 25 to 40 psig operating pressure in the accumulator. A Square D, Pumptrol, KD, Class 9013, FSG 2, on 20 — off 40, or the equivalent, is suggested.

Item 7. **Steam line strainer** — The strainer should be a 1-inch Spence full flo Al SCY strainer or the equivalent.

Item 8. **Recording thermograph** — A recording of the temperature inside the treatment chamber will provide a record of how the system operated. The operator must know if some component did not function properly. The recorder should be a 110 volt 60 HZ Foxboro model 12R temperature recorder with box pens and a 12-hour rotation chart drive. The recorder is to have a type TA-1B thermal element with a 5 foot flexible bronze bulb union with a bendable bulb type 1542 extension. The recorder should be supplied with Foxboro chart #897427 and an operating instruction manual. A recorder equivalent to the above specifications may be used.

Item 9. **Steam flow control valve** — The steam flow control valve monitors the temperature and regulates the amount of steam necessary to maintain a treatment temperature of 53°C (127.4°F). The valve should be a Spence model ET14 1 inch steam regulating valve, or the equivalent, with a temperature sensing element, 20 feet of flexible tubing capable of controlling the temperature in the system ± 1°C, an adjustment indicator scale, and a dial thermometer indicating 20° — 80°C.

Item 10. **Globe valves** — The system should have 1 inch globe valves installed as shown in the piping arrangement, Figure 1.

Item 11. **Steam injection nozzle** — The nozzle is constructed for the converted hot air boxes using ¾ x 18 inch galvanized pipe with 1/16 inch holes spaced 1 inch apart and installed in the air duct approximately 24 inches downstream from the fan outlet.
Operating Instructions

Preparation of Cane

1. Seed cane may be cut by machine or by hand. The topper should be lowered to mature cane to minimize green trash. The cane does not need to be de-trashed before heat treating.

2. Cane may be loaded for transporting to the treating area with hydraulic grab loaders. The trays or racks used with the treating chamber should be loaded in 15-inch layers.

3. Time between cutting and treatment should not exceed 5 days — 3 days after cutting is suggested. There are indications that treating immediately after cutting may not be desirable. Plant the treated cane as soon after treatment as possible.

4. Load the trays or racks as uniformly as possible. Avoid compaction. Leave approximately 3 inches between each layer. This space will increase as treatment progresses due to the cane settling within the layers.

5. Trays or racks may be unloaded for transporting to the field with hydraulic grab loaders, chain slings, or fork lifts. Mechanical loaders and trailers used to handle untreated cane should be isolated from the treatment operations to prevent reinfection of treated cane.

Operation of the Aerated Steam System

The procedure for operating the system follows. Sugarcane should be treated with a air-steam mixture for a total treatment period of 4 hours at 53°C (127.4°F).

1. Open the water supply to the steam generator.

2. Turn the steam generator pumping unit on. Make sure water is flowing through the steam cleaner then turn the burner on. As the unit begins to generate steam, re-check the water to the steam generator. The generator will burn up very quickly if there is no water in the system. An automatic water level cutoff valve should be provided with the steam generator.

3. Allow the steam pressure in the accumulator to build up until the cutoff pressure switch stops the steam generator (40-50 psi). Check to see that the steam trap attached to the accumulator is functioning (intermittently discharging water.)

4. While the steam pressure is building up, check the steam flow control valve indicator setting. Rotate the hand wheel until the pointer points to the number that corresponds to 53°C (127.4°F) on the dial thermometer.

5. Move the rack or trays loaded with seed cane into the treating chamber. Close the door.

6. When the pressure in the accumulator reaches the cutoff pressure (approximately 40 psi) and assuming the cane is in the chamber, turn the
circulation fan on and open the steam control valve to allow steam to flow into the treatment chamber. Three globe valves shown in Figure 1 control the flow of steam to the treating chamber. Valve 1 should be open all the time. Valve 3 is normally closed. Valve 2 starts and stops the flow of steam to the treatment chamber. Leaving valve 1 open keeps the regulating valve hot and ready to use at all times. Close 1 and 2 and use 3 if control valve malfunctions.

7. Turn the temperature recording thermometer on. Record the starting time and date on the chart.

8. A mercury thermometer should be inserted at eye level into the aerated steam entrance plenum. Observe the temperature of the mercury thermometer and the control valve. Rotate the hand wheel on the control valve to adjust the temperature in the treatment chamber to 53°C (127.4°F) as indicated by the mercury thermometer. If the temperature of the mercury thermometer does not agree with the temperature gauge on the control valve, adjust the gauge to indicate the same temperature as the thermometer. When adjusting the chamber temperature, rotate the hand wheel clockwise to increase the chamber temperature and counter clockwise to decrease it. As a rule of thumb, a rotation of approximately 1 inch will change the temperature 1°C.

9. Expect the temperature in the cane to reach 53°C within an hour (assuming the starting temperature is at least 24°C).

10. In case of a steam control valve malfunction, close the two globe valves, 1 and 2 in Figure 1, that isolate the control valve from the steam supply line. Control the chamber temperature by hand. Using the by-pass valve (3), carefully meter the steam to the air duct to keep the temperature at 53°C. Get competent help to service the control valve.

11. After 4 hours, shut off the supply of steam to the treatment chamber (close valve 2), turn the circulating fan off, and open the door.

12. Mark the temperature chart to indicate when the treatment was completed. Indicate on the chart where the cane is to be planted and file the chart for future reference.

13. Unload the treatment chamber. Do not leave the cane in the closed oven after the 4 hours. Germination will be seriously affected.

**Some Problems to Anticipate**

1. When using hard water, expect erratic valve operation. Minerals in the water will build up in the steam generator coils and also tend to block the control valve passages. *Use soft water.*

2. When treating two chambers with only one steam generator, be sure to stagger the starting time 2 hours. This allows the first chamber to settle to a good equilibrium temperature before the second chamber demands steam.

3. The control valve will not function satisfactorily when water logged
or when trash or rust is in the water.

a. When starting a cold box, make certain the steam trap at the accumulator is purging all water from the system. The steam trap at the control valve must purge any condensate from the line before getting to the control valve. If the temperature cycles up and down without reaching equilibrium, the control valve may be waterlogged.

b. If the box fails to come up to temperature, suspect trash in the valve. Clean all screens. Check the orifice to the pilot valve and the orifice in the line below the main valve diaphragm. A strainer should protect the control valve in addition to the fine screen in the body of the pilot valve.

c. If the accumulator fails to come up to the 40 psig cutoff pressure, the steam generator is not functioning properly. This may be due to several routine problems. If the generator burner is not operating properly, check with the supplier.
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