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Initial development and yield in sugarcane from different propagules[1]

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ABSTRACT

The use of small sections of sugarcane propagules for planting brings new challenges, due to the use of different parts of the stem, since each one contains different concentrations of reserves and hormonal balances. This study aimed to assess the influence of types of propagules used for planting sugarcane. A field experiment was carried out using a randomized block design, with three replications, in a 3 x 3 factorial arrangement (propagules with 2, 3 and 4 buds from the apex, middle and base of the stems). The original position (apical and central) and the number of buds of the propagules (2 and 3 buds) influenced the initial development of the plants and, consequently, their yield. The interaction between these two factors showed that, as the number of buds of the propagules decreases, their position plays an important role in budding. Thus, when smaller propagules are used for the establishment of sugarcane, the original position of the bud in the propagule should be considered.

KEYWORDS: Propagule length; bud position; sprouting; tillering.

RESUMO

Desenvolvimento inicial e produtividade em cana-de-açúcar a partir de diferentes propágulos

O uso de pequenas seções de propágulos de cana-de-açúcar para o plantio gera novos desafios, devido ao uso de diferentes partes do colmo, pois cada uma contém concentrações de reservas e balanços hormonais diferentes. Objetivou-se avaliar a influência de tipos de propágulos utilizados para o plantio de cana-de-açúcar. O experimento foi conduzido a campo, em blocos casualizados, utilizando-se arranjo fatorial 3 x 3 (propágulos com 2, 3 e 4 gemas provenientes do ápice, do meio e da base dos colmos), com três repetições. A posição original (apical e central) e o número de gemas dos propágulos (2 e 3 gemas) influenciaram no desenvolvimento inicial das plantas e, consequentemente, na sua produtividade. A interação entre os dois fatores mostrou que, à medida que o número de gemas dos propágulos diminui, sua posição desempenha papel importante na brotação. Dessa forma, quando propágulos menores são utilizados para o estabelecimento de canaviais, a posição original da gema no propágulo deve ser considerada.

PALAVRAS-CHAVE: Tamanho do propágulo; posição de gemas; brotação; perfilhamento.

INTRODUCTION

In commercial sugarcane fields, planting occurs through vegetative propagules (cuttings) that may contain several buds in a latent state. However, under favourable conditions, latent buds pass into an active state of growth and development, as the activity of growth regulatory enzymes alters the food reserves (Jadoski et al. 2012).

Currently, the planting systems adopted in Brazil use various technologies. The conventional planting, or semi-mechanized method, consists of fractioning and aligning cuttings into the furrow by manual planting, and mechanical covering of the ridges. In contrast, the mechanized method uses machines, termed planters, that distribute whole or sectioned stems into the furrow at planting (Ripoli & Ripoli 2010). With the increase in crop production costs and labour shortages, the expansion of crop mechanization systems involves increasingly more technologies to identify improvement strategies, particularly in agricultural productivity (Arruda 2011, Flores et al. 2012).

Mechanized planting considerably alters the distribution of the cutting types in the planting furrows. In the manual planting system, cuttings with 4-5 buds predominate, whereas, in mechanized planting, there is a predominance of seedlings with 2 or 3 buds. Another development in this area is the pre-sprouted seedlings technology (Landell et al.

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2012), termed MPB (Portuguese acronym), which uses small propagules to increase the efficiency and economic gains of seedlings for the replantation of areas, as well as renovation and expansion of commercial sugarcane areas. The use of small cuttings generates new challenges, because various parts of the stalk are used, each one with dissimilar concentrations of reserves, and various hormone balances. In this context, there is motivation to determine what type of cutting should be prioritized for planting.

One of the most important characteristics of sugarcane plants is their initial sprouting (Silva et al. 2004). An understanding of bud outgrowth in sugarcane is also relevant to achieve more reliable bud germination, shoot architecture and, therefore, crop establishment (Ehsanullah et al. 2011). Studies addressing the influence of the original cutting position in sugarcane stalks concluded that those from apical and central positions sprouted earlier and had a higher germination percentage than those from the basal position. Carlin et al. (2004) attributed these features to the bud age, since those situated in the apical and central positions were younger and, hence, had higher metabolic activity than those located in the basal position. Beauclair & Scarpari (2006) stated that early cane sprouting results from buds with low hormone concentrations (growth hormone inhibitors) and the apical dominance that exists between these buds. Namely, younger buds will trigger sprouting earlier than older buds. Moreover, younger buds may even inhibit the sprouting of older buds. Another attribute to consider, when choosing propagules for planting, is their amount of reserves, i.e., the cutting size and the consequent number of buds that should be metabolically active and act as a source of nitrogen and other nutrients (Carneiro et al. 1995).

However, previous studies about cutting sizes and stalk position for sugarcane planting (Carneiro et al. 1995, Silva et al. 2004, Beauclair & Scarpari 2006, Ehsanullah et al. 2011) assessed only the initial plant development stage, specifically their influence on yield, while the raw material quality was not considered. Our hypothesis is that early cane sprouting and, hence, initial plant development, which is a function of the cutting type used for planting, directly influences cane yield and raw material quality. Thus, this study aimed to assess the influence of various types of sugarcane plant cuttings (lengths, i.e., bud number and original position) on these two outcomes.

MATERIAL AND METHODS

The study was carried out in a traditional cane production region of the São Paulo state, Brazil, located at Tabapuã (20º53’51’’S, 48º58’W and 515 m of altitude), during the 2013/2014 crop season, using an Oxisol with 20.5 % of clay (0.4 m depth). The local climate is classified as Aw (Köppen classification), mesothermal tropical, with a mean annual temperature of 24 ºC and annual precipitation of 1,389 mm (Figure 1).

The experiment consisted of 11-month-old RB835054 sugarcane cultivar cuttings, classified according to their original bud position and cutting length (with 2, 3 and 4 buds per cutting). Regarding the original bud position, cane stalks were divided in three sections, being the apical located in the upper third, the central between the apical and basal, and basal in the lower third, in contact with the soil.

The experiment was conducted in a 3 x 3 factorial arrangement (original bud position x cutting length factors), resulting in 9 treatments, arranged in a randomized block design, with three replications. The plots were 2 m long, with 3 rows spaced 1.5 m apart. Therefore, bud distribution varied from 17 buds m^{-1}, 16.5 buds m^{-1} and 18 buds m^{-1}, respectively for 2, 3 and 4 buds per cutting.

Based on the soil chemical analyses (Table 1), mono-ammonium phosphate fertilizer was applied in the furrow at planting and at 45 days after planting (DAP), as topdressing, to provide 50 kg of N, 150 kg of P_2O_5 and 100 kg of K_2O ha^{-1} (Spironello et al. 1996). The trial started on January 30 (2013) and each row of cuttings was planted at a 5 cm overlap. Pests,

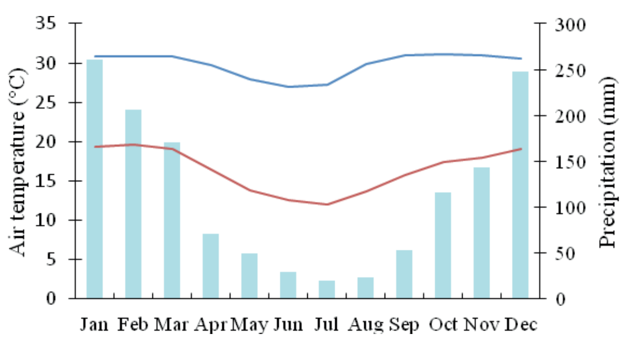

Figure 1. Climatic diagram of monthly mean values of maximum and minimum air temperatures (lines) and precipitation (bars), in Catanduva, São Paulo state, Brazil. Source: Instituto Nacional de Meteorologia - INMET (1972-2010).

Table 1. Results of the soil chemical analyses.

Layer	OM	pH	H + Al	P	K	Ca	Mg	Al	S	SB	CEC	V	m
m	g dm^{-3}	$CaCl_2$	$mmol_c$ dm^{-3}	mg dm^{-3}	——— $mmol_c$ dm^{-3} ———				mg dm^{-3}	— $mmol_c$ dm^{-3} —		—— % ——	
0.0-0.2	9.0	4.9	28.0	18.0	3.8	19.0	9.0	1.0	13.0	31.8	59.8	53.2	3.0
0.2-0.4	8.0	4.4	42.0	10.0	2.6	17.0	8.0	6.0	56.0	27.6	69.6	39.7	17.9

OM = organic matter; SB = sum of bases; CEC = cationic exchange capacity; V = percentage of base saturation.

diseases and weeds were controlled to negligible levels.

All agronomic traits assessed were split into two groups, according to the development phase: i) emergence/establishment (16-188 DAP); and ii) yield, at final harvest, i.e., at 436 DAP. For cane sprouting, two dates were considered: 16 DAP, in order to evaluate the emergence speed (early sprouting period), and 34 DAP (end sprouting period). Once the number of buds per cutting differed among treatments, the percentage of cane sprouting was calculated according to the equation below, in order to compare sprouting among the length cutting treatments:

$$\text{Sprouting (\%)} = \frac{\text{total cuttings}}{\text{Number of planted buds}} * 100$$

Tillering, plant height and stalk diameter measurements were performed at 51, 63, 124, 161 and 188 DAP. The number of stalks with at least one fully-expanded leaf was measured to study the dynamics of tillering in detail. Plant height was defined as the distance from the soil surface to the +1 leaf blade, while stalk diameter was defined in the average distance between the soil surface and the +1 leaf blade.

For yield group traits, cane yield [i.e., fresh millable stalk (Mg ha^{-1})], sucrose concentration in the juice (kg ha^{-1}) and total recoverable sugar per hectare [TRS (Mg ha^{-1}) = (sucrose concentration in the juice x cane yield) x 1,000] were measured. The sucrose concentration in the juice was estimated based on Consecana (2006), a method widely used in the Brazilian sugarcane sector.

All data were statistically appraised using the Statistical Analysis System software, version 9.3. The homogeneity of variance was checked and, when necessary, the data were transformed for subsequent statistical appraisal, using the Tukey test at 5 %.

RESULTS AND DISCUSSION

The analysis of variance indicated a significant interaction between the original bud position and cutting length, with significant effect ($p < 0.01$) for almost all agronomic traits analyzed, except for tillering and sucrose (Table 2).

Early cane sprouting (16 DAP), i.e., higher sprouting speed, was observed in smaller cuttings (with 2 and 3 buds) from apical and central positions (Table 3). Early cane emergence may be beneficial for crop establishment on the field. However, after sprouting, in an early shoot stage, there is great dependence on the nutritional propagules reserves, at least until the root system is established (Verma et al. 2013).

The literature results on early cane sprouting, when using different cutting lengths, are controversial. Jain et al. (2010) pointed out several limitations in bud chip technology, due to the faster reserve depletion resulting in poor survival stand, under field condition. Quintela et al. (1997) reported a higher sprouting rate

Table 2. Results of the analysis of variance (F estimates) for sugarcane agronomic traits, according to the original bud position and cutting length.

Variable	Sprounting (16 DAP)	Sprounting (34 DAP)	Tillering	Plant height	Cane diameter	Cane yield	Sucrose	TRS
Position (P)	501.40**	21.94**	7.23**	25.66**	6.49**	8.46**	2.40^{ns}	11.95**
Length (L)	32.20**	0.41^{ns}	0.84^{ns}	16.04**	3.79*	4.36*	0.48^{ns}	3.86*
P x L	13.07**	4.78**	2.29^{ns}	6.80**	3.75*	7.26**	2.36^{ns}	3.67*
CV (%)	11.00	20.00	18.50	3.10	3.50	27.30	12.40	29.20

DAP: days after planting; TRS: total recoverable sugar per hectare. *, ** and ^{ns}: Significant at 1 %, 5 % and not significant, respectively.

Table 3. Interaction between the plant bud position and cutting type in all agronomic traits analyzed.

Type	Sprouting (%) 16 DAP			Sprouting (%) 34 DAP		
	Apical	Central	Basal	Apical	Central	Basal
2 buds	29.105 Aa*	9.987 Ab	1.817 Ac	67.647 Aa	60.621 Aa	30.229 Bb
3 buds	24.064 Aa	7.229 ABb	1.842 Ac	69.529 Aa	53.199 Ab	45.623 Ab
4 buds	14.889 Ba	4.549 Bb	2.389 Ab	61.420 Aa	59.568 Aa	50.463Aa
Type	Plant height (m)			Stalk diameter (mm)		
	Apical	Central	Basal	Apical	Central	Basal
2 buds	99.213 Ba	108.777 ABa	65.415 Bb	21.6589 Bab	23.6866 Aa	19.8114 Bb
3 buds	124.180 Aa	100.995 Bb	102.523 Ab	24.1779 Aa	22.3801 Ab	22.7525 Aab
4 buds	116.595 ABab	120.098 Aa	95.512 Ab	22.2994 Ba	23.3894 Aa	21.6457 ABa
Type	Cane yield (Mg ha^{-1})			TRS (Mg ha^{-1})		
	Apical	Central	Basal	Apical	Central	Basal
2 buds	157.32 Aa	146.92 Aa	90.09 Bb	18.983 Aa	16.724 Aa	11.120 Bb
3 buds	162.94 Aa	138.94 Ab	169.26 Aa	19.593 Aa	18.896 Aa	17.019 Aa
4 buds	162.02 Aa	156.23 Aab	121.73 Bb	20.131 Aa	19.052 Aab	14.109 ABb

* Capital letters on the columns represent the results of the Tukey test (alpha = 0.05) comparing the number of buds, while lowercase letters on the rows are the results of the Tukey test comparing the position of the cuttings. TRS: total recoverable sugar per hectare.

of cuttings with three buds, when compared with whole cane stalk, justifying the need of using propagule fractionation to homogenize sprouting and avoid plant failures that possibly impact yield. In contrast, Lee (1984) did not report any differences in the sprouting rate, when using cuttings with three buds, if compared to the use of the whole cane as cutting seeds.

At 34 DAP (end sprouting period), it was observed that, as cutting length increased, the interference of bud position diminished, due to the amount of reserves contained in longer propagules which assist sprouting (Table 3). During the sprouting process, buds consume nitrogen and probably other sources of nutrients. Carneiro et al. (1995) reported that between 50 and 60 DAP, up to 80 % of the nitrogen present in the cuttings is exported in favour of bud sprouting and nitrogen fixing in the roots. Moreover, there is a decrease in the propagules dry mass with time, indicating a degradation of the organic reserves used in the initial sugarcane development.

In our study, there was no effect of cutting position and length on sucrose concentration. On the other hand, Verma et al. (2013) reported a decrease in the sucrose concentration and an increase in the hexoses level in intermodal tissues, whereas, in the shoots, the level of both sucrose and hexoses increased continuously during the shoot establishment. Furthermore, besides assisting sprouting, the amount of reserves in the propagule used has a great effect on survivor plants (Jain et al. 2010).

Regarding the buds position, differences in sprouting were observed only in the basal origin cutting (Table 3). In commercial fields, the random use of cuttings from different stalk sections during planting may be the main reason for the differences reported in the sprouting process (Casagrande 1991, Aude 1993, Melo et al. 1995, Beauclair & Scarpari 2006, Carlin et al. 2004, Sime 2013). According to Casagrande (1991), this pattern is due to the buds chronological age, as those located in the apical position are younger than the central and, hence, basal ones. Melo et al. (1995) associated the apical buds having younger tissues with a higher metabolic activity than central and basal buds, as there was the anticipation of an amino acid accumulation peak associated with the central and basal regions, resulting in early growth. Aude (1993) highlighted the higher content of water, nitrogen and glucose in younger buds, in contrast to older buds, that have higher levels of minerals and sucrose, which should first be transformed into glucose, demanding time and energy and, thus, delaying sprouting. Such propagules, located in the apical and central portions, according to Beauclair & Scarpari (2006), also have the lowest concentration of sprouting inhibitor hormones and the apical dominance existing between them, i.e., suppression of shoot bud development caused by hormones produced at the stalk tip. Auxin, a plant hormone essential for plant body development, is produced in the tip and transported toward the base (Taiz & Zeiger 2013). Therefore, because of these characteristics, there is a decreasing sprouting gradient from younger to older buds, namely, from apical to basal buds.

Cane tillering was the only trait in the emergence/establishment group that did not indicate a significant interaction between cutting length and origin position. However, it was affected by position (Table 4). This result was already expected, because tillering consists of lateral buds that sprout from primary shoots, with those situated in the apical and central stalk positions being more active. However, this same feature was not repeated in similar studies with the N-14 sugarcane variety (Sime 2013). According to Moore & Botha (2013), the pattern of sugarcane tillering is intrinsically related to the genetic characteristic of each variety used.

Regarding plant height, the smaller the size of the cuttings, the greater is the influence on this trait, being those located in the apical position significantly higher (Table 3). Therefore, it is apparent that sugarcane plant height is more related to cutting length rather than cutting position. The same assumption could be made for stalk diameter (Table 3).

In the yield group traits, cane yield and total recoverable sugar per hectare point to a significant interaction between the cutting original position and length, being similar to sprouting (Table 3), what reinforces our hypothesis that early cane sprouting and, hence, initial plant development, directly influences yield. Through the cuttings bud position and length interaction, it was possible to observe that, as the cutting length diminished, the original bud position played an important role. However, as cutting length increased, such interference essentially ceased. Therefore, when smaller cuttings are used to establish new plants, what is a trend in mechanized planting, sugarcane bud chips technology and pre-sprouted seedlings technology (MPB), the original bud position in the propagule should be considered. As the bud position relates to its chronological age, it seems that the age of the propagules, i.e., the age of the plant material used, should also be considered in establishing a new sugarcane plantation. In longer cuttings, the interference of the original bud position ceases, probably because they have the largest amount of reserves. Therefore, early cane sprouting and, hence, initial development, which is a function of the plant cutting type, directly influences sugarcane yield and raw material quality.

Table 4. Effect of cutting position on the number of stalks (tillering).

	CV (%)	Position		
		Apical	Central	Basal
Tillering	18.5	28.0 a	27.1 a	23.9 b

* Means followed by the same letter do not differ by the Tukey test at 5 %.

The importance of this finding becomes relevant by the fact that some studies (Viator & Richard Junior 2009, Gava et al. 2011, Scarpare et al. 2016) state that yield losses associated with large gaps in plant cane continue into subsequent ratoon crops. Indeed, the first greatest yield reduction occurs between cane planting and the first ratoon, reinforcing the importance of the selected seed material used during planting.

According to the results, the chronological age of buds and the reserves contained in the cuttings influence on crop establishment and yield. In this study, 11-month-old cane stalks were used as cuttings. However, new studies addressing different cane stalk ages, as well as different cane varieties, should be achieved. As a practical implication, the knowledge of these factors should guide for better seeding production programs, which have a duty to impact not only the first harvest, but also the entire cane cycle (the remaining ratoons).

CONCLUSIONS

1. The length of propagules used in sugarcane plantations affects the sprouting, initial plant development, yield and the total recoverable sugar per hectare;
2. Cuttings located in the apical and central position provide a higher percentage of sprouting, plant height and stalk diameter, as well as yield and total recoverable sugar per hectare. However, as cutting length increases, i.e., with the increase of the number of buds, such interference essentially ceases.

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