EFFECT OF ALTITUDE ON SUGARCANE FLOWERING SYNCHRONISATION IN CUBA

By

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Abstract

SUGARCANE breeders have found some difficulties in making crosses associated with flowering induction and synchronisation. The objectives of this investigation were to evaluate the relative importance of the factors involved in the altitude for sugarcane flowering induction and to establish the basis of a controlled breeding program. This study is related to flowering of 100 sugarcane cultivars from 1990–2007 at three altitudes (100, 400 and 800 m above sea level) in Cuba. Sugarcane flowering is primarily in response to photoperiod, and it is conditioned by additional factors that can reduce, inhibit or delay it. In September, the average maximum (28–30ºC) and minimum (21–22ºC) temperatures were optimum for flowering. The extent of flowering was much greater at 400 m, with a marked reduction at 100 m, and intermediate at 800 m. In Cuba, late-flowering sugarcane cultivars start to tassel in the first week of December. At lower altitude, the same cultivars have earlier flowering by an average of 2–4 weeks. A negative linear correlation between percentage of pollen fertility and altitude was observed. In the study, a rise in altitude was accompanied by a large drop in maximum temperature and very little change in the minimum range. Growing cultivars in nurseries at different altitudes proved a useful tool to increase the clonal range and extent of flowering in Cuba.

Introduction

Sugarcane flowering is a complex physiological process consisting of multiple stages of development, each stage having specific environmental and physiological requirements (Julien, 1972).

Natural flowering is variable because it is affected by environmental factors such as daylength, temperature, moisture and nutrition.

Flowering of parental clones is restricted to specific periods, but there are clones that flower at different dates and therefore cannot be used easily in crossing (Nuss and Berding, 1999).

The Cuban sugarcane breeding program began at Cienfuegos in 1905 and it continues until the present time. At this time, Cuban National Center for Sugarcane Hybridisation is located in Sancti Spíritus (Caraballoso *et al*., 1999/2000).

Sugarcane flowers naturally in Sancti Spíritus, but the number of clones, intensity and flowering date, as well as the fertility of pollen, is different among sites located in different altitudes and years (Aguilar and Debernardi**,** 2004).

The objectives of this investigation were to evaluate the relative importance of the factors involved in the altitude for sugarcane flowering induction and to establish the basis of a controlled breeding program.

Materials and methods

Experimental locations

The trial was carried out at three locations in the Cuban National Center for Sugarcane Hybridisation (NCH), located in different altitudes within Guamuhaya's mountains (Table 1)

Table 1—Geographic position of the test locations.

	Guayos	Buenos Aires	Mayarí
North Latitude	22º02´	21º54´	21º58´
West longitude	79º27´	79º35´	80º08´
Altitude (masl)	100	400	800

masl = metres above sea level

Photoperiod at Cuban National Center for Sugarcane Hybridisation

The three experimental sites have similar latitude (22º). The sunrise and sunset data used were obtained through the Spanish Armada's web site:

http://www.armada.mde.es/ArmadaPortal/page/Portal/ArmadaEspannola/ciencia_observatorio/03_Efemerides--01_Sol--02_Salidas_es

The duration of the day was calculated, and the inductive period was determined, considering that it is produced between times while the day lasts for 12.5 and 12.0 hours. With these data, the time of daily decrease was also calculated using the formula

Daily decrease = $\frac{30}{IP}$, where IP = Inductive period (days) and 30 are the minutes for daylength of the IP.

Climate of experimental locations

Data were provided by the Cuban National Meteorology´s Institute for the three altitudes over an 18 year period. Variables taken monthly were:

- Maximum average temperature (Tx)
- Minimum average temperature (Tn)
- Maximum average relative humidity (RHx)
- Minimum average relative humidity (RHn)
- Total rainfall (TR)
- Day with rainfall (DR)

Each variable was divided in three ranges (high, middle and low) as it is indicated in Table 2. This information was used to calculate the range of temperatures and its relationship with flower induction.

Table 2—Values range for climate variables.

Variable	High	middle	low
Tx (º Celsius)	> 30	28 – 30	< 28
Tn (º Celsius)	> 22	21 – 22	< 21
RHx (%)	> 99	98–99	< 98
RHn (%)	> 70	65 – 70	< 65
TR (mm)	> 300	200 – 300	< 200
DR (days)	> 15	10 – 15	< 10

Plant material

Cultivars

One hundred random cultivars from the Cuban Sugarcane Germplasm Bank, with a wide genetic variability, were used in the study. For each cultivar, number of stalks, flowered stalks and percentage of flowered stalks (PFS) were analysed. Date of flower emergence (DFE) and percentage of pollen fertility (PFP) also were recorded.

Results and discussion

Flowering by test locations

Buenos Aires, located at 400 m altitude, was the site with highest and earliest flowering, and intermediate values for pollen fertility (Figures 1–3). Mayarí, located T 800 m altitude, was the site with latest flowering and had lower pollen fertility than Guayos, located at 100 m altitude. Those results enable the design of a strategy for sugarcane flowering synchronisation and sex management in cultivars flowering at the three test locations.

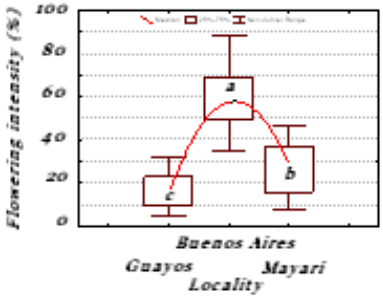

Fig. 1—Flowering intensity by location.

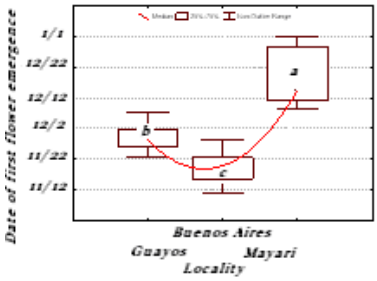

Fig. 2—Date of first flower emergence by location.

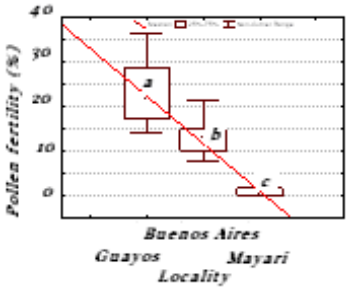

Fig. 3—Pollen fertility by location.

Comparisons among locations of different altitudes have been carried out in some countries. Van-Breemen *et al*. (1963) report greater flowering in Km 14 area, located at 450 m altitude in the Dominican Republic, while Clements and Awada (1964) found a tendency for greater flowering above 390 m in Hawaii. On the other hand Yeu (1980), in China, reported better flowering 335 m in the town of Chungshen. In Australia Pollock (1981) found good flowering in Walkamin at 580 m. Nayamuth *et al*. (2003) in Mauritius reported a tendency to better flowering with altitude. Aguilar and Debernardi (2004) studying the variety CP72-2086 at different altitudes of Mexico reported better flowering at 292 to 477 m. In Guatemala, Polo (2005) reported good flowering at two heights (300 and 760 m).

Inductive period in NCH

The inductive period in the NCH (22º north latitude) is from days 247 to 272. That is to say, from 4–29 September, totalling 26 days with a decrease of 1.15 minutes/day (Figure 4).

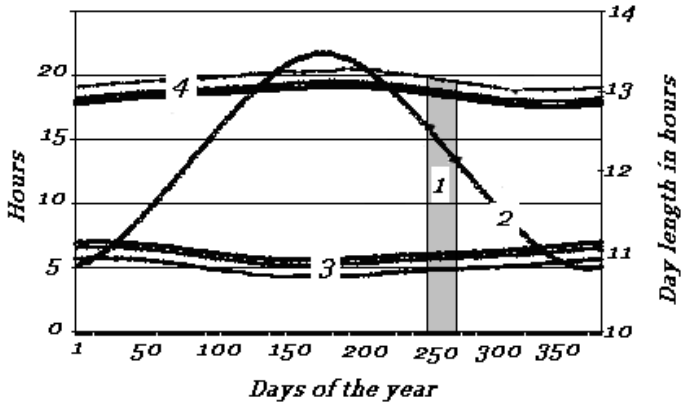

Fig. 4—Photoperiod at 22º north latitude (1: flower induction; 2: daylength; 3: sunrise with morning twilight; and 4: sunset with morning and evening twilight).

Value of decreasing of 1 minute per day has been used in some countries to produce flowers in artificial conditions (Brett and Harding, 1974; Miller and Li, 1995; Nuss and Berding, 1999; Silva *et al*., 2005; Berding *et al*., 2007). This analysis suggests that the photoperiod is not a problem for flowering under our study conditions.

Flowering and climate relation

The temperature (maximum and minimum) was the climate variable with the greatest influence on flowering (Table 3). The other variables didn't have such a marked influence. These would be associated with no difference between locations for rainfall. In contrast, the temperature, mainly maximum, decreases with altitude.

Table 3—Analysis of variance of flowering intensity for climate variables.

Source of variation	DF	Sum of Squares	Mean squares	F-value	Prob.
Tx	2	25 716.15	12 858.07	157.97	0.00
Tn	2	3666.68	1833.34	22.52	0.00
RHx	2	102.29	51.14	0.63	0.54
RHn	2	214.43	107.22	1.32	0.28
TR	2	58.52	29.26	0.36	0.70
DR	2	18.80	9.40	0.12	0.89
Error	51	4150.9	81.39		

The mean values for temperature are the best indicators for flowering potential (Figures 5 and 6). The best results were obtained at the experimental site located at 400 m (Buenos Aires). Optimum values of temperature reported by Nuss (1980) ranged 23–28ºC, while Berding (2005) considered critical temperature for flowering to be 21–32ºC.

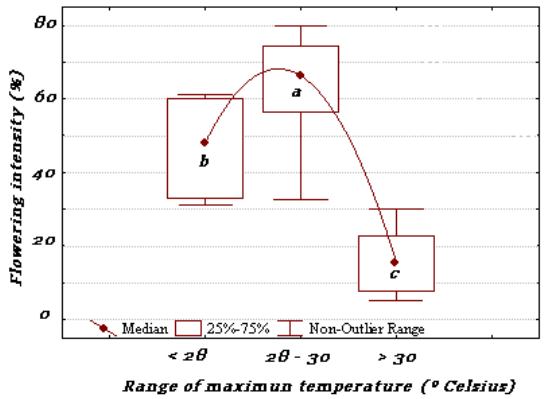

Fig. 5—Flowering intensity by range of maximum temperature.

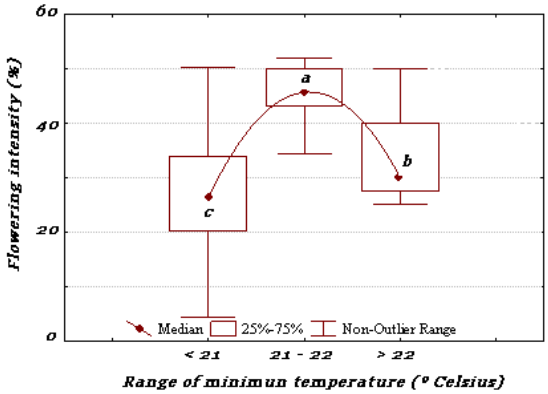

Fig. 6—Flowering intensity by range of minimum temperature.

Table 4 shows a sudden decrease in the maximum temperature with altitude but not in the minimum temperature. As a result, there is a narrower range between the temperatures. Clements and Awada (1967) reported an appropriate flowering in ranges of temperatures between 6–10ºC.

Table 4—Mean values of maximum and minimum temperature (ºC) and their difference by locations.

Locality	Altitude (m)	Tx	Tn	Difference
Guayos	100	31.6	22.4	9.2
Buenos Aires	400	28.4	21.7	6.7
Mayarí	800	27.1	19.8	7.3

Flowering is sensitive to decreases in low temperature (Coleman, 1962). Panicle emergence is delayed at temperatures below 21°C (Clements and Awada, 1967, Nuss and Brett, 1977). Lower temperature increases the time for emergence of the panicle, but also the final duration (Edwards and Paxton, 1979). When night temperatures rise, flowering could be increased by 11 days in the tropics (Berding, 1981).

The development of the pollen is especially sensitive to cold temperatures (Brett, 1950; Levi et al., 1978; Chilton *et al*., 1967; Berding, 1981). Dunckelman (1967) was able to increase or to induce pollen fertility of sugarcane parents through the control of the climate (introducing the plants at night inside a glasshouse) and selection of male progenitors. The pollen fertility decreases when temperature is lower than 18°C or higher than 27°C (Nuss and Berding, 1999; Moore, 1987). According to optimum flowering temperature values (Table 5), the best location to exploit flowering, in Cuba, was Buenos Aires.

Table 5—Sugarcane optimum flowering temperature for different world locations.

Location	Country	Tx	Tn	Difference	Reference
Coimbatore	India	31.5	22	9.5	Rao *et al.* (1973)
Groves	Barbados	28.2	22.7	5.5	Rao *et al.* (1973)
Tapachula	Mexico	29.4	19.6	9.8	Rao *et al.* (1973)
Romana	Dominican Rep.	26.8	19.9	6.9	Rao *et al.* (1973)
Kailua	Hawaii	28.1	21.9	6.2	Coleman (1960)
Km. 14	Dominican Rep.	27.3	20.6	6.7	Ellis *et al.* (1967)

Conclusions

- Buenos Aires is the location for highest flowering in Cuba, of the locations studied. It is located at 400 m altitude, with the best ranges of maximum (28–30ºC) and minimum (21–22ºC) temperature, in the month of September when the inductive period takes place, with similar values at other sites of good flowering in the northern hemisphere.
- There were differences in cultivars flowering date and pollen fertility among the locations studied. They enable the design of a breeding program with greater use of the parents flowering in these three locations through their synchronisation.

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EFFET DE L'ALTITUDE SUR LA SYNCHRONISATION DE LA FLORAISON À CUBA

Par

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MOTS-CLÉS: **Canne à Sucre, Floraison, Synchronisation.**

Résumé

LES GÉNÉTICIENS-sélectionneurs ont des difficultés pour réaliser des croisements en raison des problèmes liés à l'induction et à la synchronisation de la floraison. Les objectifs de ce travail visent à étudier l'importance relative de l'altitude sur la floraison et d'établir les bases pour l'hybridation contrôlée. L'étude concerne l'influence de l'altitude (100, 400, et 800 m au-dessus du niveau de la mer) sur la floraison de 100 cultivars de canne à sucre à Cuba entre 1990-2007. La floraison de la canne à sucre est fonction de la photopériode, mais elle est aussi tributaire d'autres facteurs qui peuvent réduire le taux de floraison, l'entraver ou la retarder. En septembre, les températures moyennes maximales (28–30ºC) et minimales (21–22ºC) conviennent à la floraison. Le taux de floraison était plus important à 140 m, intermédiaire à 800 m avec une réduction marquée à 100 m. A Cuba, les cultivars à floraison tardive fleurissent dans la première semaine de décembre. La floraison de ces cultivars est avancée de 2-4 semaines en moyenne à une élévation inférieure. Une corrélation négative linéaire a été observée entre la fertilité pollinique et l'altitude. Une élévation croissante engendre une baisse significative des températures maximales mais avait peu d'effet sur les minimales. La plantation des pépinières de cultivars à différentes altitudes augmente les possibilités de floraison pour le programme d'hybridation à Cuba.

EFECTO DE LA ALTITUD SOBRE LA SINCRONIZACIÓN DE LA FLORCIÓN DE LA CAÑA DE AZÚCAR EN CUBA

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PALABRAS CLAVES: **Caña de Azúcar, Floración, Sincronización.**

Resumen

LOS MEJORADORES de caña han encontrado dificultades para realizar cruzas en relación al florecimiento y su sincronización en caña de azúcar. Los objetivos de este estudio fueron estudiar la importancia relativa de los factores que se involucran con la altitud para el florecimiento de la caña de azúcar y establecer las bases para un sistema controlado de cruzamientos. El estudio relaciona al florecimiento de 100 cultivares entre 1990–2007 en tres altitudes (100, 400 and 800 m sobre el nivel del mar) en Cuba. La floración de la caña de azúcar está dada principalmente por el fotoperiodo y está condicionada por varios factores que pueden reducir, inhibir o demorar el proceso. En Septiembre, el promedio de temperatura máximo (28–30ºC) y mínimo (21–22ºC) fueron óptimos para la floración. La floración se extendió mejor a los 400 m de altitud, con una reducción marcada a los 100 m, e intermedia a los 800 m. En Cuba, las variedades que florecen tardíamente comienzan a mostrar flores a principios de diciembre. En altitudes menores, los mismos cultivares inician con un promedio de 2–4 semanas más temprano. Un correlación linear negativa entre el porcentaje de la fertilidad del polen y la altitud fue claramente observada. El estudio mostró que un incremento en la altitud estuvo acompañada por una baja de la temperatura máxima y un pequeño cambio dentro del rango mínimo. El estudio demostró que al sembrar cultivares en parcelas a diferentes altitudes es una herramienta útil para incrementar el rango de clones a usarse y extender la floración en Cuba.