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Leaf area of sugarcane varieties and their correlation with biomass productivity in three cycles

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The objective of this work is to study the leaf area and biomass production of 4 sugarcane varieties in cane plant cycles, first and second regrowth. The experiment was conducted at Fazenda Jequiá in the state of Alagoas, Brazil. A randomized block design with 5 replications was used. The treatments were 4 cultivars: RB92579, SP813250, RB867515 and VAT90212. The length and width of the sheet + 3 were determined as well as the following parameters; the number of tillers per square meter, the number of green leaves, leaf area, and leaf area index in most growing sugarcane in the three crop cycles. The productivity of shoot dry biomass was determined at the time of cane maturity in 3 cycles. Univariate and multivariate analyses were performed. The larger leaf area index of 4.46 m^2 m^{-2} was observed for RB92579 in plant cane cycle. The dry biomass yield was not influenced by varieties having average values of 47, 41 and 31 t ha^{-1} in the sugarcane plant cycles in the first and second regrowth, respectively. The principal component analysis enabled us to identify from Current Population Survey (CPs) variance which component can contribute to the explanation of the data.

Key words: Dry matter accumulation, leaf area index (LAI), principal component analysis.

INTRODUCTION

Sugarcane is among the largest crops in Brazil; the lower acreage was used for only soybeans and corn. The 2015 harvest of planted area of cane was 8.6 million hectares, while soybean and corn area was 33 million

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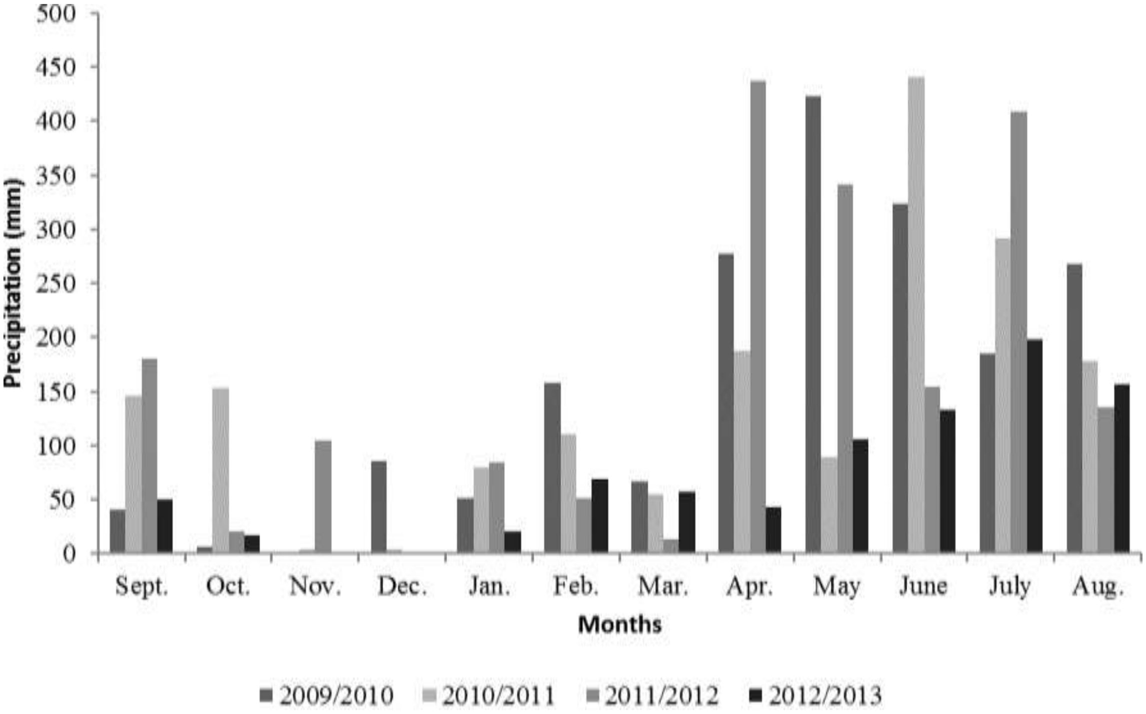

Figure 1. Monthly precipitation during the period studied.

and 15 million hectares, respectively (Ibge, 2016). This average productivity is 76 t ha^{-1}, which corresponds to less than 25% of the biological potential of the crop (Landell et al., 2008; Conab, 2016). Thus, agricultural practices such as liming, gypsum, chemical fertilizer, irrigation, inoculating with endophytic bacteria, use of compost and green manures have been taken by the sugar-energy sector to increase the productivity of sugarcane, making it a more competitive culture (Oliveira et al., 2007b; Bastos et al., 2016; Cunha et al., 2016; Pedula et al., 2016; Silva et al., 2016). Another practice that deserves attention is the choice of most productive sugarcane varieties that better adapt to specific soil and climatic conditions. This technology when properly employed helps to increase the productivity of labor, work, fertilizer efficiency and other inputs, with consequent reduction in costs and increase in the production system efficiency.

There are several varieties of sugarcane with good agronomic and industrial features such as: High response to improving soil fertility, upright growth and resistance to tipping, which facilitates harvest; high productivity stems; force of sprouts, resistance to pests and diseases, and broth with high sucrose content and easy industrialization. Regarding the characteristics of varieties, one of which most relate to agricultural income is the leaf area, due to its relationship with photosynthetic capacity. Increased leaf area provides an increase in the plant's ability to harness solar energy in order to perform photosynthesis and thus can be used to evaluate the productivity (Reis et al., 2013).

Leme et al. (1984) report that the leaf area index (LAI) is effective to evaluate the end yield, and the highest values during the development cycle would be related to the higher end production of culms. In this sense, the knowledge of the dynamics of leaf area and leaf of the system architecture in different cultivars of sugarcane may allow a better understanding of the relationship of these characteristics with the final yield.

The objective of this study is to evaluate the leaf area in the phase of maximum growth of four varieties of sugarcane, in the cycles of plant cane, first and second regrowth in Alagoas wild, correlating its effect on the production of dry biomass of the aerial part.

MATERIALS AND METHODS

The research was conducted in the municipality of Anadia, wild Alagoas, with Latitude 09° 41'04 "S and longitude 36° 18'15" W. The climate of the study area is tropical rainy, with dry summers, according to Koppen classification; its average annual rainfall is 1500 mm (Figure 1) and has average annual temperature of 29°. The terrain varies from flat to gently rolling.

The soil of the experimental area is classified as Yellow Latosol (Embrapa, 2013). It has medium texture, whose chemical characterization was carried out on soil samples collected in layers from 0.0 to 0.2 and 0.2 to 0.4 m (Table 1). The correction of soil

Table 1. Chemical analyses of soil samples at the layers 0-20 and 20-40 cm.

Layers	pH	P	K	Ca	Mg	Al	H+Al	SB	T
cm		mg dm^{-3}		cmolc dm^{-3}					
00-20	5.9	103.0	40	1.8	0.8	0.0	3.80	2.70	6.5
20-40	5.0	21.6	20	0.6	0.3	0.6	4.62	0.95	5.57
Prof	**t**	**V**	**m**	**MO**	**Zn**	**Fe**	**Mn**	**Cu**	**B**
cm	**cmolc dm^{-3}**	**%**		**dag kg^{-1}**	**mg dm-^{3}**				
00-20	2.70	42	0	1.8	2.5	75.6	9.7	1.1	0.4
20-40	1.55	17	39	0.8	0.4	53.4	0.3	0.2	0.3

pH in H_2O (Ratio 1:2.5). P K, Fe, Zn, Mn, and Cu: Mehlich extractor. Ca, Mg and Al: KCl extractor. H+Al: Calcium acetate extractor. B: Hot water extractor; S: Monocalcium phosphate in acetic acid extractor.

acidity was performed using dolomitic limestone at a dose of 150 kg ha^{-1}, calculated by the method which seeks to increase the base saturation to 60%, according to Oliveira et al. (2007a). After application of the calcareous, the soil was plowed and meshed; then the grooves were opened. Planting density fluctuated around 15 to 18 buds per meter of furrow.

The experimental design was randomized blocks, with 5 replications, consisting of 4 varieties of sugarcane: SP813250, RB867515, RB92579 and VAT90212 grown in 6 furrows of 10.0 m long portions, with space of 1 m, totaling 60 m^2 of total area. It was considered useful area of each plot, the 4 central lines with 6 meters long, totaling 24 m^2.

The fertilization of the soil was based on the recommendation of the Triunfo plant, according to the results of soil analysis (Table 1); 60, 100 and 150 kg ha^{-1} of N, P_2O_5 and K_2O were applied at the bottom of the groove. The plant cane cycle was harvested at 14 months, after the sugarcane harvest the search in the first and second regrowth continued, with each having a duration of 12 months. These cycles treatments received 500 kg ha^{-1} of formula 20-05-25.

The evaluation of leaf area was done during the maximum growth stage of the plants, in the plant cane cycle 8 months after planting and regrowth, 6 months after cutting of plant cane and first regrowth, respectively. For this evaluation, the number of green leaves was counted (fully expanded sheet with a minimum of 20% of green area, from the +1 sheet) and the leaves +3 were measured. The length and width of the third middle part of the leaf blade were obtained (Hermann and Câmara, 1999): $AF = L \times W \times 0.75 \times (N + 20)$, where C is the length of the sheet +3, W is the width of the sheet +3, 0.75 is the correction factor for the crop leaf area, and N is the number of expanded leaves at least 20% green area. For tiller number and counting, the number of green sheets of each tiller was also sampled at 1 m groove.

The production of dry biomass of shoot was done when the sugarcane had matured at 14 months after planting the sugarcane plant, and during the first and second regrowth at 12 months. The determination was performed by harvesting 2 m^2 of each plot and their extrapolation to 1 ha; after the determination of the fresh matter, subsamples of all shoot in each treatment was passed into chopper forage and dried in forced ventilation oven at 65ºC to constant weight.

The univariate and multivariate analyses were performed. Univariate statistical analyses were performed with the computer program Sisvar (Ferreira, 2008). The variables were subjected to analysis of variance by F test and those where the F was significant were compared to the averages using Scott Knott test at 5% probability. In order to group the variables into a more meaningful set (represented by the components) and identify which variables belong to which components and how each variable explains each component, the study of Principal Component Analysis (PCA) was done. Thus, the initial set of 8 variables came to be characterized by 2 new orthogonal latent variables, which allowed its location in two-dimensional figures (sort of access for main components), which are linear combinations of the original variables created with the 2 largest eigenvalues of the data covariance matrix (Hair et al., 2005). The appropriateness of this analysis is verified by the full information of the original variables held in the main components showing eigenvalues greater than the unit, or lower eigenvalues of which do not have the relevant information. The linear correlation between the production of dry biomass of shoots and length, the size of leaves, number of tillers, number of green leaves and leaf area were determined. All multivariate statistical analyses were processed in software STATISTICA® versão 7.0 .

RESULTS AND DISCUSSION

Table 2 shows the mean values of length and width of the sheet +3 and the number of plants per m^2 of four varieties of sugar cane in cycles cane plant - first and second regrowth. There was variety effect of the 3 variables. The smaller +3 sheet lengths were observed in RB92579 during the 3 cycles of culture, approximately 10% lower than the other varieties. Regarding the width of the third middle part of the leaf +3, there was a significant difference only in the second regrowth; for RB92579, the greatest width was approximately 9% higher than the average of other cultivars.

The number of plants was influenced by the variety of cane plant cycles and first regrowth. In cane plant, RB867515, SP813250 and VAT 90212 did not differ, but obtained a number of tillers of 20% less than RB92579. In the first regrowth, RB92579 and SP813250 were similar and about 18% superior to the other 2 genotypes (Table 3). In the coefficients of variation for length of the sheets to the width of the sheets, the number exhibits a range from 2.37 to 14.86%. In the works consulted, the coefficients of variation for the biometric parameters of sugarcane in the maximum growth phase were less than 15% (Almeida et al., 2008; Oliveira et al., 2011; Silva et al., 2012) which confirm this study.

Table 2. Valores average length and width of +3 leaf of four varieties of sugarcane in the maximum growth stage, in the plant cane cycles (PC), first regrowth (PR) and second regrowth (SR).

Varieties	Length of leaves (cm)				Width of leaves (cm)			
	CP	PR	SR	Average	CP	PR	SR	Average
RB92579	149b	138b	120b	135	4.78^a	4.17^a	3.89^a	4.28
RB867515	164^a	153^a	134^a	150	4.72^a	4.28^a	3.59^b	4.19
SP813250	159^a	150^a	133^a	147	4.50^a	4.23^a	3.49^b	4.07
VAT90212	167^a	155^a	135^a	152	4.82^a	4.37^a	3.55^b	4.24
Average	160	149	132	147	4,.70	4.26	3.63	4.19
C.V(%)	3.78	2.37	4.52		4.83	3.86	4.34	

Means followed by the same letter do not differ significantly by the Scott-Knott test at 5% probability.

Table 3. Valores average of number of plants m^{-2} and green leaves tiller^{-1} of four varieties of sugarcane in the maximum growth stage, in the plant cane cycles (PC), first regrowth (PR) and second regrowth (SR).

Varieties	Number of plants m^{-2}				Number of green leaves tiller^{-1}			
	CP	PR	SR	Average	CP	PR	SR	Average
RB92579	10.40^a	8.70^a	8.40^a	9.16	7.85^a	7.98^a	6.73^a	7.52
RB867515	7.60^b	6.90^b	6.90^a	7.13	7.14^a	7.07^a	7.02^a	7.07
SP813250	9.10^b	8.70^a	8.90^a	8.9	6.38^a	5.88^a	5.84^a	6.03
VAT90212	8.40^b	7.50^b	7.10^a	7.66	7.28^a	7.12^a	6.62^a	7.00
Average	8.87	7.95	7.82	8.21	7.16	7.01	6.56	6.91
C.V(%)	8.51	12.83	14.86		21.52	21.39	17.31	

Means followed by the same letter do not differ significantly by the Scott-Knott test at 5% probability.

Table 4. Valores average of leaf area (LA cm^2 tiller^{-1}). leaf area index LAI (m^2 m^{-2}) of four varieties of sugarcane in the maximum growth phase, the plant cane cycles (CP), the first regrowth (FR) and second regrowth (SR).

Varieties	LA (cm^2 perfilho^{-1})				LAI (m^2 m^{-2})			
	CP	FR	SR	Average	CP	FR	SR	Average
RB92579	5.296^a	4.326^a	3.071^a	4.231	4.46^a	3.05^a	2.04^a	3.18
RB867515	5.126^a	4.476^a	3.304^a	4.302	3.19^b	2.49^a	1.82^a	2.50
SP813250	4.552^a	3.789^a	2.753^a	3.698	3.22^b	2.54^a	1.87^a	1.27
VAT90212	5.606^a	4.650^a	3.096^a	4.45	3.76^b	2.78^a	1.70^a	2.74
Average	5.145	4.31	3.056	4.17	3.66	2.72	1.86	2.74
C.V(%)	16.42	16.29	13.71		16.36	18.91	11.09	

Means followed by the same letter do not differ significantly by the Scott-Knott test at 5% probability.

In studies conducted in state of Alagoas by Silva (2007), it was found that in the plant cane cycle, the number of plant of RB92579 was statistically always above that of RB867515. Also according to Silva (2007), the maximum growth phase of the average population density of RB867515 and RB92579 was respectively 10 and 14 plants per square meter similar to values obtained in this work. Similar results for the first regrowth were observed by Almeida et al. (2008)'s study with 4 varieties of sugarcane conducted in Rio Largo. The population density fluctuated around 11 plants per square meter. Megda et al. (2012) had a number of 12 plants per square meter tillers in most growing variety of SP891115, therefore 30% higher than that observed in this study.

Tables 3 and 4 presents the means values of number of leaves per tillers, leaf area, leaf area index of 4 varieties of sugar cane in cycles cane plant - first and second regrowth. Only the variable leaf area index in

Table 5. Values of dry biomass productivity average of shoots of four varieties of sugarcane in the maximum growth phase, the cycles of plant cane, and first and second regrowth.

Varieties	**Dry biomass productivity t ha^{-1}**			
	Plant cane	**First Regrowth**	**Second Regrowth**	**Average**
RB92579	46.81^{a}	44.51^{a}	31.76^{a}	41.02
RB867515	49.91^{a}	38.95^{a}	31.00^{a}	39.95
SP813250	47.75^{a}	40.56^{a}	33.25^{a}	40.52
VAT90212	46.05^{a}	40.23^{a}	31.60^{a}	39.29
Average	47.63	41.06	31.90	40.19
C.V(%)	11.32	12.06	9.30	

Means followed by the same letter do not differ significantly by the Scott-Knott test at 5% probability.

plant cane cycle presented varietal effect; the highest LAI was observed in the variety RB92579. This variety has shorter leaves, but then the number of plants per square meter exceeds the others, reflecting in leaf area approximately 24% higher than the average of the others. The average number of green leaves per tiller was 7.16, 7.01 and 6.56, for the sugarcane plant cycles, the first and second regrowth, respectively (Table 3). Machado et al. (2009) found similar results in a study conducted with 2 genotypes of sugarcane in plant cane cycle in São Paulo; they obtained 7 leaves per plant at the stage of maximum crop growth. For the leaf area by tiller, it is observed that for decreased cycles, the average of the 4 varieties on the cane was about 40% higher than that found in the second regrowth. The mean values obtained in plant cane, first and second regrowth were 5,145, 4,310 and 3,056 cm^2, respectively. Oliveira et al. (2007a) in a study conducted with 3 varieties of sugarcane (RB72454, RB855113 and RB855536) in plant cane cycle in red Latosol in Northwestern Paraná observed that the maximum growth phase leaf area per tiller was close to 5,000 cm^2, corroborating with the results of this study.

The leaf area index of RB92579 observed by Almeida et al. (2008) in studies conducted in the CECA/UFAL, in 180 after planting was 4.5, one of the largest in the studies reviewed. In a research also conducted in CECA/UFAL, with assessments conducted at intervals of 30 days, Silva (2007) found that the average rate of leaf area of the variety RB92579 was statistically always greater than the RB867515. In 130 to 370 days after planting the cane, the average value of leaf area index of RB867515 and RB92579 was respectively 2.3 and 3.0. In the maximal growth phase, leaf area index of RB92579 was close to 5.0, whereas for RB867515 it was approximately 4.0 . Silva et al. (2012), in a study conducted in sub-middle São Francisco Valley, evaluated the leaf area of the first regrowth of RB92579 irrigated; the LAI ranged from 1.07 to 180 days after cutting (DAC), and from 5.55 to 332 DAC.

Table 5 presents the average values of dry biomass productivity of the aerial part of the 4 varieties in cycles cane - plant first and second regrowth. There was no effect on the range of 3 cycles of cultivation. The dry biomass productivity of the shoot was 47, 41 and 31 tons per hectare in plant cane cycles, first and second regrowths, respectively. Mendes (2006), in a research conducted with 8 varieties of sugarcane in a Ultisol in Minas Gerais, obtained for RB867515 variety in plant cane cycle and first regrowth an accumulation of dry matter was 43 and 33 t ha $^{-1}$, respectively; the results corroborate that of the present study. Calheiros et al. (2012) in a study conducted in the area of Alagoas in Oxisoil obtained 35 t ha^{-1} of dry matter accumulation for RB92579 and 30 t ha^{-1} for RB867515.

The aboveground biomass productivity observed in the present work could be medium- high, since Alagoas phase maximum growth of sugarcane occurs in short days and, therefore, under low light, unlike Center -South of Brazil, where the increased brightness coincides with the greater water availability. The non-coincidence of the maximum water availability with light influences negatively the photosynthetic rates, resulting in lower productivity of sugarcane in Alagoas, compared to South-Central (Oliveira et al., 2011).

The graphical representation of the main components (Figure 2) allowed the characterization of the variables most discriminated in the formation and differentiation through the variables evaluated. As the percentage of variance explained by the PLCs, it appears that for sugarcane plant (Figure 2A), the first and second components account for 89.63% of the total variance, being 58.75% in the PC1 and 30.88% CP2 for the first regrowth (Figure 2B); it represents the PLCs 94.34% of the total variance while for the second regrowth (Figure 2C), it corresponds to 98.20% of the total variance. Mardia et al. (1979) confirmed that in a principal component analysis the first two or three components accumulate relatively high percentage of the total variation, generally over 70%; they explain the variability

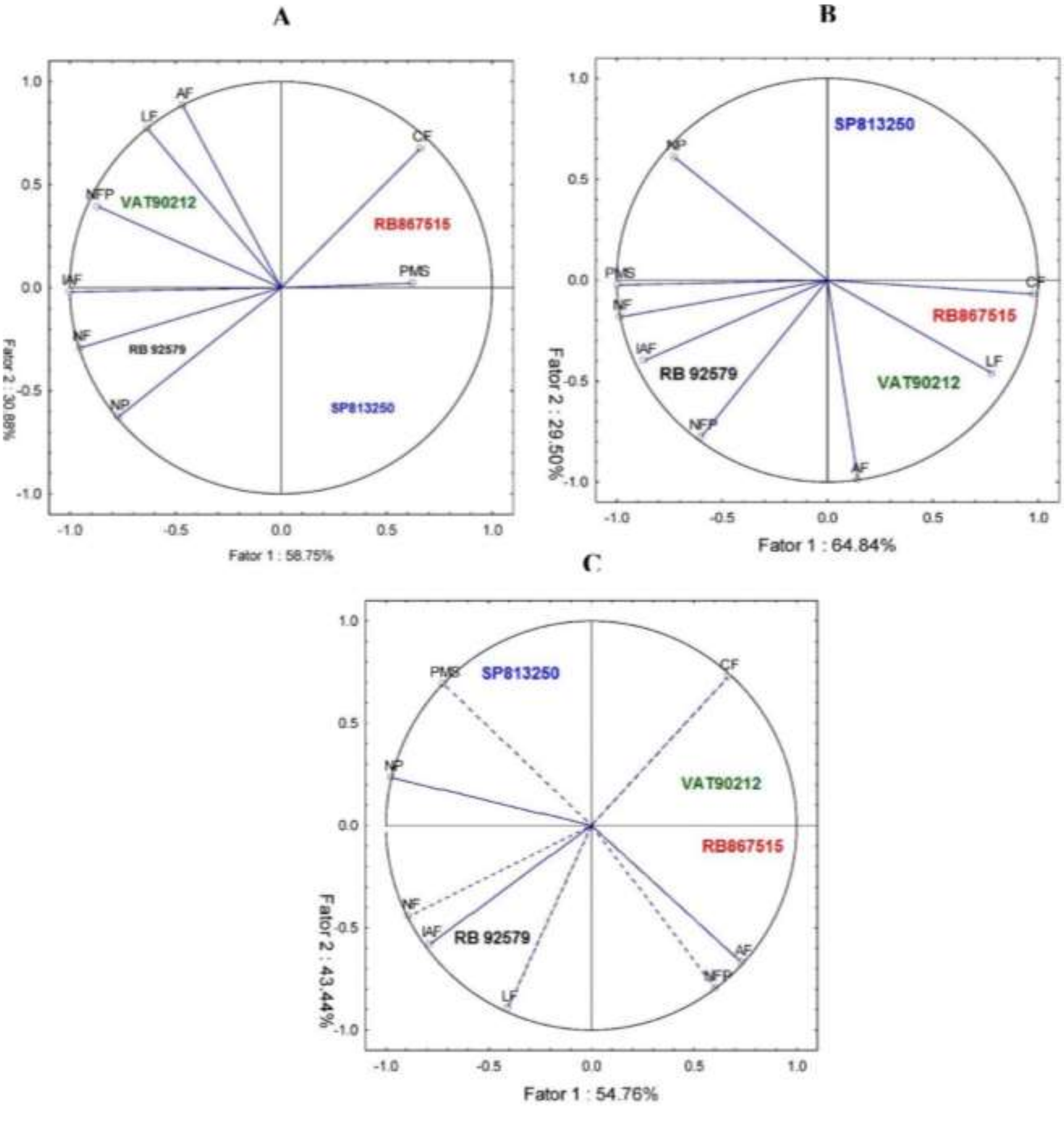

Figure 2. Components chart top of groups of varieties and variables of sugarcane in three different cycles. A = Plant cane; B = first regrowth; C = second regrowth.

manifested among cultivars and variables, which occurred in this study, since the two first principal components accounted for more than 70% of the total variance available.

The analysis of components made it possible to distinguish different patterns of distribution of variables when correlated with the stock in 3 different cycles. In this pattern of distribution, it is observed that to cultivate SP813250, isolating it in the second quadrant showed no degree of relationship with the variables studied (Figure 1A). This indicates that this cultivar is not suited for these variables, and from agronomic point of view, it was not be influenced, so that there was greater production. Pincelli and Silva (2012) studied morphological changes in sugarcane cultivar; they also find no relation variables such as LAI and leaf area per tiller (LA) for the production of the variety SP813250. In contrast to the other cultivars, there was an association between dry matter production (DMP) and length sheet (LS) to cultivate RB867515; to cultivate RB92579, there was association between number of plants (NP), number of green leaves (GL) and LAI; while to cultivate VAT90212, there was was no relation in the number of leaves per plant, leaf width and leaf area per tiller.

From the graph component of the first regrowth (Figure 2B), a similar pattern of distribution was observed between VAT90212 and RB867515 cultivars in the variables leaf area, leaf width and length. This similarity in the distribution obtained for these 2 varieties, shows the similarity in their genetic characteristics, reflected in low variability of the evaluated parameters; such justification is related to the second production cycle. As observed in plant cane, to cultivate SP813250, there was no association with any group of variables for the first production cycle. For the variable number of plants (Figure 2B), it is observed that this is not related to any cultivar. The cultivar RB92579 was associated with NFP, LAI, NF and PMS, presenting for the second cycle the same distribution pattern as observed for the plant cane cycle, but in this situation the PMS and NFP variables have greater relationship with this cultivar in the period assessed.

The second regrowth (Figure 2C) shows a pattern of high differentiation when compared to the others, for all cultivars showed relation with the other variables. According to Hair et al. (2005), this ratio can firstly be explained by the greater variance of 98.20%, which favors a pattern of relatively homogeneous distribution between the variables and cultivars. In the cultivate SP813250, only the second regrowth showed similarity with the variables studied; PMS and NP are those mostly identified with this cultivar. As is shown in Figure 2, there is no overlap between the variables; this indicates the non-occurrence of the graphic representation, thereby showing the ability to represent the largest accumulation of explained variance (Hair et al., 2005). Another important fact is that some variables are close to the unit circle, showing that they have a greater contribution in relation to variables that are farther apart.

Conclusion

The larger leaf area index was seen in RB92579. The dry biomass yield was not influenced by varieties. The principal component analysis enabled us to identify from CPs variance what each component can contribute to the data explanation, and prove effective in differentiating between the studied variables and cultivars groups for different cycles, showing the importance of each cultivation in different production cycles of sugar cane.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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