English Version

Physiology development in the vegetative stage of sugarcane

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Abstract

The objective of the work is to characterize aspects of the physiology related to the development in the different stages of the vegetative growth of the sugarcane. Sugarcane is a crop of great economic importance in the world. It is grown as feedstock for the production of sugar and ethanol, and Brazil is the biggest producer, accounting for 33% of world production, highlighting the state of Sao Paulo, that leads with 60% of national production. Several factors can interfere on productivity and technological quality of sugarcane, which ultimately represents the integration of different conditions to which the culture was subjected. In this sense, some of the aspects of greatest importance to have good final yield or good stand of seedlings is related to the practice of planting, get into consideration factors essential to the great growth. This work will discuss some of aspects of the physiology development of the sugarcane under the vegetative stage.

Key-words: root system; levels of sprouting; biomass

Introduction

Sugarcane is a monocot, alogamous and perennial plant, probably originating from the regions of Indonesia and New Guinea, belong to the family *Poaceae*. Its current cultivars are interspecific hybrids, considering that in the genetic constitution the species *S. officinarum, S. spontaneum, S. sinense, S. barberi, S. robustum and S. edule* are involved.

It is a plant of sexual reproduction; when commercially cultivated, however, is asexually multiplied, by vegetative propagation. It is characterized by the inflorescence of the type panicle, hermaphrodite flower, culm in cylindrical growth composed by nodes and internodes, alternating and opposed leaves, tied by the nodes of the stalk, with layers of silica in their borders, and opened leaf sheath. It is cultivated in tropical and subtropical regions of more than 90 countries, spread in a large strip of latitude from 35 °N to 30 °S, being adapted to several conditions of climate and soil, which demand rainfall between 1500 and 2500 mm per vegetative cycle (RODRIGUES, 1995).

Sugarcane is a culture of great economical importance in the world. It is harvested mainly as feedstock for the production of sugar and alcohol. Brazil is the largest producer, responding for 33% of the world production, with a highlight of the State of São Paulo, which leads with 60% of the national production.

If the economy of the country keeps growing in the following years, the production of sugarcane must increase at least 6% per year, to supply the internal market. The ideal would be an increase above 8%, to supply Brazil and export the exceeding. The production of sugar shall increase until it reaches 46 millions of tones in the crop 2019/20, according to estimates of the AngraFNP. The production of ethanol will keep on expansion, due to the increasing consume of the biofuel, reaching 65 millions of liters produced in 2019/20 (AGRIANUAL, 2010).

The expansion of the reed beds must occur, in a close future, in Goiás, Mato Grosso do Sul and Minas Gerais. In the coming years, the new sugarcane

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plantations may surpass a million of hectares in these states. The main Brazilian productive regions are South Center and Northeast, which enables two harvest periods, from April to November and from September to April, respectively, providing the crop development in different climate conditions (TAVARES, 2009).

Root development

One of the most important factors in the relation plant-water-soil is the architecture and distribution of the root system of the plants, as well as their dynamics of growth (VASCONCELOS, 2002). The knowledge of the root system of the sugarcane enables the appropriate use of the agricultural techniques, as: spacing, place of appliance of fertilizers, operations of cultivation, soil drainage and irrigation systems, control of the erosion, use of intercropping, among others (CASAGRANDE, 1991). The study of the root system has been relegated due to the variability of the physical, chemical and biological conditions of the soil, which influenced in the root distribution. This variability may lead to results not representative of the normal development of the root system of the plants (VASCONCELOS et al., 2003).

The development of the root system of the perennial cultures and semi-perennial, as sugarcane, presents an aggravator, concerning the renovation of the roots between the cycles, or in the same cycle, becoming necessary the identification of living cells or metabolically active in a total sampled mass (FARONI, 2004). After the cut of the plant-cane, the old root system remains active for some time and, during this period, is substituted by the roots of the new tiller of the ratoon, with a slow and gradual process. The roots of the ratoon are more superficial than those of the plant-cane by the fact that the tillers of the ratoons sprout closest to the surface than those of the plant (FARONI, 2006).

Due to the same fact, the larger the number of cuts, the more superficial the root system of the ratoons (BACCHI, 1983). The development of the root system is typical for each species, having a cumulative growth of the root system during the culture cycle, from the plant-cane the successive ratoons; the death or the renew of the root system is not caused by the harvest of the culture but by the water deficiency, independent on the phase of development (AGUIAR, 1978; VASCONCELOS, 2002). The root system of the sugarcane (rhizome and roots) is essential to the regrowth of the ratoons, once it covers the role of energetic and nutritional organic reserve (CAMARGO, 1989; MALAVOLTA, 1994, TRIVELIN et al., 2002). At the same time in which the ratoon growth occurs, a new root system is formed, and some live roots are important to feed the shoots in the initial phase of development (CASAGRANDE, 1991).

According to RUSSEL and FILLERY (1996), few studies about roots have been developed and the procedures adopted in the evaluation of the nitrogen of root system rarely recover the fine roots and the rhizodeposits. The studies of FARONI (2006) suggest the use of the isotopic marker ^{15}N, trough leaf application, to analyze the root system of the sugarcane, since ^{15}N is translocated until the subterraneous part of the plant, enabling to identify and quantify live roots.

Still concerning the edaphologic conditions, the compaction of the soil cultivated with sugarcane has been considered a factor which affects productivity (YANG, 1977), being a consequence of the elevated level of mechanization of this culture. The subsoiling in areas of reform of the reed bed has become a routine operation and, as a consequence, there is the worsening of the compression, besides increasing the cost of production. The aeration of the soil is necessary so there is a maximum of absorption of the nutrients by the roots. According to QUEIROZ-VOLTAN (1998), an inefficient supply of oxygen influences the absorption of the essential elements N, P, K, Ca, Mg, Cl, B, Zn, Cu, Mn and Fe. The aerobic respiration is the largest energetic supply used for the absorption of nutrients and, in order to gave an appropriated aeration to their survival, roots need 10% of volume of air in soil (KIRKHAM, 1987).

Studies of the autonomy of plant roots of sugarcane were performed by QUEIROZ-VOLTAN (1998), analyzing the effect of the soil compression in some aspects of the structure of the sugarcane plant roots, developed in crop conditions, in latossolo with sandy texture. The conclusions of the author were that there is a tendency that the roots developed in more compressed soils present the relation between cortex thickness and vascular cylinder with a highest value.

Similarly, TROUSE JR. (1967) determined, in experiments in vases with simulated compression, six stages of degradation of sugarcane plant roots, in the four types of soil from Hawaii, and concluded that with the increase in the soil density, the roots tended to develop in a more angled form, with few roots more developed and young roots, able to penetrate in the soil.

The considerations of OTTO (2007), about the distribution of the root system of sugarcane, evidenced that the nitrogen fertilization of crop did not promote a higher accumulation of sugarcane root mass and favored the concentration of the roots in the superficial layer. Besides the observed, the author reports that 70% of the roots are concentrated in the first 20 cm and 80% are distributed in the central 60 cm of the ratoon, considering that the soil compression and the low contents of phosphorus, calcium and magnesium and the high contents of aluminum do not allow the root system to deepen in the soil.

In this sense, regarding the thematic nitrogen fertilization in sugarcane, a large number of experiments performed decades ago in several regions of Brazil showed that the response of the sugarcane to nitrogen is lower and less frequent that that observed in ratoon-cane (ALBUQUERQUE; MARINHO, 1983; ZAMBELO Jr; AZEVEDO, 1981; CANTARELLA; RAIJ, 1985). Less than 40% of the 81 experiments performed in the state of São Paulo with plant-cane showed response to nitrogen (CANTARELA; RAIJ, 1985). Values still lower were presented by AZEVEDO et al. (1986), who only found significant responses in less than 20% of an universe of 135 experiments performed all over Brazil.

Several factors have been listed to explain the low responses of the plant-cane to nitrogen, among them the mineralization of the organic matter of the soil and of the cultural waste of the cane itself, favored by the revolving of the soil during the reform of the reed bed (CANTARELLA; TRIVELIN; VITTI, 2007). Other factors which justify the low response of the plant-cane to nitrogen include the highest vigor of the root system of the plant-cane compared to the ratoon, the improvement of the soil fertility associated to liming, the biological fixation of nitrogen, the lowest initial demand for nutrients in the plant-cane, the losses of nitrogen by leaching and the contribution of the nitrogen contained in the culm of the seed (AZEVEDO et al., 1986; ORLANDO FILHO et al., 1999, apud CANTARELLA; TRIVELIN; VITTI, 2007). In a large part of the experiments with plant-cane it was verified a low response of the culture to the nitrogen fertilization, while for the culture regrowth (ratoon-cane) most of the experiments showed response in the production of culms (CARNAÚBA, 1990).

At the same time that several works did not verify response of the sugarcane to the application of nitrogen, many observed the contrary. The productivity of cols of the plant-cane went from 62 to 104 t ha^{-1} when it was added 120 kg ha^{-1} of nitrogen in a Latossolo Vermelho Amarelo Distrófico álico[1] (KORNDORFER et al., 1997). On the other hand, CANTARELLA et al. (2007), who evaluated the plant-cane and three consecutive ratoons, verified that the application of 60 and 120 kg ha^{-1} of nitrogen promoted an increase in the productivity in the order of 20 and 35% in relation to the control, respectively, in the average of the 4 cycles, in a Latossolo Roxo Eutrófico[1].

Sprouting

According to ARAÚJO (2006), the choice of the cultivar to the cultivation is one point which deserves special care, not only by its economical importance, as generator of green mass and richness in sugar, but also by its dynamic process, since annually there are new cultivars, always with technological improvements when compared to those which are being cultivated. In Brazil, as in other countries producers of sugarcane, cultivars have been continually tested aiming to increase the productivity, obtain better resistance to plagues and diseases and better adaptation to the variations of climate, types of soil, techniques of cut or management.

Several factors may interfere in the productivity

1 Brazilian soil classification

and in the technological quality of the sugarcane which, in the end, represents the integration of the different conditions which the culture is subjected to (GILBERT et al., 2006). As a consequence of these and other causes of variation along the cycle, there is a necessity of prevision of the crop responses to different stimuli (MARCHIORI, 2004).

Some of the aspects of greater importance to have good final productivity or good stand of seedlings are related to the practices of planting, considering factors indispensible to the culture optimization, as choice of the area and the cultivar, sanity of seedling, period of planting, prepare of the appropriated soil, depth of planting, cover of the ratoons and distribution of buds in the furrow.

The propagation of sugarcane is generally made trough pieces of culm, containing one or more buds. The sprouting is an important phase, since a good establishment of this reflects in a good stand, which will bring to the cultivated area vigorous plants. According to SIMÕES NETO (1987), the phase of sprouting of the buds is affected by two types of factors: those characterized as intrinsic, coming from the metabolic system of the plant, and those called extrinsic.

In the matter of better development of the levels of sprouting, DILLEWIJN (1952) reports that it must be considered how long the seedlings must be stored, before their distribution in the furrow. The author observed in his studies that when there is an interval of three days between the cut and the planting, the stem pieces coming from the culm apex present better sprouting than the other parts of the culm.

According to CASAGRANDE (1991), in relation to the depth of planting, two aspects must be observed, the depth of the furrow and the thickness of the soil layer which is placed over the stem pieces. According to the author, the lack of soil humidity may damage the stem pieces sprouting, as well as the excess caused by the irrigation, irregular drainage and accumulation of rain water. CASAGRANDE (1991) still reports that, even having identical environmental conditions, the sprouting may be different between the several cultivars of sugarcane.

The good capacity of sprouting is a desirable capacity of the cultivars, mainly when the planting period involves periods with unfavorable environmental conditions (FARONI, 2006).

Due to the lack of tradition in the sugarcane production, the culture has not been largely researched in Cerrado. With the need of expansion of the productive areas to meet the internal and external demand of their products, as well as their energy, the areas of Cerrado are an important alternative. According to CESNIK and MIOCQUE (2004), the cultivation fields, mainly in the new regions, multiply in a rather disordered way, accepting indiscriminately the use of cultivars without the proper phytosanitary care and without the necessary tests of productivity. Thus, it is increasingly large the stimulus and the incentive to the studies with focus in the knowledge of the new cultivars existent and that are best adapted to the conditions of acidity, low fertility and water deficit in the region of Cerrado, aiming at the progress in the Brazilian productivity. In this sense, GODOY et al. (2009) evaluated the sprouting and the tillering of cultivars of ratoon-cane of third cycle in environment of Cerrado, observing how parameters of mean value of height and number of tiller, leaf area per tiller and biomass of the ratoon shoot of cultivars of sugarcane, which enabled the conclusion that for the conditions of Cerrado the cultivar CTC4 presented the best index to the phase of culture establishment.

Still concerning the studies in the environment of Cerrado, CARGNIN et al. (2008), focused their study in the sprouting of sugarcane cultivars, which allowed to observe that the sprouting under the conditions of the Brazilian Cerrado is satisfactory to the cane culture, with significant differences between cultivars concerning the seedling sprouting. However, there is no relation between the low sprouting of the seedlings and the plant-cane and the ratoon.

Tillering

Diola and SANTOS (2010) describe that the tillering begins approximately 40 days after the planting and may last until 120 days, being a physiological process of continuous underground rooting of the nodal joint compressed to the primary bud. It provides to the crop the number of culms necessary to a good production. Early formed tillers help to produce thicker and heavier stems, while those formed later die or remain short or immature. The maximum population is reached between 90 and 120 days. At 150-180 days, at least 50% of the tillers die and a stable population is established. Although 6 to 8 tillers are produced from a gem, it is observed annually that 1.5 to 2 tillers per gem remain to form canes.

Several factors as variety, light, temperature, soil humidity (irrigation), spacing and practices of fertilization influence in the tillering.

Light is the most important factor, since the appropriate light in the plant base during this period enables basal vegetative buds.

CASAGRANDE (1991) also reports the importance of the light in the tillering, and he determines that to verify this, it is necessary only to observe the sugarcane planted under the trees of close to a fence entwined with trees and shrubs.

CRISTOFOLETI (1986) reports that the sugarcane plants coming from greenhouse 56 days old and planted in the field, under conditions of low luminosity, had practically all their tillers dead. However, when planted under normal conditions of luminosity has a normal process of tillering.

Considering that the tillering is regulated by the auxins produced in the plant apex, it can be verified that they fall in continuous flow (DILLEWIJN, 1952). These auxins have double effect, at the same time promoting the enlargement of the stem and blocking the development of the lateral buds. Under the effect of the high light intensity, the flow of the auxins from the apex to the base would be reduced, and, consequently, there would be decrease in the degree of inhibition of the lateral buds, resulting thus the formation of tillers.

In the case of the low light intensity, as well as in seasons with short days, tillering would be reduced or terminated, depending on the degree of manifestation of the luminosity, in terms of intensity and length.

FIGUEIREDO (2008) cites that the change of the collection system (burned cane to crude cane), may also interfere, since among the several factors which influence in the reduction of the tillering, the low luminosity under the straw layer may be important.

After the luminosity, temperature is one of the most important factors to tillering. DILLEWIJN (1952) reports that the tillering increases as the temperature increases, until a maximum of approximately 30° C. Temperature below 20° C delays the tillering.

Among the mineral elements, most of the researchers report that the most important to tillering are nitrogen and phosphorus. In a general way, it has been observed that, in soils with low fertility, tillering has been lower, demanding more expending with seedlings.

Soils with low retention of humidity are more likely to derive sugarcane a low tillering. On the other hand, soils with excess of humidity, poorly drained, may also damage the tillering (CASAGRANDE, 1991).

Spacing also influences in tillering. According to DILLEWIJN (1952), the final number of manufacturable culms that a sugarcane crop can produce, in certain conditions, is fixed in some particularly strict limits. The effort to overcome these limits planting exceeding quantities of buds is abortive, and constitutes a waste. The more used spacing in Brazil are 1.4 m and 1.5 m.

When out of control, plagues and diseases influence negatively in the tillering (the cornstalk borer (*Elasmopalpus lignosellus*) and sugarcane borer (*Diatraea saccharalis)* are noteworthy).

From March an onwards, with poorer conditions of luminosity and heat, the cane planted in this period tend to have a lower index of tillering, when compared to the one planted in the other months.

When out of control, weeds also influence negatively in the tillering, reducing up to 3 to 4 times the number of culms/m and from 6 to 7 times the final production (due to the scrub competition).

Growth of the shoot

The growth of the shoot of the sugarcane depends on several biotic and abiotic factors such as: planting period, temperature, humidity, soil fertility, variety, plague attack, competition per weeds etc.

Concerning the planting period, which is one of the factors which interfere the most in the growth, sugarcane crop is divided in 3 different periods: cane of a year, cane of a year and a half, and winter cane.

CASAGRANDE (1991) affirms that the cane of a year (12 months), planted in September-October, have its own maximum development from November to April, decreasing after this month due to adverse climate conditions, with possibility of harvest, depending on the variety, after the month of July. Sugarcane of a year and a half (18 months), planted from January to the beginning of April, has a restrict, null or even negative growing tax, in function of the climate conditions from May to September; when having good rainfall conditions, the phase with larger development of the crop is processed from October to April, with maximum peak of growth, from December to April.

The third period (winter cane) is planted from May to August, enabling satisfactory results, however there is a mandatory necessity of irrigation or fertirrigation due to low water availability, at least in the initial phase of crop development.

About the accumulation of dry matter (DM) of the shoot, MACHADO et al. (1982) observed that it was a sigmoid curve obtained trough the function of logistics:

$$P(g\,m^{-2}) = \frac{5389{,}5}{1 + \exp(5{,}6609 - 0{,}01874\,T)}$$

In which: P is the total dry matter and T is the number of days after the planting

Concerning the Leaf Area Index (LAI), SHIH and GASCHO (1980) noticed that the maximum value was reached when the plant was 6 months old, while the same maximum of culms was obtained when it was 5 months old. The increase of the LAI presages high production of photossynthates and high production of sugars. One of the forms of increasing the LAI would be the reduction of the spacing, with more expressive responses in zones with shorter growing stations.

According to DIOLA and SANTOS (2010), the growth of the stems begins 120 days after the planting and lasts until 270 days, in a crop of 12 months. This is the most important phase of crop, since is when it occurs the formation and lengthen of the culm, which results in production. The leaf production is frequent and quick during this phase and the leaf area index reaches values between 6 and 7. In favorable conditions, stems grow quickly, almost 4 to 5 internodes per month. The irrigation, fertilization, heat, humidity and conditions of luminosity favor the lengthen. Temperatures of approximately 30° and humidity at about 80% are the most appropriated to this phase.

Since it is classified as a C4 plant, cane presents a growing and use of water rate highly efficient. ROCKSTROM et al. (1999) report an efficiency of the use of water from 123 to 168 L per kg of dry mass. YATER and TAYLOR (1988) published registers of inferior expenses in Australia (between 69 and 111 liters per ton of cane), considering that the average of the C4 plants is between 250 and 350 L kg^{-1} of dry mass and that of the C3 plants is between 450 and 1000 liters of water per ton of dry matter.

CASAGRANDE and VASCONCELOS (2010) affirmed that the superior limit of temperature of the C4 plants is at approximately 45° C (C3 has an approximate limit of 30° C) and absence of photorespiration, i.e., even in situations of water stress, it can perform the photosynthesis with an efficient mechanism of gather and transport CO_2.

Final considerations

The plants do not respond similarly to the root development, sprouting, tillering and growth of the shoot, some are capable of developing in satisfactory way in edafic conditions and others are not. According to the observation of several authors, the physiology of the development of the vegetative stage ranges between cultivars in the same species according to the phenological cycle, and there are cases in which there are more differences between cultivars than differences between species. Therefore, the comprehension of the physiology of each stage of the phenological cycle is necessary to establish good stands to the culture and consequently to obtain good productivity.

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