PLANNED RECOMBINATION IN SUGARCANE BREEDING: ARTIFICIAL INITIATION OF FLOWERING IN SUGARCANE IN SUB-TROPICAL AND TROPICAL CONDITIONS

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ABSTRACT

Planned rather than opportunistic sugarcane crosses are required to continue with improving sugar production. Natural flowering is variable because it is affected by environmental variables such as daylength, temperature, moisture and nutrition. Parental clones flower during specific periods, but because clones are flowering at different times, they cannot be crossed easily. With photoperiod facilities, the time of flowering can be manipulated so that early-flowering clones flower later and late-flowering clones flower early. Clones that rarely flower naturally can be induced to flower in order to use them as parents. Such facilities enable breeders to obtain crosses that have been planned for specific purposes. Flower-inducing facilities have become essential tools for a number of breeding programmes.

Keyword: Photoperiod, induction of flowering, daylength, synchrony of flowering.

INTRODUCTION

Sugarcane breeding is the principal method of improving sugar yields and controlling diseases in the sugar industries of the world. The first attempts to breed new clones were instrumental in controlling diseases such as serreh and mosaic in Java (Stevenson, 1965). The breeding and release of the famous cultivar POJ2878 were the result of a planned cross which could only be made only when weather conditions allowed. The successful cross was made in 1921.

Improved knowledge of breeding and selection in sugarcane highlights the need for making planned crosses for special traits such as resistance to diseases and pests, or high early sucrose for the commercial sector. Parental clones have to flower at the same time for such planned crosses to be made. When sugarcane flowers naturally, specific clones flower at a specific time relative to other clones, each within a short period of up to 14 days. Implementing crosses among clones that flower at different times is virtually impossible unless panicles can be obtained from areas where planned parental clones flower at the required times.

Artificial control of flowering is being practised successfully in a number of countries (Berding, 1995; Miller and Li, 1995; Moore and Nuss, 1987) and this enables breeders to plan and make the required crosses. The procedures to successfully produce panicles under artificial conditions are well documented. This paper indicates presently known limitations to flowering and summarises some practical aspects of facilities required. Procedures followed in managing plant destined for initiating treatments, and in the different countries are outlined.
FACTORS LIMITING FLOWERING

Photoperiod

In sugarcane, flowering is inducted by a slow decrease in daylength from about 12 h 30 min. Flowering is best in areas where the daylength declines at a rate of 30 to 60 s/d from about 12 h 45 min (Berding, 1995) and 12 h 30 m (Moore and Nuss, 1987). This occurs naturally in countries where flowering is profuse such as Barbados, Coimbatore, India and Hawaii and Dwangwa in Malawi. In areas 5° North or South of the equator, the long days are less than 12 h 45 min and the change to shorter days is much less than the required 30 to 60 s/d, hence flowering is not profuse. Similarly, in higher latitudes of 30° or more, the inductive period is too short for many clones to flower.

Temperature

The flowering process has certain temperature requirements and, if these are not met, flowering does not occur. Flowering in commercial sugarcane fields in Zimbabwe was reduced or prevented when night temperatures during the critical period of initiation dropped below 18°C on four to ten occasions (Gosnell, 1973). Conversely, flowering in tropical countries was inhibited by high temperatures of above 32°C during the start of initiation (Martin and Berding, 1995; Moore and Nuss, 1987). In Queensland, the mean proportion of stalks flowering, for a set of nine standard clones, when initiated in the summer months was 11.8% compared with the mean of 60.5% when inducted in the cooler months (Berding, 1995). Seed set is also reduced by temperature; when this falls below 18°C or rises above 27°C, pollen fertility is reduced.

Moisture

Temperature and moisture frequently are related in effecting flowering. Low moisture during the initiation period reduces flowering. A quantitative relationship exists between amount of irrigation applied and the extent of flowering (Berding, 1995; Gosnell, 1973). Adequate moisture is critical for initiation, panicle development, time of panicle emergence, and seed set (Moore and Nuss, 1987).

Nutrition

High levels of nitrogen, particularly at the time of initiation, may inhibit or delay flowering. The extent of the inhibition is affected by the age of the cane, the clone and the availability of water. Flowering at Mount Edgecombe (ME) was delayed by 25 days because of excessive amounts of nitrogen in the soil.

ARTIFICIAL INDUCTION OF FLOWERING

Facilities and procedures

Berding (1995) gives a description of a photoperiod facility in which modern building materials were used. The essential features of a facility are:

- a large building into which the cane can be moved
- automatic heating when temperatures drop below 20°C and cooling when temperatures rise too high
- sufficient lighting: the best lighting in the facility was provided by an incandescent to fluorescent wattage ratio of 30:70
- controls to implement changes in daylengths
- the ability to move cane on trolleys into and out of the facility.
Cane is planted into drums or bins containing a growth medium, either sand and peat or more complex multi-component media, and is grown from 100 days (in the tropics) to 150 to 200 days (in the sub-tropics) before the first photoperiod treatments are implemented. The cane is watered daily and fertilized with nitrogen-containing fertilizers according to a specific schedule. The application of nitrogen is stopped four to six weeks prior to the start of the treatments. When the treatments commence, the cane is moved into the facility daily to effect the daylength treatments. In some countries, this occurs after sunset (Brett and Harding, 1974) or before sunset (Berding, 1995). Daily watering is essential, and, to ensure that no water stress occurs, potted plants stand in a maintained water table. The management of the plant nitrogen has to be rigorous and precise; too much nitrogen reduces or delays flowering and too little may affect the amount of flowering, the size of the panicles, and seed set.

PHOTOPERIOD TREATMENTS

Photoperiod facilities have become essential tools in the sub-tropical countries of Argentina, China, Florida, Louisiana and South Africa. In the tropics, facilities have been constructed in Australia (Meringa), Colombia, Cuba and Taiwan.

The age of cane when initiation starts at Meringa is 100 days, and at ME is 150 to 200 days. The number of inductive days can vary from 15 to 20 days. Clones that are regarded as non-flowering may require more inductive days than the free flowering clones. Flowering is induced by gradually reducing a daylength of between 12 h 30 min and 12 h 45 min by 30 to 60 s/d until the flowers emerge. At ME, panicles have been produced regularly since 1974 by starting with a daylength of 12 h 30 min and reducing this by 30 s per day. The treatments commence at different times and flowering peaks are also different, with flowering occurring about 100 days after the start of the treatments. At Meringa, the best treatment was by starting with a daylength of 12 h 45 min and shortening the days by 30 s per day (Berding, 1998).

Flowering is also initiated on a large scale by exposing the cane to constant inductive daylengths for periods of 30 to 60 days and then reducing the daylength by a natural decline (LaBorde et al, 1997) or by a decline of between 30 and 100 s/d. (Miller and Li, 1995). Peaks in flowering are achieved in the former case by keeping the cane in the constant daylength for different periods and the date on which the treatments are discontinued (LaBorde et al, 1997).

Delayed flowering can be achieved by delaying the start of the whole induction process, such as described by Berding and Moore (1996). Another way is to begin with a constant daylength and only start with declining daylengths later, or start with declining daylengths and during this period halt the process by implementing constant daylengths (Nuss, 1980). The delay is proportional to the number of days exposed to constant daylengths. In sub-tropical areas, flowering is delayed by exposing the cane to cooler ambient temperatures (Brett et al, 1975). Delay in flowering is also achieved by additional nitrogen, applied either before initiation commences or 20 days after the initiation process has begun. Flower initiation occurs, but panicle emergence is delayed by up to 20 days.

Date of flowering can be advanced by starting the initiation process earlier, or by increasing the rate of decline from a slow 30 s/d to 60 s/d. At ME the faster decline resulted in panicles emerging 19 days earlier in the treatment with a 60 s decline. The faster decline reduces pollen stainability and pollen shed (Moore and Nuss, 1987).

Synchronization of flowering is the ultimate aim of breeders, so that crosses can be planned in advance and made. This has not been very successful with natural flowering, as parental clones do not necessarily flower at the same time. Time of flowering is, under comparable climatic conditions, a repeatable trait. Once the time of flowering of parental clones in various treatments is known, the clones can be planted in the different
photoperiod treatments to ensure that synchronization of time of flowering occurs and that the required crosses are made (Nuss, 1978). Photoperiod procedures at the LSU facilities are aimed at synchronizing time of flowering of parental clones (LaBorde *et al*., 1997).

**CONCLUSIONS**

Photoperiod facilities have become an essential tool in several countries in providing breeding and selection programmes with valuable seed. In Florida, six of the last eight clones produced had at least one parent induced to flower in the photoperiod house. Similarly, in South Africa, clones N24 to N26 could not have been bred without such a facility. At Meringa, panicles were obtained in the facility from parent clones that had rarely flowered in Queensland. Photoperiod facilities provide breeders with panicles at regulated times and enable the use of parent clones that rarely flower in plots.

**REFERENCES**


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RECOMBINACIÓN PLANIFICADA EN EL MEJORAMIENTO DE LA CAÑA DE AZÚCAR: INDUCCIÓN ARTIFICIAL DE LA FLORACIÓN EN LA CAÑA DE AZÚCAR BAJO CONDICIONES SUB-TROPICALES Y TROPICALES

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RESUMEN

Se requiere crugamientes planificados en veg de los oportunistas para continuar con el mejoramiento de la producción de azúcar. La floración natural varía mucho por el efecto que tienen las variables ambientales tales como longitud del día, temperatura, humedad y nutrición de la planta. El ideal es de que los progenitores florezcan durante periodos específicos, pero la realidad es de que éstos lo hacen en diferentes épocas y por lo tanto no se puede cruzar con facilidad. Mediante la disponibilidad de infraestructuras que permitan el control del fotoperíodo, la época de floración se puede manipular de tal manera que los clones que florezcan temprano lo hagan más tarde y aquellos que florecen tarde lo hagan más temprano. A su vez, los clones que presenta dificultad para florecer naturalmente, su floración se puede llegar a inducir para que se puedan emplear como progenitores. Esta clase de facilidades ayuda a los mejoradores en la obtención de cruzamientos planificados con propósitos específicos. Las casas de fotoperíodos se han convertido en herramientas esenciales para una gran cantidad de programas de mejoramiento.

Palabras claves: Fotoperíodo, fisiologia, variables ambientales, casas de fotoperíodo.

A SUCRE: INDUCTION ARTIFICIELLE DE LA FLORAISON DE LA CANNE EN CONDITIONS TROPICALES ET SUBTROPICALES.

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RÉSUMÉ

Pour continuer à améliorer la production de sucre, il est nécessaire de pouvoir planifier les croisements entre variétés de canne. La floraison naturelle est variable car elle dépend de variables environnementales comme la longueur du jour, la température, l'humidité et la nutrition. Les clones parentaux fleurissent pendant des périodes spécifiques mais comme ce n'est pas aux mêmes moments ils ne peuvent pas être croisés facilement. Avec des équipements pour réguler la photopériode, la date de floraison peut être manipulée de façon à ce que les clones à floraison précoce fleurissent plus tard et les clones à floraison tardive fleurissent plus tôt. La floraison peut être provoquée chez des clones qui fleurissent rarement en conditions naturelles pour les utiliser comme parents. Ce type d'équipement permet aux sélectionneurs d'obtenir des croisements qui ont été planifiés pour des objectifs spécifiques. Ces dispositifs d'induction de la floraison sont devenus des outils essentiels pour un grand nombre de programmes de sélection.