THE USE OF HEAT TREATMENT FOR SUGARCANE DISEASE CONTROL*

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ABSTRACT

Heat treatments of sugarcane setts are known to cure a dozen diseases which can pass systemically from one vegetative generation to the next. Heat treatments are applied; 1) to reduce the incidence of disease in order to increase yield or to protect susceptible varieties from increasing inoculum pressure; 2) to increase the frequency or the rate of germination of seed cane in order to improve the stand; and, 3) to destroy pests in seed cane shipments. Heat treatments have not been shown to cause mutations in cane or in cane pathogens. The temperature and time required for a cure varies with the disease and the heat treating system used. The heat treatment systems differ in the relative proportion of air and water present and, therefore, in their desiccating and heating characteristics. Heat treatment of certain diseases affects germination of setts, depending on their physiological status and conditions at planting. Certain precautions can be taken to improve germination. The aerated-steam treatment offers the best combination of disease cure and sett survival and can be very useful for the simultaneous control of several systemic diseases.

INTRODUCTION

Sugarcane diseases can be controlled by one or a combination of the following methods:

(i) Use of healthy seed cane

(ii) Sanitation and hygienic practices to reduce disease spread and inoculum

(iii) Use of resistant varieties

(iv) Protective fungicide treatment and curative treatment (mainly heat treatment).

The use of these methods was contemplated since the early years of the modern sugar industry. Thus the occurrence of serreh disease a century ago catalysed the initiation of research on three of them, namely:

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(1) a system of graded nurseries, roguing as necessary, and the long distance transport of healthy seed cane, the method adopted; (2) the development of resistant varieties through interspecific hybridization; (3) the heat cure of diseased seed cane.

Later, the development of resistant hybrid varieties, proved valuable for controlling devastating diseases such as downy mildew, Fiji, gumming and mosaic, some of which have caused outbreaks which threatened the industry in certain areas.

As estimates of disease losses have become more precise, it has been evident that undramatic diseases may cause losses of 10 to 20%. However, varieties resistant to these diseases may not be available or susceptible varieties may be agronomically superior to the resistant ones. The purchase and long distance transport of healthy seed cane may be too costly. Heat treatment is an important measure for ensuring healthy seed stock for the control of these diseases and can be used either alone or in an integrated system of disease control.

Heat treatment of seed cane developed quite inauspiciously. It required nearly 35 years to establish a cure for serch (Wilbrink57), and by that time the disease was well on its way to extinction. The first commercial use of heat treatment was for the control of chlorotic streak (Martin51) and it has been used for 30 to 40 years wherever the disease is a problem. The discovery of ratoon stunting disease and the research on its cure by hot water or hot air (Hughes and Steind125) led to the extensive adoption of heat treatment for its control. The stimulatory effect of short heat treatments on germination has led to the use of hot-water treatments together with fungicides to avoid seed cane problems with soil pathogens such as pineapple disease (Wismer58). Heat treatment in conjunction with roguing has been used to reduce the inoculum potential of smut; it is also used routinely in quarantine to eliminate mites, insects and nematodes.

**DISEASES CURED BY TREATMENT**

The systemic diseases of sugarcane for which heat cures have been reported are included in Table I. To keep the table within manageable proportions the number of references has been restricted to only one of a group of similar time/temperature combinations.
### TABLE I. Heat treatments of seed cane for the cure of systemic sugar cane diseases.

<table>
<thead>
<tr>
<th>Disease and pathogen</th>
<th>Treatment system and time/temperature combinations</th>
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<tbody>
<tr>
<td></td>
<td>Hot Air</td>
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<tr>
<td>Chlorotic streak*</td>
<td>52°C/20 min</td>
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<tr>
<td>Downy mildew (Sclerospora sacchari)</td>
<td>50°C/3 hr</td>
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<tr>
<td>Grassy shoot disease (mycoplasma)</td>
<td>54°C/8 hr</td>
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<tr>
<td></td>
<td>(Singh {et al^{49}})</td>
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<tr>
<td>Leaf scald (Xanthomonas albilineans)</td>
<td>Cold water</td>
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<tr>
<td></td>
<td>56°C/3 hr</td>
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<tr>
<td></td>
<td>59°C/10 min**</td>
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<tr>
<td></td>
<td>Day 1: 52°C/20 min</td>
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<tr>
<td></td>
<td>Day 2: 57.3°C/20 min</td>
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<tr>
<td></td>
<td>Day 3: 57.3°C/20 min</td>
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<tr>
<td>(Virus)</td>
<td>(Steindls^{51})</td>
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<tr>
<td>Ratoon disease (RSD)^*</td>
<td>54°C/8 hr</td>
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<td></td>
<td>(Steib {et al^{49}})</td>
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<td></td>
<td>58°C/8 hr</td>
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<td>50°C/3 hr</td>
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<td></td>
<td>Day 1: 52°C/20 min</td>
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<tr>
<td></td>
<td>Day 2: 57.3°C/20 min</td>
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<tr>
<td>Red rot (Glomerella tucumanensis)</td>
<td>54°C/8 hr</td>
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<tr>
<td>Sereh*</td>
<td>45°C/30 min then 50-52°C/30 min***</td>
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<tr>
<td>(M. scitaminea)</td>
<td>50.5°C/1 hr</td>
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<tr>
<td></td>
<td>52°C/45 min</td>
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<tr>
<td>Spike*</td>
<td>52°C/1 hr</td>
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<tr>
<td>Streak (virus)</td>
<td>59°C/10 min++</td>
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<tr>
<td>White leaf disease (mycoplasma)</td>
<td>55°C/20 min</td>
</tr>
<tr>
<td>Wilt (Cephalosporium sacchari)</td>
<td>50°C/2 hr</td>
</tr>
</tbody>
</table>

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* Causal agent not identified.
++ Followed by tissue culture.
+++ Such treatment is not considered “serial” because it does not allow for the adaptation of cane at organ level.
Heat treatments used for sugarcane require 24 hours or less of treatment time. Treatments in which diseased plants are grown for weeks or months at elevated temperatures, so common with other crops (Nyland & Goheen\textsuperscript{36}), have not been used successfully with sugarcane. Due perhaps to the intense and brief treatments, these are usually not completely effective and are not adequate, by themselves, as a method of disease eradication.

Only three or four of the diseases given in Table I (chlorotic streak, grassy shoot, RSD, white leaf) are presently being regularly controlled commercially by heat treatment. Some of the treatment combinations may evidently cure more than one disease. Thus a treatment for downy mildew will also cure RSD, smut, grassy shoot and chlorotic streak. It is hoped that a treatment will become available that is capable of freeing seed cane from all major seed-borne diseases. So far heat treatment of diseases like Fiji and gumming has not been quite successful. Noth\textsuperscript{35} obtained some control of gumming disease with hot water treatment at 50-51°C/2hr but recently (Anon.\textsuperscript{3}) it has been found that the pathogen may resist temperatures as high as 58°C for one hour, although some less drastic treatment combinations will reduce considerably the number of viable bacteria in treated setts. Perhaps too much emphasis should not be laid on complete elimination of the pathogens in such cases but only a reduction in inoculum which may allow the treated plants to recuperate from the residual infection by themselves.

Heat treatment at high temperature followed by tissue culture to salvage surviving cells, which has been successful for mosaic and streak (Roth\textsuperscript{40,41}), may allow the regeneration of a variety which has been totally infected with a virus disease.

Heat treatment may also be useful for certain non-systemic diseases. Several leaf spots and sheath rots may be seed-borne, due to propagules remaining on the remnants of the leaf sheath, or else the rind may be superficially infected (e.g. \textit{Cytospora} sheath rot). Heat treatment, especially for quarantine purposes, can ensure freedom from these diseases in seed cane. Abbott\textsuperscript{1} prevented brown spot infection by treatment of cuttings in hot water (52°C/20 min). Hot air treatment (54°C/8 hr) has enabled the elimination of \textit{Cytospora} sheath rot in cane undergoing quarantine (Ricaud, unpublished).

\textbf{FACTORS AFFECTING DISEASE CURE AND SETT SURVIVAL}

The success of a heat treatment will depend on both the extent of elimination of the disease propagules within the entire tissues of the sett and the survival of the latter. For some diseases the threshold of resistance of the pathogen to certain time/temperature combinations is well below the lethal point for the death of the cutting (e.g. smut, chlorotic streak); treatment in such cases is easy. For others, the two thresholds are very close and the success of treatment is critical.
Several factors affect both disease cure and sett survival. The duration of the treatments given in Table I refers to the total time that the cane is exposed to the treatment temperature. The actual temperature in the interior of the sett may attain the treatment temperature for a shorter duration or may even remain below the treatment temperature for the entire 8 hours of a hot air treatment (Antoine4), Schexnayder42) or for a short hot water treatment (Antoine6). For a successful cure, the whole of the sett tissues must reach the required threshold of time/temperature combination for the death of the pathogen. The rate of heat transfer within the cutting has been found to depend on the diameter of the setts (Antoine4,5,9) but not on their fibre content (Antoine6). Most heat treatments, however, have been worked out on the response of average-sized canes and the stalk diameter does not influence the outcome except for oversize cuttings, which should therefore be avoided in practice (Antoine5).

Varieties differ in the minimum treatment required to cure a disease; furthermore, within a variety, young cane may be cured by a shorter treatment or at a lower temperature than older cane. When a whole stalk or large sett is treated and the cure is not complete throughout, certain pathogens may spread within the treated stalk or sett and infect many or all of the new canes. Thus, in Louisiana, serial hot water treatment of mosaic on whole stalks gives quite successful control if the stalks are divided into one-node setts for planting after treatment (Benda14), but when the whole stalks are planted directly, most or all new canes will become diseased (Benda15).

The resistance to injury by heat varies with variety, age as well as growing conditions for the source plants and at planting after treatment; it may also vary with disease. Diseased cane may be less resistant than healthy cane and one strain of a pathogen may increase vulnerability to heat more than other strains. Several workers have investigated the factors influencing survival after treatment and have formulated various precautions necessary to ensure maximum germination after heat treatment (Antoine7,8,10, Barrie12, Hughes & Steindl25). Because of the variable growing conditions and planting conditions, recommendations that may be generally applicable have numerous exceptions. In general cane for treatment should be taken from fields in which the plants are well grown, not heavily bored, not severely lodged, and not heavily diseased. If possible, young and succulent cane (or part of the stalk) should be avoided, otherwise stubble cane may be preferable to plant cane. Sheaths should be removed shortly before hot air treatment. How long before hot water treatment leaves and sheaths should be removed from mature canes is quite variable; for younger canes, the presence of leaf sheaths improves survival.

Additives to the hot water in treatment tanks have been explored. The addition of urea and other chemicals has been found to favour survival (Antoine8,10, Hardy24) but the effect is not beneficial to all varieties (James26). The addition of fungicides, especially for the short hot water treatment of chlorotic streak (52°C/20 minutes), has been recommended (Wismerr8).
The practices which favour maximum germination of treated cane seem to be those which reduce further stress. Treated cane should be planted as soon after treatment as possible, in well prepared soil with adequate moisture. The setts should be covered lightly and further soil, when necessary, should be added after germination. Where winters are relatively severe or a dry season well defined, treatment should be completed in time for the cane to germinate before the onset of cold or drought.

A cold water dip after either hot water or hot air treatment usually improves germination by allowing the cane to cool quickly.

**SELECTION OF HEAT TREATMENT**

The selection of a heat treatment from the various time/temperature combinations that are known to cure a disease should aim at the optimum balance of cure and survival. Considering the various factors that affect these two criteria, the selection of a widely applicable treatment may not be easy. Different countries may adopt different treatments for the same disease (e.g. RSD, hot water treatment 50°C/2 hours or 3 hours, or hot air, etc...).

The selection of a control treatment is also influenced by the logistics of mass treatment. The duration must have a sufficient margin of safety to absorb the additional treatment time needed to add and withdraw the cane, as well as to allow for the initial stabilization of the temperature of the treatment medium.

To determine a control measure which meets specified standards of survival and cure, the following procedure may prove useful. The desired result is selected, e.g. 50% survival and 95% control. Within the range of temperatures known to cure the disease, three temperature are selected, and for each temperature separately, three durations that are likely to give a range of responses in survival and cure. The nine time/temperature combinations are tested on setts or whole stalks from diseased stools.

For each temperature separately, the data on proportion of survivors per duration of treatment is plotted on graph paper, with the logarithm of proportion of survivors as ordinate and duration of treatment (minutes) as abscissa. For each temperature, the treatment duration resulting in 50% survival is estimated graphically. The process is repeated for the cure data, and the duration for 95% cure among the survivors is estimated. The six time estimates, three for survival, three for cure, are entered on a graph in which the logarithm of minutes of treatment is the ordinate and the inverse of the treatment temperature in degrees Kelvin is the abscissa. The three points for cures are joined as are the three points for survival. If the line, or part of the line, for cures lies below the line for survival, so that at one temperature, the log duration in minutes is less for cure than for
survival, then the experimental results indicate that the selected combination of survival and cure is attainable (Geard23). The margin of safety for each temperature is the difference between the points on the ordinate. Because the ordinate is the logarithm of treatment duration, even though the lines appear parallel, the margin of safety decreases as the temperature increases. Repetition and variation in the experiment indicate how widely applicable the results may be.

The procedure described is derived from the Arrhenius equation which assumes a single reaction, or by extension, a master reaction (Resconich38, Price and Knorr37). Because the master reaction may be no more than a fiction of convenience, the results should not be extrapolated beyond the temperatures tested.

FROM HEAT CURE TO CONTROL

To develop a heat cure into a commercial control practice that will be useful is not only a problem of plant pathology, but also involves economic judgment and a good deal of extension work. No control practice will be widely accepted or long used unless there is sufficient economic return to offset the costs and effort. The need must be perceived by, and the control practice must be acceptable to, a very conservative constituency.

Epidemiologically, a commercial control practice reduces the inoculum potential of a disease while the frequency of susceptible plants is maintained. How long the infection of these plants can be delayed and how readily and by what additional measures this period can be extended determines the usefulness of a control treatment. Whether the spread is slow and largely from case to cane within a field (as in leaf scald and RSD) or from soil (as in chlorotic streak), very active from cane to cane within and from adjoining fields (as in smut and gummosis) or from other hosts to cane (as in mosaic when corn and cane are grown side by side), determines the strategy for effective disease control.

When control measures have been decided upon, a regular cycle of treatment must be established. The cane to be treated again should be selected from the healthiest field available, e.g. the first stubble of direct heat-treated cane, so that, if the rate of treatment failure stays constant, the absolute number of diseased plants following treatment will be minimal. To be effective, the control must be continuous and must be considered as routine a part of farming as applying fertilizer. Such regular treatment has been found very effective in reducing the occurrence of chlorotic streak in Mauritius.

It can be difficult to assess the extent of cure after heat treatment, especially for diseases with long latent phases or without external symptoms. One or more propagations may be required before the assessment can be performed with confidence. Practical methods for the detection of latent infection can be of great use in such cases to ensure the health status of seed cane nurseries.
The rate of spread of a disease determines how frequently the cane should be retreated. In practice, adequate precautions to prevent reinfection are necessary. Whenever possible, the treated cane should be planted far from heavily diseased fields, or resistant varieties should be planted as buffer. Cultivation tools should be cleaned before working the treated cane, and there should be no replanting of gaps with untreated cane. With such precautions and whenever roguing can be carried out, it may be possible to propagate seed cane through several progeny generations before retreatment is necessary. The amount of cane to be treated is determined by the extent of propagation, the planting rate, and the average yield in tons per hectare.

Two aspects of the use of heat cure in disease control need emphasis, with respect to: (1) the propagation of cane in new areas and (2) the selection of variety-adapted strains of pathogens. The first question is well understood and should be catered for in quarantine from outside as well as within territories. Baker has emphasized the importance of seed-borne infection in the preferential selection of a strain of a pathogen more virulent to a certain crop variety. This aspect has been discussed for gumming disease of sugarcane (Ricaud & Sullivan), whereby the multiplication of a variety in which a new virulent strain of the pathogen has developed, causing systemic infection, can help to perpetuate the new strain. The same concept would apply for mosaic. A heat cure should thus be very useful for the control of these diseases.

HEAT EFFECTS

Most heat treatments sufficient to cure diseases in sugarcane have rather drastic effects on the plant and its pathogens. Small increases in heat resistance of the pathogen, or small decreases in heat tolerance of the cane could make a control treatment ineffective.

The extensive use of heat treatment for RSD and chlorotic streak control has apparently not produced heat resistant strains of these pathogens. Yet heat treatment would seem to be an excellent method for the selection of heat resistant mutant forms. That such mutants have not become established suggests that numerous genetic changes are required at once or that the genetic changes have concomitant effects that lessen the mutant's capacity to compete or survive.

Although heat treatment has not been shown to select heat-resistant mutants, differences in heat resistance among the strains of a pathogen do occur and have to be taken into consideration in the choice of a heat treatment. Thus, higher thermal inactivation points were measured for strains A, B or D than for strain H of sugarcane mosaic virus (Abbott & Tippett). The control of the common field strain in Louisiana, strain H, by a heat treatment with temperatures too low to control strains A, B or D, could have resulted in the preferential selection of the latter strains. Fortunately, most commercial cane varieties are resistant to these heat resistant strains.
and the choice of a heat treatment that would control them as well is not necessary under these conditions.

No gene mutations in sugarcane have been ascribed to heat treatment, but numerous of physiological changes have been noted. These changes may affect the seed cane itself, or they may be long-term, expressing themselves in the roots and shoots growing from the treated seed cane. Changes in the first instance include increased secretion of sugar (Benda & Irvine16), temporary loss of the ability to form a red pigment upon fungal infection (Messiaen & Quiot33,34), increased susceptibility to mosaic infection (Benda13) and loss of apical dominance and of bending in the treated stalks laid horizontally (Brandes & van Overbeek18). For heat dosages which are not lethal, the rate of germination of roots and shoots may be increased, as well as the proportion of buds that germinate from setts. Some of the effects on growth are believed to be due to the destruction of hormones controlling bud and root dormancy.

The long-term changes occur in cells which were not themselves heat treated. Sett roots from treated seed cane when growing in the light do not respond to the positive photogeotropism characteristic of roots from untreated seed cane (Benda, unpublished). The young shoots from heat-treated seed cane are more susceptible to mosaic infection than those from untreated setts (Bourne17, Zummo59). Other changes which have been associated with heat treatment but which may reflect changes in the disease status of the cane are: increased incidence of flowering (Stevenson & Walker53, Dunckelman & Todd21), decreased juice quality (Schexnayde53), and increased susceptibility to smut (James27). No long-term adverse changes in yield potential have been noted following hot-water treatments (Thomson54). It is important to determine all long-term changes to ascertain that heat treatments do not cause or select gene mutations that could alter varietal characteristics.

SYSTEMS OF HEAT TREATMENT

Heat treatment units are equipped with a treatment chamber, a thermostatically controlled heating system, a separate circulating system to ensure turbulence of the heating medium and permeation of the cane mass to facilitate heat exchange, and a container system to move the cane rapidly in and out (Antoine7, Cochran et al20, Edison & Ramakrishnan23, Hughes & Steib15, IISR*, Menon et al32, Steib & Hadden#(ii)). It is not intended to discuss the details of various designs. It should be stressed however that the design of the circulation system is the most important aspect which determines treatment efficiency for each treatment system. If adequate circulation is not maintained, the treatment may not be effective even though the unit “functions” perfectly.

* Blue prints for heat treatment units:
Heat treatment systems may be divided into those that use water as treating medium and those that use air. The basic mechanism for disease cure is believed to be the same for both.

**Water systems**

Because water has greater heat capacity per unit volume than moist air, the hot-water system is more efficient for disease cure, requires less total treatment time, the temperature is more easily controlled throughout the treatment unit and the cane reaches treatment temperature much more quickly. However, hot water is also more lethal to cane for treatment of pathogens with high thermal death points.

The system can be modified to accept bud chips (Silva44), sets, whole stalks in baskets or whole stalks handled in bulk. The cane may be treated cleaned or not but must not be packed nor allowed to float out of the water.

The single hot-water treatment is the most widely used system to heat-treat canes in the tropics where mature stalks 10 to 12 months of age are available. In subtropical regions, the injury from long hot-water treatment for RSD control may reduce cane survival to unacceptable levels. As already pointed out, even for tropical conditions several precautions have to be taken to improve sett survival. In Louisiana, cane 6 to 7 months old is hot-water treated commercially for RSD control by following these practices.

Serial hot-water treatment has been tried by several investigators for treating diseases which cannot be treated satisfactorily at the maximum temperatures applicable with a single treatment (Benda14,15, North35, Wang56). With this method the cane is treated two or more times, one hot-water treatment each day on successive days. The first treatment, or pretreatment, should be a relatively mild one, usually milder than the subsequent treatments and it serves to adapt the cane to heat, provided that moderate conditions of temperature and humidity prevail between the treatments (Benda14). The adapted cane is more heat resistant to subsequent treatments and can withstand longer treatments and higher temperatures than cane which has not been pretreated. It is not known whether fully mature, or overmature, stalks can be adapted by means of a pretreatment, nor whether sugar cane pathogens can also become heat-adapted. Apart from its possible use against diseases for which heat cure has not yet been possible or satisfactory, this method may prove useful for eliminating several diseases of seed cane simultaneously or for allowing treatment of younger cane in order to extend the treatment season in subtropical areas.

**Air systems**

The advantage of hot-air treatment is that it is less detrimental to cane growth and can be used for treating young cane with immature nodes. Such cane will survive hot-air treatment much better than a single hot-water
treatment (Liu et al.). The reason for this may be due to a more gradual increase in the temperature of treated setts. However, hot-air treatment is less efficient for disease cure, takes longer time and requires more hand labour. In the conventional hot-air treatment, the canes are heated as whole stalks from which the leaf blades and sheaths are removed and which are arranged in layers on racks. There is great variability within and among treatment due to differences in the stacking of the canes, result in variations in equalizing of temperature in different parts of the unit.

The conventional hot-air treatment has gradually evolved to combine the advantages of hot-air and hot-water treatments with increasing moisture content of the treatment medium. In the conventional hot-air system the moisture to saturate the heated air is taken from the cane (Schexnayder). In the original designs of hot air ovens the air is circulated and heated outside the treatment chamber, so that there is gradual loss of moisture and towards the end of the treatment the air medium becomes very dry. This causes excessive desiccation of treated canes. In the IISR system the heating elements are within the treatment chamber which is well sealed so that the moisture level is maintained throughout treatment (Menon et al.). In the aerated-steam treatment, steam is added to saturate the air before it comes in contact with the cane (Cochran et al., Edison & Ramakrishnan).

The increased heat capacity of moist air affects the temperature of control and treatment time. The moister the air, the better the heat exchange between the treatment medium and the cane, the more precisely can the average temperature be maintained, briefer will be the treatment time and the lower the temperature of treatment. Furthermore the cane is less desiccated.

The aerated-steam treatment is the most recent modification of the air systems. Survival of one-node setts has been found to be superior with this treatment than with either hot-air or long hot-water treatment (Edison & Ramakrishnan). It has not been shown however that the germination of young cane following aerated-steam treatment is as good as that after hot-air treatment.

In practice the advantages of aerated steam compared to other air systems are that: (1) it is more versatile, cane can be cleaned or not, cane may be racked or not and any quantity of cane up to the capacity of the unit, can be treated; (2) it requires less hand labour; (3) it requires shorter treatment times; and (4) there is less danger of fire from trash adhering to stalks.

So far the aerated-steam treatment has been used successfully to cure grassy shoot, mosaic and RSD. It could very well be developed to provide a practical and universal treatment for several seed-borne diseases of cane.

EMPLEO DE LOS TRATAMIENTOS CALORÍCOS PARA EL SELLO DE LAS ENFERMEDADES DE LA CANA DE AZÚCAR

G.T.A. Benda y C. Ricaud

RESUMEN

Con los tratamientos calóricos de las estacas de caña de azúcar, podemos controlar una docena de enfermedades que pueden pasar de generación a una otra, con un modo sistémico. Los tratamientos son aprovechados: 1) para reducir la incidencia de las enfermedades y por consiguiente de acrecentar la producción, o para disminuir la presión de inoculum sobre algunas variedades sensibles, 2) para favorecer la germinación de las estacas, 3) para eliminar los parásitos en las remesas de estacas de caña. No se demostró que los tratamientos calóricos entrenan alguna mutación en las cañas de azúcar o sobre los patógenos esta planta.

El tiempo y la temperatura de los tratamientos a escoger, dependen de que enfermedad encontremos y de que método a aprovechar. Los métodos de tratamiento son distintos en las proporciones de agua y de aire, y por tanto en la capacidad que tienen de calentar o de agostar. Los tratamientos calóricos para el sello de algunas enfermedades pueden afectar la germinación de las estacas tratadas, dependiente de su estado fisiológico y de las condiciones de crecimiento después de la plantación. Es posible de tomar algunas precauciones para mejorar la germinación. El tratamiento con una mezcla de aire y de vapor, ofrece las mejores condiciones de controlar la enfermedad y la buena germinación. Puede ser además útil en el tratamiento simultáneo de bastantes enfermedades sistémicas.