English Version

Physiology aspects of sugarcane production

Eder Victor Braganti Toppa[1], *Cleber Junior Jadoski*[2], *Alessandra Julianetti*[3], *Tarcisio Hulshof*[4], *Elizabeth Orika Ono*[5], *João Domingues Rodrigues*[6]

Abstract

The economic yield of sugarcane production is given by sucrose, and non reducing sugars used to make molasses and also fiber, which can be used as an energy source for the plant. The physiological stage of the sugarcane that provides an economic return is maturing, and this can be seen from two different viewpoints: the botanical and physiological. Thus, this study aims to address different aspects of the physiology of the culture of sugar cane in terms of sucrose accumulation, maturation and flowering.

Key-words: Sucrose starvation; maturers; flowering

Introduction

For the purposes of production of bioenergy, a crop must have quick growth and biomass production with great harvest yield, and in terms of produced energy must exceed the fuels with mineral origins. Fulfilling the criteria above, sugarcane is nowadays the most promising energy crop (WACLAWOVSKY et al, 2010).

Sugarcane is a plant which belong to the genus *Saccharum L.*. There is at least six species of the genus, in which cultivated sugarcane is a multispecies hybrid, being called *Saccharum spp*.

The economical yield of sugarcane is given by the production of sucrose (the most valuable compound), moreover by non reducing sugars used to form the molasses and also fiber, which can be used as an energy source for the plant. The industrial process of the cane can also be directed aiming at the production of alcohol, which is used as fuel and by then, used in all the alcohol-chemical industry.

Sugarcane culture occupies in Brazil an area of approximately 5 million hectares, with production of around 340 million tones of stalks in the crop 2001/2002. The main products generated are sugar – approximately 300 million bags – and alcohol – about 11 billion liters/year.

Among the main productive regions of the country it is noteworthy the Mid Center, with 3.5 million ha cultivated, and the state of São Paulo is responsible for 2.5 million ha, in which the average yield is 70 t/ha, and the region Northeast, which grows about 1 to 1.5 million ha, and has an average yield of 55 t/ha.

Maturation

The physiological phase of the sugarcane which provides an economic yield is the maturation. The sugarcane maturation is defined by physiologists as a senescent stage, between the fast growth and the final death of the plant.

It is possible to perform an estimation of the ideal stage of maturation to obtain the greatest industrial yield, correlating the pol cana, which is an indicative of the amount or sucrose of the sugarcane, to other technological parameters as brix (content of soluble solids), purity and AR (reducing sugar)

Received on: 15 jan. 2010. Accepted for publication on: 03 apr. 2010.

[1] Agronomic engineer, student of Master's degree in Agricultre with emphasis in Plant genetic breeding of the Faculty of Agicultural Sciences – Unesp . E-mail: edertoppa@fca.unesp.br

[2] Agronomic engineer, student of Master's degree in Agricultre with emphasis in Ecophisiology of Big Crops from the Faculty of Agicultural Sciences – Unesp. E-mail: cjadoski@fca.unesp.br

[3] Agronomic engineer, student of Master's degree in Agronomy with emphasis in Phytotechny from the Faculty of Agicultural Sciences – Unesp. E-mail: alessandra.julianetti@syngenta.com

[4] Agronomic engineer, student of Master's degree in Agronomy with emphasis in Phytotechny from the Faculty of Agicultural Sciences – Unesp. E-mail: tarcisio.hulshor@bayer.com

[5] Prof.ª Student of doctor's degree in Vegetal Physiology from the Faculty of Agicultural Sciences – Unesp. E-mail: eoono@ibb.unesp.br

[6] Professor Doctor in Vegetal physiology of the Faculty of Agricultural Sciences - Unesp

(FERNANDES, 2003).

The maturation of the sugarcane can be considered under two different viewpoints: botanical and physiological. Botanically, sugarcane is mature after sending flowers and forming seeds which can originate new plants. Considering the vegetative production, which is used commercially, the maturation may be considered earlier in the cycle, when the gems are already in condition to originate new plants. Physiologically, the maturation is achieved when stalks reach their potential of storage of sucrose, i.e., the point of maximum accumulation possible (SILVA, 1989).

The climate conditions of the Southwest region of Brazil, mainly state of São Paulo, are favorable to the natural physiological maturation of the sugarcane beginning in the months of April/May and climax in the month of August. The sum of the gradual drop in temperature with the reduction and interruption of the rainfall delays and/or inhibits the vegetative growth of the plant, while the process of photosynthesis continues to occur normally, with the production of sucrose, which is transported and stored in the vacuole of the parenchymatous cells in the internodes of the stalk (GHELLER, 2001).

According to RODRIGUES (1995), the content of water, nitrogen and potassium in the soil and temperature are factors of major importance in the interference of the degree of the maturation of the sugarcane. Different varieties of cane show different responses to the susceptibility and resistance to the potential of water in the soil. Therefore, the water regime with greater efficiency in promoting the cane maturation is that which presents greater restriction to the growth, although it maintains a liquid supply sufficient to the synthesis, transportations and storage of sugar.

According to AZEVEDO (1981), the most important factors which determine the maturation are: low temperatures, moderated drought and contents of nitrogen in the soil. During the plant life, the percentage of humidity decreases gradually, decreasing from 83 to 71%. The content of sucrose increases less than 10 to more than 45% of the weight of the dry matter; the curves of variation of humidity and of the content of sucrose in function of the time are a great image one of the other. The reduction of the temperature has direct effect in the nutrient absorption, which, if reduced, reduces the vegetative growth and most part of the produced sugars are stored. If the soil humidity reduces, there is a reduction in the water content on the plant tissues, and the dehydration forces the conversion of the reducing sugars in sucrose. Concerning nitrogen, when there is an excess of it, there is a delay of maturation and reduction of the percentage of sucrose, increasing the content of reducing sugar.

A very important tool to anticipate the process of maturation of the cane or provide improves in the quality of the feedstock to the processed is the use of chemical products, which are named maturers. The agricultural efficiency of the maturers depend on the period of application, on the climate condition, on the genetic potential of the variety and on the use in conditions in which the maturation is not favored.

The products traditionally used as maturers belong to the group of the growth inhibitors (trinexapac-ethyl and sulfometuron-methyl) or to the group of the compounds with herbicide action (glyophosate).

The same way, the application of maturers in the sugarcane crop has become practice increasingly common in the sugar-alcohol sector. The aim is to anticipate and maintain the natural maturation and thus available raw material of good quality to the early industrialization, besides aiding in the management of varieties (GHELLER, 2001).

Synthesis, translocation and accumulation of sucrose

According to RODRIGUES (1995), sugarcane has genetic characteristics which determine the capacity of this plant to store photosynthesized carbohydrates (sucrose) in stems, being an important discriminatory parameter of the productive potential of the different varieties. The process of maturation of the cane involves a complex metabolic system, which begins with the photosynthetic activity in the chloroplasts of the leaf cells, ending with the accumulation of photosynthesized carbohydrates in the stems.

For MAGALHÃES (1987), the sequence of events in the formation of starch or sucrose involves metabolic systems located in the chloroplasts and in the cytoplasm, connected by the "transporters of phosphate" located on the membranes of the chloroplasts. For this author, the main points of control of the synthesis of sucrose are located in the catalyst reactions by the enzymes sucrose phosphate synthase (SPS) and fructose 1,6 bisphosphatase (FBPase).

The synthesis of sucrose which occurs in the cytosol and the synthesis of starch which is verified in the chloroplast are competitive processes that are established in the sugarcane leaves. The metabolic pathways of synthesis of sucrose and starch have several phases in common, involving certain enzymes, however these enzymes have isoenzymes that have different properties and are unique for an appropriate cellular compartment. The excess of triose phosphate can be used either to the synthesis of sucrose in the cytosol, or to the synthesis of starch in the chloroplast, considering that the conditions which promote one of them, inhibit the other. The key-compounds of the system, which regulate their partition, involve the relative concentration of orthophosphate (Pi) and of triose phosphate in the cytosol and in the chloroplast, besides the concentration of fructose 2,6-bisphosphate in the cytosol. The communication between the compartments is made through the transporter phosphate/triose phosphate, which catalyses the movement in opposed directions. A low concentration of orthophosphate in the cytosol limits the exportation of triose phosphate through the transporter, being used for the synthesis of starch. Inversely, an abundance of orthophosphate in the cytosol inhibits the synthesis of starch in the interior of the chloroplast and promoted the exportation of triose phosphate to the interior of the cytosol, where it is converted in sucrose (LEITE, 2005).

The transference of the sucrose from the cells of the mesophyll for the vascular system of the phloem involves passage through the plasmalemma and the cell wall. This transportation of sucrose acts in association with the transport of potassium and depends on the metabolic energy. Sucrose in the main energetic source transported in the floema (MAGALHÃES, 1987).

Therefore, sucrose heads towards the vascular system (phloem) and, when exiting them, suffers a series of transformations before being stored in the vacuoles. Based on the explications by ALEXANDER (1973), the transformations begin in the spaces outside the parenchymal tissue, in which sucrose is transformed into glucose and fructose, due to the action of invertases. These hexoses, once formed, will penetrate the metabolic compartment of the cell of the parenchymal tissue, outside the vacuole, and the penetration is made through a process of diffusion. Inside the compartment, the reactions are more complex since these hexoses suffer a fast process of interconversion and phosphorylation.

According to RODRIGUES (1995), through the break of the bond phosphate from the sucrose-P and consequent release of energy, it occurs the active stage of the accumulation, which involves active transportation of the sucrose-P to the interior of the cell. This does not occur with sucrose since its concentration inside the cell is higher than outside, in this case passive transportation. When in the interior of the vacuole, effectively the sucrose is stored.

During the maturation, the sugarcane stores sucrose from the base to the plant apex. In the beginning, the bottom third of the stem shows higher content of sugar than the medium third, and, this, more content than the apex third. Along with the progression of the maturation, the content of sucrose tends to equalize itself in the various parts of the stems, when the apex presents composition similar to the base. Only the immature internodes of the green leaves and the overripe internodes of the base (with high content of fiber) do not retain appreciable amount of sugar (FERNANDES, 1982).

Each internode accumulates its own sugar, being the only values of sucrose more elevated in direction of the center of the stem, declining in the direction of the tips. These differences are more pronounced in the youngest internodes, reflecting probably a distribution different from invertases, in which the intercalary meristem (tree rings) contains more invertases than the central tissues of the internode (RODRIGUES, 1995).

The mechanism of accumulation of sucrose in young tissues and adults is the same, however in the young tissues it occurs the process of hydrolysis of the sucrose by the vacuolar acid invertase, moving the resulting hexoses quickly to the cytoplasm, where they are used to the cell growth and development. The almost null activity of the vacuolar acid invertase indicates that the plant is obtaining an effective accumulation of sucrose. As the cells distance from the meristematic region, they lengthen with higher concentration of sucrose, achieving the process of maturation (CASAGRANDE, 1991).

Thus, the invertase enzymes direct the carbohydrates to the plant growth or to the accumulation of them in the vacuoles, where the increase of their concentration will provide the ripening or maturation of the stems, which occurs when the culture presents the greater qualitative and quantitative yield of sugar.

Flowering

The flowering of the sugarcane is controlled by a complex of factors, which involves mainly the photoperiod, temperature, humidity and solar radiation (CASTRO, 2001), besides the plant maturity and the soil fertility (FARIAS et al, 1987). The interaction between these factors may increase, maintain or prevent the transformation of the sugarcane apex from vegetative to reproductive growth (DUNKELMAN and BLANCHARD, 1974).

For most of the sugarcane cultivars, the floral induction occurs with a photoperiod from twelve hours to twelve hours and a half (CLEMENTS and AWADA, 1967 apud ARALDI et al. 2010). There is a necessity, however, of other specific climate conditions, during and after the induction, for the beginning and development of the inflorescence.

Minimum temperatures below 18 °C (COLEMAN, 1963; PALIATSEAS, 1963; PEREIRA et al., 1983, 1986) and maximum above 31 ºC ELLIS et al., 1967; JULIEN et al., 1974), thus as water deficiency in the inductive period, lead, in general, to a delay in the initiation and development of the panicles, as well as reduce the number of panicles formed (COLEMAN, 1960; CHU & SERAPION, 1971; HUMBERT et al., 1969).

PANJE and SRINIVASAN (1960) verified a delay of fourteen days in the flowering o most of the clones studied of *S. spontaneum* when, in the inductive period, the rainfall was only 74 mm. PEREIRA et al. (1986), analyzing climate data during the induction, from 1972 to 1985, in the region of Araras, SP, found, in relation to the cultivar NA 56-79, that during the years with flowering the average rainfall was 198 mm in ten days, against 65 mm in six days in the years in which the flowering did not occur.

YEU (1980) and ELLIS et al. (1967) emphasize that the smallest difference between the extreme temperatures, the highest rainfall and the largest number of days with rain in the inductive period favor an intense flowering. Still concerning the difference between extreme temperatures, PEREIRA et al. (1986) observed that, in years with flowering, the average difference between the maximum and minimum temperature has been of approximately 10 °C against 14 °C in the years in which the plants have not flowered.

Another important factor related to temperature is frequency of days and/or night with non-inductive temperatures. PALIATSEAS (1963) shows that there is a cumulative effect of the temperature. For COLEMAN (1963), apparently 50% of the nights with temperature lower than 18° C in the inductive period inhibit the floral induction.

It is known that different cultivars behavior differently in relation to the number of necessary days, inside the inductive period, for the formation of the floral stimulus (COLEMAN, 1969). The necessary quantity of this stimulus may lead to panicle differentiation in the beginning or in the end of the inductive period.

The process of flowering is divided, didactically, in four phases: transformation of the growth zone in flower bud; transformation of it in inflorescence; development of the inflorescence and of the flag leaf and emission of the inflorescence. Soon, ending the first phase, the second one begins, developing in the main axis the ramifications and, soon after that, the secondary branches (ARALDI et al. 2010).

The best conditions to the flowering happen in the equatorial regions of the globe, where there is photoperiod of 12 hours of light and 12 hours of dark, with small ranges of temperature. The flowering is inversely proportional to the latitude of origin of the cultivar. Thus, cultivars produced in São Paulo (21° South), tend to flower with greater facility when they are closed to Equador; the inverse occurs with varieties produced in the equatorial region, if taken to a sub-tropical region. This evidences that the action of the latitude is directly related to the photoperiod to which the plant is submitted. Thus, sugarcane is considered sensitive to luminosity to flower, being a plant that only flowers when submitted to days with length inferior than a critical photoperiod, being therefore a plant of short days.

The process of flowering of the sugarcane is extremely sensitive to the environment, which affects the floral initiation and the fertility of the pollen. The ideal photoperiod seems to be from 12 to 12.5 hours, considering that most of the cultivars respond to this photoperiod in the different regions of the world (CASTRO, 1984). Next to Equador, the flowering can be induced in any period of the year. In highest latitudes, the flowering is seasonal, occuring mainly in Fall, when the photoperiod is decreasing, i.e., when plants are concluing the vegetative period. Apparently, there is also a necessity of a period of vigorous vegetetive growth period, before the period of induction, since to the formation of the panicle there is use of sugar stored before, with consequent pith process of the superior part of the stem. This conditions occur in the Fall, making it impractical the flowering in the Spring.

In this phase, it appear the meristematic tissue that will form the flag leaf sheath, which will protect the inflorescence. The leaf that suffers modification to transform into flag is leaf 8, modification this translated to decrease in the leaf blade and great development of the protective sheath of the inflorescence (LEMENTS and AWADA, 1967). The third phase is characterized by the lengthen of the flag leaf sheath (it reaches 70 - 80 cm) and the development of the inflorescence, whose main axis reaches more than 60 cm. The leaf sheath develops to provide space to the inflorescence, as well as to avoid that it breaks, since its tissue is fragile yet. It also occurs in this phase the development of the spikelets, until the formation of the complete structure, as well as the maximum development of the sheath of the flag leaf. This way, the next step is the emission of the inflorescence, followed by the opening of the flowers and pollination. For CLEMENTS and AWADA (1967), the complete emission lasts 4 to 5 weeks, while the opening of the flowers, formation of fruits and maturation, not more than 2 to 3 weeks.

Nitrogen is a nutrient which is noteworthy in the flowering of sugarcane.

A vigorous growth of the sugarcane before the induction is necessary to obtain the maximum flowering in the culture. However, high doses of nitrogen, especially in the moment of induction, reduce the flowering (ALLAM et al., 1978). BERDING et al. (2004) demonstrated that the double of the dosage of nitrogen reduced the emergence of the panicles. In Edgecombe Mount, South of Africa, the flowering was reduced for 25 days due to the excessive quantity of nitrogen in the soil (NUSS e BERDING, 1999). Besides high dosage of nitrogen, the low dosage may affect also the intensity of the flowering, flower size and seed production (BRUNKHORST, 2001). However, nitrogen is necessary in great quantity, but this quantity of fertilizer per sugarcane genotype, to facilitate the flowering in breeding programs, is still unknown (LABORDE, 2007).

BERDING and MOORE (2001) questioned the knowledge of the interaction between nutrition and process of flowering in sugarcane. The maintenance of the constant regime of nutrition maintains better the reproductive phase, the development phase and the phase of emergence of panicles of sugarcane, according to BRUNKHORST (2001) and BRUNKHORST (2003). The role and the management of the nitrogen still require more attention. Regarding to phosphorus, the great amount required for an appropriated growth of sugarcane is 3-5 g kg^{-1} of plant dry matter during the vegetative stage. The probability of toxicity with phosphorus increases with quantities higher than 10 g kg^{-1} of dry matter (BELL et al., 1990). Concerning potassium, HUMBERT (1974) observed that the behavior of the sugarcane has changed in relation to the variety used. High doses of potassium increased the index of flowering of the variety H42-8596, but decreased for the variety H38-2915, and other varieties did not show any sensibility.

The flowering of the sugarcane is controlled by a complex of factors involving mainly the photoperiod and temperature, besides humidity and solar radiation. The process of florescence itself is very complex, involving phytochrome, hormones, florigene, nucleic acids and several factors, according to CASTRO (1993).

In the flowering period, there is an increase in the activity of the acid phosphatase. After the formation of the tassel, this activity decreases, due to the dryness of the apex. This tendency is also observed in the leaf tissue. According to WELLENSIEK (1962), the high energy of the phosphates is required during the specific reactions on the flowering, and the acid phosphatase releases this energy of the phosphates. It also reduced the concentration of sucrose of the stalk transforming the sucrose in glucose and fructose, which are reactive sugars (instable).

It is known that the phytochrome of the type I (phy A) is stimulator of the flowering and that type II (phy B, C, D, E, F) is inhibitor. This way, in *Arabidopsis*, mutants without phyA have delayed flowering and mutants without phyB have fastened flowering. One of the hypothesis is that phyA is an inhibitor of a substance (hormone) which, by its turn, inhibits the flowering. It is important to emphasize that, even though the photoperiodic response can be seen in the leaf, the response of the flowering occurs in the stem apex. This spatial distribution requires the presence of substances inhibitor or stimulator, capable of being translocated. Experiments of grafting confirm the presence of these substances. These experiments leaded some researchers, still in the decade of 1930, to postulate the existence of florigene. Several attempts to isolate and characterize this hypothetical hormone have been performed, without success, aiming to comprehend the mechanisms of interaction with phytochromes (CASTRO et al, 2005).

The transition from the vegetative phase to the reproductive derives from an interaction of endogenous signs with signs of the environment (LEVY and DEAN, 1998). The low temperatures and the photoperiod would be the most important environmental factors (KANIA et al, 1997), and, among the endogenous signs, with an emphasis to the role of the gibberellins.

The GA applied in a plant in the vegetative stage may activate its transformation to the flower stage, stimulating the inductive mechanism of plants of long days (PLD). Several works show that GA inhibits the flowering in plants of short days (PSD). ALEXANDER (1973) demonstrated that GA inhibited the flowering in sugarcane. It is believed that the endogenous GA is quantitatively reduced by the flower substances produced in the phase of the flowering. By monitoring the sugarcane apex (*Saccharum spp.* Hibrid), MOORE (1987) found that the flower apex contains from eight to nine times more percentage of isso-GA3 than the vegetative apex and reduced quantity of GA19 and GA36.

Final considerations

The diversity of studies existent about the different compounds of the vegetal physiology of the sugarcane culture demonstrate the adaptation of distinct technological methods to the obtaining and accumulation of sucrose in levels considered satisfactory. These methods are closely related to biotic factors, i.e., specific to each cultivar, and also abiotic, which relate the cultivation with drastic conditions of the ecosystem, as climate changes and soil fertility. The understanding of each physiological aspect related directly with the crop production is relevant to explore all the productive potential of each cultivar.

References

ALEXANDER, A.G. **Sugarcane Physiology.** Amsterdam: Elsevier, 1973. 752p.

ALLAM, A.I. Effect of nitrogen and moisture on sugarcane flowering. **Proc. Int. Soc. Sugar Cane Technol.**, v. 16, p. 875- 882, 1978.

ARALDI, R.; SILVA, F.M.L.;ONO, E.O.;RODRIGUES,J.D.;Florescimento em cana-de-açúcar. **Ciência Rural**, Santa Maria, v. 40, n. 3, p. 694-702, mar, 2010

AZEVEDO, H. J. **Fisiologia da cana-de-açúcar.** Araras: Programa Nacional de Melhoramento da Cana-de-açúcar, 1981. 108 p. Apostila.

BELL, R.W. Growth and nodulation of tropical food legumes in dilute solution culture. **Plant Soil**, v. 122, p. 249- 258, 1990.

BERDING, N. *et al.* Tropical, managed initiation of sugarcane flowering: optimization of nonphotoperiodic variables. **Proc Aust Soc Sugar Cane Technol**, v. 26, p. 1-12, 2004 (CDROM).

BERDING, N.; MOORE, P.H. Advancing from opportunistic sexual recombination in sugarcane: Lessons from tropical photoperiodic research. **Proc. Int. Soc. Sugar Cane Technol.**, n. 24, p. 482-487, 2001.

BRUNKHORST, M.J. A Preliminary investigation into the effect of plant nutrient levels on sugarcane flowering. **Proc. South Africa Sugar Technol Assoc.**, v. 75, p. 143-150, 2001.

BRUNKHORST, M.J. Investigation into the flowering of sugarcane variety N29 grown under different nutrient regimes. **Proc S Afr Sugar Technol Assoc**, v. 77, p. 306-312, 2003.

CASAGRANDE, A.A. **Tópicos de morfología e fisiologia da cana de açúcar**. Jaboticabal: FUNEP, 1991. 157p.

CASTRO, P.R.C. Controle da florescência da cana-de-açúcar. **Álcool & Açúcar**, v. 4, n. 17, p. 44-49, 1984.

CASTRO, P.R.C. Fisiologia da cana-de-açúcar. In: ENCONTRO CANA-DE-AÇÚCAR, 1992, São Paulo. **Anais...** São Paulo: Rhodia Agro, 1993. p.4-8.

CASTRO, P.R.C. **Fisiologia vegetal aplicada à cana-deaçúcar.** Maceió, 2001. 7p.

CASTRO, P.R.C. **Manual de fisiologia vegetal: teoria e prática**. São Paulo: Agronômica Ceres, 2005. 650p.

CHU, T.L.; SERAPION, J.L. Flower initiation and tassel, emergence in sugar cane. **Journal Agricultura! University of Puerto Rico**, Rio Pedras, 55:101-115, 1971.

CLEMENTS, H.F, AWADA M. Experiments on the artificial induction of flowering in sugarcane. **Proc. Int. Soc. Sugar Cane Technol,** v.12, p.795-812. 1967.

COLEMAN, E.R. Physiology of flowering in sugarcane. **Proc. Int. Soc. Sugar Cane Technol.**, v.13, p.992-1000. 1960

COLEMAN, E.R. Effect of temperature on flowering in sugar cane. **International Sugar Journal**, v.6, p. 351-353, 1963.

DUNKELMAN, P.H.; BLANCHARD, M.A. Controlled photoperiodism in basic sugarcane breeding. Proc **Int Soc Sugar Cane Technol**, v. 4, p. 80-85, 1974.

ELLIS, T.O.; BREEMEN, J.F. van & ARCENEAUX, G. Flowering of sugarcane in relation to maximum temperature during the induction period. **In:** CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS, 12., San Juan, 1965. Proceedings. Amsterdam, Elsevier, 1967. p.790-794.

FARIAS, S.O. et al. Controle de florescimento em cana-deaçúcar através do corte no período de indução floral. In: CONGRESSO NACIONAL DA STAB, 4., 1987, Olinda, PE. **Anais...** Olinda: STAB, 1987. p.718-721.

FERNANDES, A.C. **Cálculos na agroindústria da cana-de-açúcar**. Piracicaba: STAB, 2003. 240 p.

FERNANDES, A.C. **Refratômetro de campo. Boletim Técnico Copersucar,** São Paulo, v. 19, p. 5-12, 1982.

GHELLER, A. C. A. Resultados da aplicação de maturadores vegetais em cana-de-açúcar, variedades RB72454 e RB835486 na região de Araras, SP. **In:** 4 Jornada Científica da UFSCar, 2001, São Carlos. Resumos. 2001.

HUMBERT, R.P.; LIMA, G.M. & GOVEAS, J. Tassel control progress with reglone in the mexican sugar industry. **In:** CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE

TECHNOLOGISTS, 13., Taiwan, 1968. Proceedings. Amsterdam, Elsevier, 1969. p.462-467.

HUMBERT, R.P. **El cultivo de la caña de azúcar.** Tradução de Alfonso Gonzalez Gallardo. México: Compañía Editorial Continental, 1974. 719p.

JULIEN, R.; SOOPRAMANIEN, G.C. & LORENCE, D. Juvenility, senility, climate and flowering in *Saccharum*. **In:** CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS, 15., Durban, 1974. Proceedings. Durban. Hayne & Gibson, 1974. p.984-990.

KANIA, T. et al. FPF1 Promotes flowering in Arabidopsis. **The Plant Cell**, v.9, p. 1327-1338, 1997.

LABORDE, C.M. **Sugarcane tasseling under artificial photoperiod conditions as affected by nitrogen rate and temperature**. 2007. 84f. Dissertation Submitted to the Graduate Faculty of the Louisiana State University partial fulfillment of the requirements for the degree of Doctor of Philosophy.

LEITE, G. H. P. **Maturação induzida, alterações fisiológicas, produtividade e qualidade tecnológica da cana-de-açúcar (*Saccharum officinarum* L.)**. 2005. 156 f. Dissertação (Mestrado em Agricultura) – FCA/UNESP, Botucatu, 2005.

LEVY, Y.Y.; DEAN, C. The transition to flowering. **Plant Cell**, v.10, p.1973-1990, 1998.

MAGALHÃES, A. C. N. Ecofisiologia da cana-de-açúcar: aspectos do metabolismo do carbono na planta. In: CASTRO, P. R. C.; FERREIRA, S. O.; YAMADA, T. (Eds.). **Ecofisiologia da produção agrícola**. Piracicaba: Associação Brasileira para Pesquisa da Potassa e do Fosfato, 1987. p.113-118.

MOORE, P.H.; NUSS, K.J. Flowering and flower synchronization. In: HEINZ, D.J. (Ed.). **Sugarcane improvement through breeding**. Amsterdam: The Netherlands; Elsevier, 1987. p.102-127.

NUSS, K.J.; BERDING, N. Planned recombination in sugarcane breeding: artificial initiation of flowering in sugarcane in subtropical and tropical conditions. **Proc Int Soc Sugar Cane Technol**, v.2, p. 504-508, 1999.

PALIATSEAS, E.D. Further studies on flowering of sugar cane in Louisiana. **In:** CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS, 11., Mauritius, 1962. Proceedings. Amsterdam, Elsevier, 1963. p.805-814.

PANJE, R.R. & SRINIVASAN, K. Studies in *Saccharum spontaneum*. A note on the flowering sequence of *Saccharum spontaneum* clones. **In:** CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS, 10, Hawaii, 1959. Proceedings. Amsterdam, Elsevier, 1960. p. 819-824.

PEREIRA, A.R.; BARBIERI, V.; MANIERO, M.A. Condicionamento climático da indução ao florescimento em cana-de-açúcar. **Revista da Sociedade dos Técnicos Açucareiros e Alcooleiros do Brasil**, Piracicaba v.4, n.6, p.56-59, 1986.

PEREIRA, A.R.; BARBIERI, V. & VILLA NOVA, N.A. Condicionamento climático da indução ao florescimento em cana-de-açúcar. **Boletim Técnico PLANALSUCAR**, Piracicaba, v. 5, n. 3, p. 267-286, 1983.

RODRIGUES, J. D. **Fisiologia da cana-de-açúcar**. Botucatu: Instituto de Biociência, 1995. 101 p. Apostila.

SILVA, G. M. et al. The use of ethephon to manage sugarcane varieties in different locations of the central – southern region of Brazil. In: CONGRESS OF I.S.S.C.T., 20, 1989, São Paulo. **Proceedings…** p. 623-645.

YEU, W.K. Studies on flowering of sugar cane in the South of Haiwan, China. In: CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS, 17, Manila, 1980. **Proceedings...** Makati, Metro Manila, 1980. p.1301-1306.

WACLAWOVSKY, A.J.; SATO, P.M.; LEMBKE, C.G.; MOORE, P.H.; SOUZA, G.M. Sugarcane for bioenergy production: an assessment of yield and regulation of sucrose content. **Plant Biotechnology Journal** v. 8, p. 1–14, 2010.

WELLENSIEK, S. J. The control of flowering. **Natl. J. Agric. Sci**. v. 20, p. 936-39, 1962.