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Productivity and Biochemical Characteristics of Sugarcane When Submitted to the Action of Chemical Ripeners

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Abstract

The utilization of chemical ripeners is an important tool, since they are applied to accelerate the maturation process, enhance raw material quality, optimize agro industrial and economic results, and help crop planning, allowing essential crop management in a modern production system. The objective of this study was to evaluate agricultural productivity and biochemical characteristics of the sugarcane when submitted to the application of chemical ripeners in different crop years. The experimental design utilized randomized blocks arranged in split split plots. The main plots consisted of the application of the following products with their respective doses: control (C) (without application), sulfomethuron-methyl (0.02 kg ha^{-1}) + glyphosate (0.15 L ha^{-1}) (SG), ethephon (0.34 L h^{-1}) + glyphosate (0.15 L ha^{-1}) (EG), glyphosate (0.35 L h^{-1}) (G), compounds of organic carboxylic radicals (1.0 L h^{-1}) + glyphosate (0.15 L h^{-1}) (CG). The subplots were composed of evaluation times: 0, 15, and 30 days after application of the products. The sub-subplots consisted of two crop years, 2008 and 2009. In the evaluations, the levels of brix levels, pol, reducing sugars, total reducing sugars, fiber, purity, humidity, recoverable theoretical sugar, tons of Culms per hectare and tons of sugar per hectare, shikimic and salicylic acids. The application of CG showed better results for sugarcane technological characteristics on the 30th day after application. 0.35 L ha^{-1} of glyphosate favored an increase in the concentrations of shikimic and salicylic acids. The application of a mixture of compounds of organic carboxylic radicals + glyphosate presented better results for sugarcane technological characteristics at 30 days after application in the studied crop years. The application of 0.35 L ha^{-1} glyphosate favored an increase in the concentrations of shikimic and salicylic acids in the crop years of 2008 and 2009.

Keywords: growing, hormones, plant regulators, *Saccharum* spp.

INTRODUCTION

Sugarcane (*Saccharum* spp.) is native to southeastern Asia and has been cultivated in Brazil since the 16th century. Nowadays, due to plant breeding, several varieties have been developed and adapted to different climatic conditions, soils, and so on (CAPUTO et al., 2007).

Although presently there is a diverse availability of Poaceae varieties, sucrose levels from these materials are not always able to guarantee the yield expected by sugar-energy industry, and, therefore, many times chemical substances are applied to optimize results (SILVA et al., 2010).

Thus, the utilization of chemical ripeners is an important tool, since they are applied to accelerate the maturation process, enhance raw material quality, optimize agro-industrial and economic results, and help crop planning, allowing essential crop management in a modern production system (VIANA et al., 2008; ROBERTO et al., 2015).

Chemical ripeners are compounds applied to the plant so that the correct dose can stop sugarcane vegetative development due to their inhibiting action on metabolism, causing maturation, that is, translocating and storing sugars in the stalks (LEITE et al., 2009a).

Salicylic acid is the main signaling compound to develop plant resistance to pathogens and abiotic stresses and some pests as well. This acid is produced from phenylalanine, one out of three aromatic amino acids whose synthesis is blocked by glyphosate. The analysis of available information shows that for a plant to be resistant to biotrophic pathogens (that do not cause the death of parasitized cells such as viruses, rust, coal and others), it needs to produce and accumulate salicylic acid besides presenting the correct resistance genes.

Failure to produce this acid causes susceptibility which may be reverted by the exogenous compound application, showing the mistaken participation of salicylic acid as resistance inducer. Low doses of glyphosate can inhibit salicylic acid synthesis and increase plant susceptibility to diseases (MESCHEDE et al., 2012).

Therefore, this study aimed to evaluate the agricultural productivity and biochemical characteristics of sugarcane when submitted to the application of chemical ripeners at the beginning of different crop years.

MATERIAL AND METHODS

Experiments were carried out in 2008 and 2009 on Santo Antônio farm, located in the municipality of Igaraçu do Tietê, São Paulo state, at the following geographical coordinates: 22º 33’ 18’’ S latitude and 48º 31’ 51’’ longitude, 509 m altitude.

The area primary production environment has semi-plain topography and its soil is eutroferric red latosol according to Embrapa (2013) classification. According to Köppen classification, the predominant climate in the region is Aw, dry, with an average yearly temperature of 21.6º C and average relative air humidity of 70 %. The average yearly rainfall is 1.344 mm, 2000 kg ha^{-1} of limestone and 600 kg ha^{-1} of NPK 10-25-25 were applied to a sugarcane crop at planting in February 2007, following the technical recommendation in function of soil analysis. A dose of 1.2 L ha^{-1} of Imidacloprid, an insecticide, was applied. The experiment was set up with cane plant in March 2008 and with ration cane in 2009, when chemical ripeners were applied on RB85-5156 variety at the beginning of the crop.

Each plot consisted of seven 10-m rows with 1.40-m spacing. The samples were collected from five central rows, totaling an area of 70 m^2. The plots consisted of applications of the following products: C – control, that is, without application; SG – sulfomethuron-methyl (0.02 kg ha^{-1}) + glyphosate (0.15 L ha^{-1}); EG – ethephon (0.34 L ha^{-1}) + glyphosate (0.15 L ha^{-1}); G – glyphosate (0.35 L ha^{-1}); CG – compounds of organic carboxylic radicals (1.0 L ha^{-1}) + glyphosate (0.15 L ha^{-1}).

The application of chemical ripeners was done with a CO_2 - pressurized spraying equipment with 6-m T-shaped lance and 6 AXI 11002 nozzles, jet spaced 0.5 m, which allowed the simultaneous application on two rows approximately 50 cm apart. The utilized pressure was 40 pounds $inch^{-2}$, and juice volume was 300 L ha^{-1}. The application started at 8h00 hours and finished at 11h00 hours, a period in which little wind was observed. The average temperature varied from 25 to 30ºC and with relative air humidity from 60 to 80%. The subplots consisted of three sampling periods, 0, 15 and 30 days after the application (daa) of products used as ripeners. The sub-subplots consisted of different crop years, 2008 and 2009.

At these times, sugarcane stalks were harvest by hand from a linear meter in the useful area of the plots. The stalks were clipped at the height of the apical buds, that is, at the breaking point and sent to the laboratory for analysis of the following characteristics: Brix (% juice), pol (% juice), reducing sugars (RS%), total reducing sugars (TRS %); fiber (%), purity (%), humidity (%) and recoverable theoretical sugar (RTS) (kg t^{-1}), according to the methods of chemical and technological determination by Consecana (2006). At harvest, the plots were completely harvested and the stalks were clipped for weighing and determination of Tons of Culms per Hectare (TCH) and Tons of Sugar per Hectare (TSH).

On the pre-established evaluation dates, 15 plants per plot were randomly collected and submitted to laboratory analyses to determine shikimic and salicylic acids. The leaves were dried in air circulation oven at 60 ^{o} C for 72 hours. Then, they were ground in a Wiley cutting mill.

For analysis of shikimic acid (SkA) and Salicylic acid (SA), 400 mg of each sample was weighed and then added to 10 mL of water with pH 7.0 in a 50 mL glass bicker. Next, each bicker was placed in the center of a microwave oven (Panasonic Model NN-S62 B) for 20 s at 100 W and the average temperature of 49.8°C (±2.8°C), according to Matallo et al. (2009). After cooling, the sample was filtered in Whatmann Grade 1 paper filter and Millex – GV syringe filter (Millipore).

The analyses were carried out in a liquid chromatographer and mass spectrometer (LCMS), Shimadzu, with the following features: LC-20AD pump; SIL-10AF injector, CTO-10AS up oven, CBM-20 A controller, DGU-20A5 degasser, and LCMS-2010 EV mass spectrometer. The analytical method utilized Gemini (Phenomenex) C18 column, particle size of 5 nm, 150 x 4.6 mm dimensions, movable phase A: water with 0.5% acetic acid, phase B: methanol and 0.5% of acetic acid, 0.4 L min-1flow, oven temperature at 30°C, ionizing type in negative mode, m/z shikimic acid: 173, m/z salicylic acid: 137, equipment tuning condition done by its own routine utilizing polyethylene glycol as standard.

Total time of 20 minutes was determined for the acid race. The retention time of shikimic acid was 5 minutes (± 0.1), and of Salicylic acid, it was 19 minutes (± 0.1) according to Matallo et al. (2009).

The statistical analyses were done by Assistant (SILVA and AZEVEDO, 2016). The averages were compared by Tukey’s test at 5% of probability, according to (BANZATO and KRONKA, 2006).

RESULTS AND DISCUSSION

As shown in Table 1, there was significant difference and interaction among the factors for technological variables of Brix (% juice), pol (% juice), reducing sugars (RS%), total reducing sugars (TRS %) in sugarcane variety when different chemical ripeners were utilized in the evaluated crop years. There was a significant difference among most factors regardless of the technological characteristics as well as for all interactions among them.

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Table 1. Evaluations of technological parameters Brix (% juice), Pol (% juice) Reducing Sugars (RS%) and Total Reducing Sugars (TRS%) of sugarcane submitted to application of mixtures of chemical ripeners at different harvest times and crop years.

Variation causes	Brix (% juice)	Pol (% juice)	(RS%)	(TRS%)
		Ripeners (R)		
Control	13.26d	10.35c	0.83a	11.74c
SG	14.81b	12.31b	0.67b	13.64b
EG	13.73cd	11.65b	0.72b	12.99b
G	14.37bc	12.32b	0.70b	13.67b
CG	16.40a	13.94a	0.58c	15.26a
MSD	0.93	0.99	0.07	0.97
CV%	5.85	7.47	9.78	6.61
F(R)	36.43**	36.96**	30.77**	37.07**
		Sampling times (S)		
0 daa	14.26b	11.84b	0.72a	13.19b
15 daa	14.32b	12.00b	0.71a	13.35b
30 daa	14.95a	12.51a	0.67b	13.84a
MSD	0.47	0.44	0.03	0.43
CV%	5.03	5.68	8.66	4.95
F(T)	8.35**	7.76**	6.08**	7.86**
		Year (Y)		
2008	14.46a	12.06a	0.70a	13.41a
2009	14.57a	12.17a	0.70a	13.51a
MSD	0.30	0.29	0.02	0.29
CV%	4.88	5.71	7.64	5.08
F(Y)	0.54ns	0.55ns	0.41ns	0.55ns
MxT	13.11**	8.44**	5.53**	8.68**
VxY	9.56**	6.95**	7.05**	6.76**
ExY	7.52**	5.37*	5.44**	5.24*
MxSxY	7.08**	6.77**	5.83**	6.67**

Small letters compare averages in the column. Letters that are the same do not differ among themselves by Tukey's test at 5% probability within the same factor, **significant at 1% of probability ($p<0.01$), *significant at 5% of probability ($0.01=<p< 0.05$), ns – non-significant ($p>=0.05$), daa – days after application, MSD – minimum significant difference, (R) – ripener, (T) – sampling time, (Y) – year, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

Table 2 shows the average values regarding the outcomes of a significant interaction of sugarcane between the mixtures of chemical ripeners and different sampling times and different crop years for brix (% juice) and pol (% juice).

Table 2. Average values regarding the outcomes of a significant interaction of sugarcane between the mixtures of chemical ripeners and different sampling times and different crop years for brix (% juice) and pol (% juice).

Ripeners	Sampling times daa	Brix (% juice) 2008	Brix (% juice) 2009	Pol (% juice) 2008	Pol (% juice) 2009
C	0	11.94B	13.57A	8.83B	10.69A
	15	13.54A	13.59A	10.64A	10.90A
	30	13.74A	13.15A	10.91A	10.16A
SG	0	15.09A	14.34A	12.81A	11.61B
	15	14.82A	14.83A	12.26A	12.26A
	30	13.95B	15.81A	13.35B	13.59A
EG	0	15.10A	14.74A	12.72A	12.10A
	15	15.37A	11,34B	13,06A	9,85B
	30	12.42A	13,40A	10,67A	11,52A
G	0	13.91A	14,67A	12,00A	12,54A
	15	12.23B	14,77A	10,55B	12,68A
	30	14.65B	16,00A	12,59A	13,58A
CG	0	15.24A	13,99B	13,04A	12,08A
	15	17.00A	15,71B	14,40A	13,41A
	30	17.85A	18,59A	15,12A	15,62A
	MSD	Lin.:1.18		Lin.:1.15	

Capital letters that are the same do not differ among themselves by Tukey's test at 5% probability, daa – days after application, MSD – minimum significant difference, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

A significant effect among the treatments was found for brix (% juice) and pol (% juice), mainly with CG at 30 daa in years 2008 and 2009. The utilization of chemical ripeners is an important tool because the products are applied to anticipate the maturation process, promote enhancement in raw material quality and help crop planning (CAPUTO et al., 2008). Similarly, the use of chemical ripeners in this study enhanced the technological quality of sweet sorghum. Similar results were observed by Viana et al. (2008) in sugarcane crop, where G and CG induced an increase in sucrose of all sections of the sugarcane stalk due to physiological stress.

According to Prasad et al. (2007), the ideal harvest stage of sugarcane occurs when juice presents brix ranging from 15.5 to 16.5°, which is an important level to obtain juice that has high fermentation quality and consequently maximizes ethanol production per hectare. Silva et al. (2010) observed ripening anticipation and an increment in pol content when there was an application of SG. Those authors also pointed out that the mixture of sulfomethuron methyl and ethyl-trinexapac to glyphosate, in general, provided similar results to ripeners when applied separately.

Table 3 presents the average values regarding the outcomes of significant interaction for sugarcane between the mixtures of chemical ripeners and different sampling times and different crop years for the technological characteristics of Reducing Sugars (RS%) and Total Reducing Sugars (TRS%).

Table 3. Average values regarding the outcomes of significant interaction for sugarcane between the mixtures of chemical ripeners and different sampling times and different crop years for the technological characteristics of Reducing Sugars (RS%) and Total Reducing Sugars (TRS%).

	Sampling times	RS%		TRS%	
Ripeners	daa	2008	2009	2008	2009
C	0	0.95A	0,81B	10,26B	12,0A
	15	0.82A	0,77A	12,02A	12,25A
	30	0.79A	0,85A	12,28A	11,55A
SG	0	0.62B	0,74A	14,11A	12,97A
	15	0.68A	0,69A	13,59A	13,60A
	30	0.73A	0,58B	12,68B	14,89A
EG	0	0.64A	0,71A	14,03A	13,45A
	15	0.62B	0,83A	14,37A	11,21B
	30	0.79A	0,73A	12,03A	12,87A
G	0	0.73A	0,68A	13,37A	13,88A
	15	0.82A	0,68B	11,93B	14,03A
	30	0.69A	0,58B	13,95A	14,88A
CG	0	0.61B	0,72A	14,34A	13,44A
	15	0.58A	0,63A	15,74A	14,75A
	30	0.50A	0,45A	16,42A	16,90A
MSD		Lin.: 0.08		Lin.: 1.14	

Capital letters in the same line do not differ among themselves by Tukey's test at 5% probability, daa – days after application, MSD – minimum significant difference, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

In addition, there was an increase in Reducing Sugars content for the control treatment, as shown in Table 3. When ripeners were utilized, there was a decrease in the average values of Reducing Sugars. As times to collect material passed by, the values for that characteristic gradually decreased. The increase in Reducing Sugars favors plant growth and directly affects its purity, showing a smaller efficiency of the industry to recover sucrose. On the other hand, its reduction favors sugarcane ripening. The same was observed in the study by Viana et al. (2008) where the values decreased significantly as time passed by, reaching low values at 71 daa.

The greatest values for Total Reducing Sugars (TRS%) again occurred when CG was applied as shown in Table 3. For this characteristic, it was verified that the best sampling time was at 30 daa. The increase in Reducing Sugar content favors plant growth and directly affects juice purity, resulting in lower efficiency recovery of sucrose by the industry. On the other hand, the reduction of these carbohydrates enhances the technological quality of the juice, favoring sugarcane ripening (LEITE et al., 2009a; ROBERTO et al., 2015).

According to data presented in Table 4, a significant interaction was observed in the results for fiber (%), purity (%), humidity (%) and TRS (kg t^{-1}). There was a significant difference among most of the technological characteristics separately as well as for all their interactions.

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Table 4. Average values regarding the outcomes of significant sugarcane interaction between mixtures of chemical ripeners and different sampling times and different crop years for fiber (%); Purity (%); humidity (%) and TRS (kg t^{-1}).

Variation causes	fiber (%)	purity (%)	humidity (%)	TRS (kg t^{-1})
Ripeners (R)				
Control	10.78c	77.96c	75.95a	106.25c
SG	11.41ab	83.07b	73.77b	123.47b
EG	11.07bc	81.57b	74.67b	117.61b
G	11.25ab	82.29b	73.79b	123.78b
CG	11.71a	86.09ª	72.12c	138.18a
MSD	0.45	2.39	1.22	8.84
CV%	3.70	2.65	1.51	6.61
F(R)	12.68**	32.39**	28.43**	37.07**
Sampling times (T)				
0 daa	11.11b	81.58b	74.40a	119.41b
15 daa	11.20b	81.81b	74.17a	120.84b
30 daa	11.42a	83.21a	73.61b	125.33a
MSD	0.20	1.35	0.42	3.94
CV%	2.85	2.51	0.88	4.95
F(T)	7.22**	5.49*	11.91**	7.86**
Year (Y)				
2008	11.23a	82.08a	74.12a	121.67a
2009	11.26a	82.32a	74.00a	122.34a
MSD	0.19	0.76	0.29	2.66
CV%	3.94	2.17	0.94	5.08
F(Y)	0.10ns	0.42ns	0.75ns	0.55ns
VxR	3.52*	5.27**	10.54**	8.68**
VxT	2.21ns	6.59**	9.04**	6.76**
MxT	4.98**	4.92*	10.11**	5.24*
VxMxT	0.88ns	5.75**	6.90**	6.67**

Small letters compare averages in the column. Letters that are the same do not differ among themselves by Tukey's test at 5% probability within the same factor, **significant at 1% of probability ($p<0.01$), *significant at 5% of probability ($0.01=<p< 0.05$), ns – non-significant ($p>=0.05$), daa – days after application, MSD – minimum significant difference, (R) – ripener, (T) – sampling time, (Y) – year, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

The average values related to the outcomes of significant interactions between the mixtures of chemical ripeners and different sampling times of sugarcane stalks for fiber (%) are shown in Table 5.

Table 5. Average values related to the outcomes of significant interactions between the mixtures of chemical ripeners and different sampling times of sugarcane stalks for fiber (%).

	Sampling times		
Ripeners	0 daa	15 daa	30 daa
		Fiber (%)	
C	10.76aA	10.74cA	10,84cA
EG	11.28aA	11.52abA	11,42bcA
SG	11.18aA	10.90cA	11,12bcA
G	11.19aA	11.07bcA	11,51bA
CG	11.15aB	11.77aA	12,20aA
MSD	Col.: 0.59		Lin.: 0.46

Small letters compare averages in the column. Capital letters compare averages in the line. Letters that are the same do not differ among themselves by Tukey's test at 5% probability, daa – days after application, MSD – minimum significant difference, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

For Fiber, the CG treatment presented greater values as samplings were done at different times. The increase in fiber content due to the application of chemical ripeners had already been observed by Viana et al. (2008); Leite and Crusciol (2008). However, Caputo et al. (2008) and Leite et al. (2009c) did not observe significant alterations in fiber content when ripeners without mixtures were applied. Leite et al. (2009b) verified that there was an increase in fiber content in some sugarcane varieties when ripeners were utilized.

Table 6 shows the average values related to the results of significant interaction between different sampling times of sugarcane stalks and crop years for fiber (%).

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Table 6. Average values related to the results of significant interaction between different sampling times of sugarcane stalks and crop years for fiber (%).

	Year	
Sampling times	2008	2009
	Fiber (%)	
0 daa	11.14aA	11.08bA
15 daa	11.34aA	11.06bA
30 daa	11.20aB	11.63aA
MSD	Col.: 0.34	Lin: 0.33

Small letters compare averages in the column. Capital letters compare averages in the line. Letters that are the same do not differ among themselves by Tukey's test at 5% probability, daa – days after application, MSD – minimum significant difference, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

An increase in the average values of fiber (%) was verified at 15 daa in the crop year of 2008 and at 30 daa in 2009. According to Viana et al. (2008), fiber content over 14% reduces the efficiency of juice extraction in the mill; however, sugarcane varieties with fiber content below 10% are more susceptible to mechanical damages caused by cutting and loading, resulting in sugar losses due to contamination by microorganisms that have access to the internal part of stalks. The fiber content increase due to the application of chemical ripeners has already been observed by other authors such as Leite et al. (2009b). However, Caputo et al. (2008) did not verify significant alterations in fiber content with application of ripeners.

Table 7 presents the averages related to the outcomes of significant interaction between mixtures of chemical ripeners and different sampling times and different crop years in sugarcane variety for purity (%); humidity (%) and TRS (kg t^{-1}).

Table 7. Averages related to the outcomes of significant interaction between mixtures of chemical ripeners and different sampling times and different crop years in sugarcane variety for purity (%); humidity (%) and TRS (kg t^{-1}).

	Sampling times	purity (%)		humidity (%)		TRS (kg t^{-1})	
Ripeners	daa	2008	2009	2008	2009	2008	2009
	0	73.93B	78.71A	77.38A	75.56B	92.87B	109.19A
C	15	78.47A	80.07A	75.65A	75.72A	108.81A	110.89A
	30	79.34A	77.26A	75.47A	75.93A	111.15A	104.60A
	0	84.90A	80.95B	73.40B	74.59A	127.72A	117.42A
SG	15	82.73A	82,53A	73,47A	73,81A	123,02A	123,09A
	30	81.40B	85,92A	75,06A	72,3B	114,81B	134,79A
	0	84.24A	82,04A	73,72A	74,06A	127,01A	121,72A
EG	15	84.92A	77,99B	73,32B	76,85A	130,06A	101,49B
	30	79.08A	81,17A	75,34A	74,72A	108,93A	116,48A
	0	81.37A	82,85A	74,35A	73,40A	121,01A	125,66A
G	15	78.15B	82,75A	75,58A	73,45B	108,02B	127,03A
	30	78.61B	86,03A	73,60A	72,33B	126,28A	134,66A
	0	81.15A	81,63B	73,26A	74,32A	129,81A	121,64A
CG	15	86.01A	84,74A	71,25B	72,57A	142,48A	133,54A
	30	88.85A	90,45A	71,00A	70,30A	148,62A	152,97A
MSD		Lin.: 2,97		Lin.: 1.15		Lin.: 10,33	

Capital letters in the same line do not differ among themselves by Tukey's test at 5% probability, daa – days after application, MSD – minimum significant difference, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

Regarding purity (%), an increase in the average values was verified when CG treatment was utilized at 30 daa in the crop years of 2008 and 2009. It is known that juice purity is correlated to the sugarcane ripening process and the minimum recommended levels are 80% for the initial crop and 85% throughout the cultivation (LEITE and CRUSCIOL, 2008). These results corroborate the ones by Viana et al. (2008), who also found greater purity values after the application of SC.

Leite et al. (2009c) observed that when applied separately, sulfometuron methyl and glyphosate increase sugarcane juice purity significantly. The results corroborate the ones by Caputo et al. (2007), who also found greater purity values after the application of sulfomethuron methyl.

Table 8. Average values of TCH and TSH agricultural productivity parameters and SkA and SA biochemical characteristics of sugarcane variety submitted to the application of chemical ripeners, different harvesting times and crop year.

Variation causes	TCH	TAH	SkA (μg g^{-1})	SA (μg g^{-1})
		Ripeners (R)		
Control	117.00a	17.20a	1.29c	1.81c

SG	121.43a	17.57a	1.31c	3.30b
EG	118.48a	15.74a	4.18b	3.18bc
G	102.31a	15.36a	6.70a	6.32 a
CG	112.35a	17.13a	6.73a	4.01b
MSD	21.66	3.42	1.16	1.48
CV%	9.96	10.83	15.11	20.87
F(R)	2.58ns	1.78ns	117.76**	27.11**
		Year (Y)		
2008	113.98a	16.23a	3.88a	3.98 a
2009	114.65a	16.97a	4.20a	3.47b
MSD	5.43	0.91	0.58	0.48
CV%	5.84	6.80	17.90	15.89
F(Y)	0.07ns	3.19ns	1.49ns	5.50*
MxY	4.14*	1.36ns	14.55**	34.90**

Small letters compare averages in the column. Letters that are the same do not differ among themselves by Tukey's test at 5% probability within the same factor, **significant at 1% of probability ($p<0.01$), *significant at 5% of probability ($0.01=<p< 0.05$), ns – non-significant ($p>=0.05$), daa – days after application, MSD – minimum significant difference, (R) – ripener, (T) – sampling time, (Y) – year, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate methyl.

According to Table 7, humidity (%) presented greater values in the control treatment. When ripeners were used, there was a reduction of average humidity values. As sampling times passed by, the values gradually decreased. These results confirmed the ones found by Silva et al. (2010) who verified humidity decrease during maturation and also observed that glyphosate and sulfomethuron methyl stood out as promoters of greater increases in TRS at harvest.

There was an increase in average values for Recoverable Theoretical Sugar when CG was utilized at 30 daa. According to Leite et al. (2009c), the total recoverable theoretical sugar (TRTS) is important for the sugar-energy industry to estimate the amount of sucrose in the raw material that can be recovered as crystal sugar. These results are similar to the ones found for brix, pol, and total reducing sugars, mainly the mixtures cited previously. Leite et al. (2009a) reported that the agronomical efficiency of ripeners depends on the application time, climatic condition, and genetic characteristic of the variety. Moreover, they have to be applied when the ripening condition is not favored such as in cases of application off the season or under climatic conditions that do not favor this process. Therefore, the genetic potential of varieties is explored regarding sucrose accumulation to improve the quality of ray material. This trend was also observed by Viana et al. (2017) who verified that there is a stabilization of RTS values in stalks as sugarcane ripens.

According to Table 8, the average values of TCH and TSH agricultural productivity parameters and SkA and SA biochemical characteristics of sugarcane variety submitted to the application of chemical ripeners, different harvest times and crop year.

The average values are shown in Table 9 regarding the results of significant interaction of parameters of Tons of Culms per Hectare (TCH) and the biochemical characteristics of the shikimic acid (SkA) and salicylic acid (SA) of sugarcane variety submitted to application of chemical ripeners, different harvest times and crop years.

Table 9. Average values are shown in Table 9 regarding the results of significant interaction of parameters of Tons of Culms per Hectare (TCH) and the biochemical characteristics of the shikimic acid (SkA) and salicylic acid (SA) of sugarcane variety submitted to application of chemical ripeners, different harvest times and crop years.

	TCH		SkA (μg g^{-1})		SA (μg g^{-1})	
Ripeners	2008	2009	2008	2009	2008	2009
C	125.10aA	108.90aB	1.04bA	1.55bA	2.08cA	1.54bA
SG	116.13abA	126.73aA	1.16bA	1.47bA	1.69cB	4.92aA
EG	119.03abA	117.93aA	2.25bB	6.11aA	3.00bcA	3.37aA
G	96.86bA	107.76aA	7.11aA	6.29aA	8.68aA	3.96aB
CG	112.76abA	111.93aA	7.85aA	5.61aB	4.44bA	3.57aA
MSD	Col.: 23.38	Lin.:12.14	Col.: 1.64	Lin.:1.31	Col.: 1.70	Lin.: 1.07

Capital letters in the same line do not differ among themselves by Tukey's test at 5% probability, daa – days after application, MSD – minimum significant difference, Col. – column, Lin – line, C – control, SG – sulfomethuron methyl + glyphosate, EG – ethephon + glyphosate, G – glyphosate, CG – compounds of organic carboxylic radicals + glyphosate

It is possible to observe that the control treatment presented the best average values for TCH of the crop year of 2008 which did not occur in 2009. These results corroborated the ones by Silva et al. (2010) who verified that sulfomethuron-methyl and the control promoted the smallest decreases in productivity. Leite and Crusciol (2008) observed significant reductions in productivity in G treatment and CG treatments.

In Table 9, it is possible to observe that in the crop year of 2008 the plants treated with CG presented greater concentrations of shikimic acid, followed by G treatment. However, in the crop year of 2009, the control treatment and the one with SG presented smaller average values.

These results corroborate the ones by Matallo et al., (2009), working with glyphosate and shikimic acid concentration in citrus observed that the plants that received glyphosate application always presented the greatest concentration of shikimic acid compared to control plants. High levels of shikimic acid, detected from the applications of glyphosate, were detected in sunflower, wheat, and millet (HENRY et al., 2007).

A greater concentration in the values of salicylic acid in sugarcane can be observed in sugarcane when submitted to G application in the crop year of 2008, which did not occur in 2009. Thus, even if there is a decrease in salicylic acid biosynthesis, the plant has an alternative or secondary pathway for its synthesis, that is, the salicylic production depends on the plant metabolism and the stressing factors to which it is submitted.

CONCLUSIONS

The application of a mixture of compounds of organic carboxylic radicals + glyphosate presented better results for sugarcane technological characteristics at 30 days after application in the studied crop years.

The application of 0.35 L ha^{-1} glyphosate favored an increase in the concentrations of shikimic and salicylic acids in the crop years of 2008 and 2009.

REFERENCES

Banzato, D.A., Kronka, S.N. 2006. Experimentação agrícola. vol.III, Jaboticabal: FUNEP, 237p.

Caputo, M.M., Beauclair, E.G.F., Silva, M.A., Piedade, S. M. S. 2008. Resposta de genótipos de cana-de-açúcar à aplicação de indutores de maturação. Bragantia, 67(1), 15-23. http://dx.doi.org/10.1590/S0006-87052008000100002

Caputo, M.M., Silva, M.A., Beauclair, E.G.F., Gava, G.J.C. 2007. Acúmulo de sacarose, produtividade e florescimento de cana-de-açúcar sob reguladores vegetais. Asociación Interciencia, 32(12), 834-840.

CONSECANA - Conselho dos Produtores de Cana-de-açúcar, Açúcar, Álcool do Estado de São Paulo. 2006. Manual de instruções. 5, Piracicaba: Consecana, 112p.

Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA. 2013. Sistema brasileiro de classificação de solos. III, Brasília, 353p.

Henry, W.B., Shaner, D.L., West, M.S. 2007. Shikimate accumulation in sunflower, wheat and proso millet after glyphosate application. Weed Science, 55(4), 1-5.

Leite, G.H.P., Crusciol, C.A.C. 2008. Reguladores vegetais no desenvolvimento e produtividade da cana-de-açúcar. Pesquisa Agropecuária Brasileira, 43(8), 995-1001. http://dx.doi.org/10.1590/S0100-204X2008000800007

Leite, G.H.P., Crusciol, C.A.C., Silva, M.A., Venturini Filho, W.G. 2009a. Qualidade tecnológica da cana-de-açúcar em função da aplicação de maturadores em meio de safra. Bragantia, 68(2), 527-534. http://dx.doi.org/10.1590/S0006-87052009000200028

Leite, G.H.P., Crusciol, C.A.C., Silva, M.A., Venturini Filho, W.G., Suriano, A. 2009b. Qualidade tecnológica, produtividade e margem de contribuição agrícola da cana-de-açúcar em função da aplicação de reguladores vegetais no início da safra. Ciência Rural, 39(3), 726-732. http://dx.doi.org/10.1590/S0103-84782009000300015

Leite, G.H.P. 2009c. Reguladores vegetais e atividade de invertases em cana-de-açúcar em meio de safra. Ciência Rural, 39(3), 718-725. http://dx.doi.org/10.1590/S0103-84782009000300014

Matallo, M.B., Almeida, S.D.B., Cerdeira, A.L., Franco, D.A., Blanco, F.M.G., Menezes, P. T.C., Luchini, L.C., Moura, M.A. M., Duke, S.O. 2009. Microwave-assisted solvent extraction and analysis of shikimic acid from plant tissues. Planta Daninha, 27, 987-994. http://dx.doi.org/10.1590/S0100-83582009000500012

Meschede, D.K., Velini, E.D., Tonin, F.G., Carbonari, C. 2012. Alterações no metabolismo da cana-de-açúcar em função da aplicação de maturadores. Planta Daninha, 30(1), 113-119. http://dx.doi.org/10.1590/S0100-83582012000100013

Prasad, S., Singh, A., Jain, N., Joshi, H.C. 2007. Ethanol production from sweet sorghum syrup for utilization as automotive fuel in India. Energy and Fuels, 21, 2415-2420. http://dx.doi.org/10.1021/ef060328z

Roberto, G.G., Cunha, C., Sales, C.R.G., Silveira, N.M., Ribeiro, R.V., Machado, E.C., Lagôa, A.M.M.A. 2015. Variation of photosynthesis and carbohydrate levels induced by ethephon and water deficit on the ripening stage of sugarcane. Bragantia, 74(4), 379-386. http://dx.doi.org/10.1590/1678-4499.0062

Silva, F.A.S., Azevedo, C.A.V. 2016. The Assistat Software Version 7.7 and its use in the analysis of experimental data. African Journal Agriculture Resarch, 11(39), 3733-3740. http://dx.doi.org/10.5897/AJAR2016.11522

Silva, M.A., Gava, G.J. C., Caputo, M.M., Sorrilla, P.F., Bassetto, S. C. 2010. Produtividade de colmos e de sacarose em cana-de-açúcar em função da interação entre cultivares e maturadores. Scientia Agraria, 11(4), 323-329. http://dx.doi.org/10.5380/rsa.v11i4.1826

Viana, R.S., Silva, P.H., Mutton, M.A., Mutton, M.J.R., Guimarães, E.R., Bento, M. 2008. Efeito da aplicação de maturadores químicos na cultura da cana-de-açúcar (*Saccharum* spp.) variedade SP81-3250. Acta Scientiarum Agronomy, 30(1), 65-71. http://dx.doi.org/10.4025/actasciagron.v30i1.1130

Viana, R.S., Velini, E.D., Lisboa, L.A.M., Assumpção, A.C.N.D., Figueiredo, P.A.M. 2017. Application of chemical ripeners mixtures the technological quality and agricultural productivity of sugarcane. Revista Caatinga, 30(3), 541 – 550. http://dx.doi.org/10.1590/1983-21252017v30n301rc