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Chemical ripeners and different harvest periods in sugarcane in State of Paraná, southern Brazil

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The objective of this work was to evaluate the effects of control action (natural ripening, without ripeners) and of glyphosate, paraquat, fluazi-p-butil, ethephon, etyl-trinexapac, sulfometuron methyl and KNO_3 on the number of stalks per area, diameter of the median third of stalks and productivity (tons of canesstalks per hectare), and brix, pol of the sugarcane and extractable sugar. It was used a randomized block design with four replicates in a sub-split plots. KNO_3 contributes to improve agronomic quality by increasing productivity of stalks and the most favorable harvest period to the variable was from 60 to 120 days after ripener application (DAA). Etyl-trinexapac, sulfometuron methyl and KNO_3 increased technological variables and the most adequate harvest period for ratoon sugar cane was 120 days after application (DAA) of ripeners and control, because they provided gains for variables ATR, Brix and PC in comparison to the respective initial reference times.

Key words: Plant regulators, *Saccharum* spp., technological quality.

INTRODUCTION

The major objectives are yields in cane and sugar production process are the cane and sugar yields of stalks; the technological quality of raw materials and agronomic and operational durability of crop, aiming at

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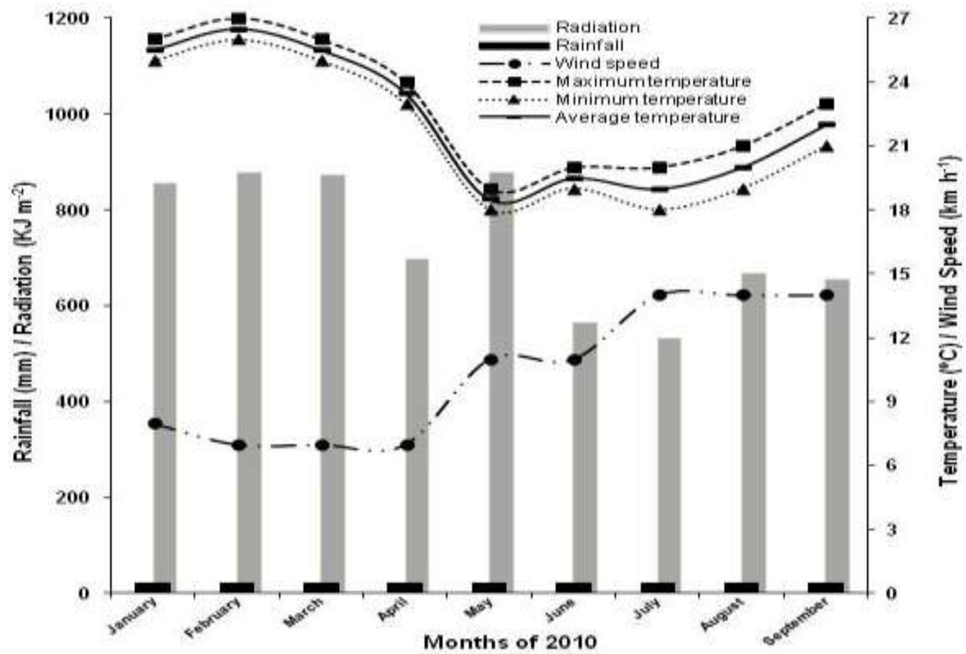

Figure 1. Monthly precipitation, maximum, average and minimum temperatures, wind speed and global solar radiation recorded during the experiment with ratoon sugar cane at the Automatic Weather Station of the INMET-MAPA in 2010 crop, in Icaraíma-PR.

the economic revenues of the enterprise (Segato et al., 2006).

Natural ripening is induced by the climatic conditions with the gradual decreasing in temperature and precipitation. Which reduces vegetative stage benefiting the accumulation of sucrose that supply the plants, with the continued qualitative and quantitative supply of stalks with suitable levels of sucrose, it is necessary to increase the agronomic and technological yield of the crop (Leite et al., 2008). Martins and Castro (1999) define chemical ripeners who compounds that are able to interfere vegetative development is a part of the plant physiology of sugarcane by inducing ripening; increasing the qualitative content of sucrose; and sugar productivity of stalks in order to anticipate harvest.

Glyphosate, which is inhibitor of EPSPs (5-enolpyruvylshikimate-3-phosphate) and biosynthesis of essential amino acids, stands out at sub-dosage; Paraquat, which inhibits the Photosystem I (PS I), the fluazifop-p-butyl, ACCase (Acetyl Coa carboxylase) synthesis inhibitor (Crusciol et al., 2010),and ethephon as well, whose action mode which releases ethylene, affecting cell elongation and stalk growth with accumulation of sucrose (Rodrigues, 1995). Etyl-trinexapac acts on the metabolism of sugar cane by reducing the production of active gibberellins, facilitating the accumulation of sucrose (Viana et al., 2008). Sulfometuron-methyl acts by inhibiting ALS enzyme (Acetolactate synthase), interfering with cellular metabolism, paralyzing the growth without killing the apical bud (Leite and Crusciol, 2008). Also, potassium nitrate (KNO_3) which also acts as an inducer of the synthesis of ethylene, inhibiting the growth of stalks and inducing the accumulation of sucrose (Rodrigues, 1995).

The objective of this work was to evaluate the effects of control action (natural ripening, without ripeners) and of glyphosate, paraquat, fluazi-p-butil, ethephon, etyl-trinexapac, sulfometuron methyl and KNO_3 on the number of stalks per area, diameter of the median third of stalks and productivity (tons of canes stalks per hectare), and brix, pol of the sugarcane and extractable sugar.

MATERIALS AND METHODS

The experiment was conducted in Icaraíma, State of Paraná (southern Brazil), located at latitude 23°25'49" and longitude 53°28'50" W and at altitude of 371 m, during the 2009/2010 crop. The soil was classified as Paleudults Soil (USDA-NRCS, 2011). According to Köppen, climate prevailing in the region is Cfa (humid subtropical), with minimum temperature below 18°C, maximum temperature above 22°C and rainfall from 1200 to 1500 mm per year (IAPAR, 2009). Monthly climatic data concerning maximum, average and minimum temperatures, rainfall, wind speed and global solar radiation during the experiment were collected from the Estação Meteorológica Automática of INMET-MAPA (Automatic Weather Station) in Icaraíma, Paraná in the 2010 crop (Figure 1). The soil showed particle size analysis showed 180; 770 and 50 g dm^{-3} of clay, sand and silt, respectively, and chemical analysis of soil at 0-20 cm depth showed the following results: P (mg dm^{-3}) = 13.29; OM (g dm^{-3}) = 10.7, pH ($CaCl_2$) = 5.47, H + Al ($cmol_c$ dm^{-3}) = 2.34; Al ($cmol_c$ dm^{-3}) = 0.0, K ($cmol_c$ dm^{-3}) = 0.06, Ca ($cmol_c$ dm^{-3}) = 1.12, Mg ($cmol_c$ dm^{-3}) = 0.42.

A randomized block design was used with four replicates in a split subplot. The plots were four harvest periods (15, 30, 60 and 120 days after application – DAA – of ripeners) and the control subplots (no ripener application) and seven types of chemical ripener, using the commercial doses recommended by the respective manufacturers (glyphosate 0.4 L ha^{-1}.; paraquat 2.0 L ha^{-1}; fluazifop-p-butyl 0.4 L ha^{-1}, ethephon 0.67 L ha^{-1}; etyl-trinexapac 1.0 L ha^{-1}; sulfometuron methyl 0.02 kg ha^{-1} and KNO_3 3.0 kg ha^{-1}). It was used 0.1% v/v of ethanol-etilenoxi adhesive spreader in all applications.

Ripeners were applied at the phenological stage 4 (maturation) in the third stalk, with a manual sprayer with a metal "spear "tube with a double exit for the 110.02 twin flat spray tips of the fan type spray. The volume of the solution was 220 L ha^{-1} at constant flow. The application was done in the early morning and late afternoon, in the period during which the monitoring of the conditions of relative humidity (64%), temperature (27°C) and wind speed (5.0 km h^{-1}) was made with the aid of a portable thermo-hygrometer and anemometer gadget. The values found in the monitoring were considered appropriate for the application of pesticides.

The sugarcane variety used was 'RB 867515', at third ratoon (three years harvest) in a row spacing of 1.10 m. Its main features are the average cycle (period for industrial use - PIU - more than 150 days); high productivity; high adaptability and stability in various soil and climatic conditions. This variety is responsive to the application of ripeners (UFSCAR-PMGCA, 2010).

The following agronomic variables were evaluated: number of stalks per hectare (NCH), diameter of the median third of the stalks (DMC) and productivity or cane yield (TCH). The technological variables Brix, sugar cane pol (PC) and total recoverable (extractable) sugar (TRS) were evaluated as well in the municipality of Ivaté, State of Paraná.

During the experiment, the entire experimental area was sampled by collecting randomly and at turns 10 samples of stalks. They were cut at ground level and at the apical bud height, then bunched, identified with labels and sent to a laboratory for technological analysis. Determination of the initial conditions of Brix, PC and TRS, named initial times of reference IT_{BRIX}, IT_{PC} and IT_{TRS}, respectively with 119 kg t^{-1}, 12% and 17%, evaluated before application of ripeners.

Each plot consisted of four rows with sugar cane, with an area of 26.40 m² and dimensions of 4.40 x 6.00 (m), with two central rows forming the plot useful area with dimensions of 8.80 m² and 2.20 x 4.00 (m). Counting of all industrially stalks was performed at every harvest period (15; 30; 60 and 120 DAA) by which the variable agronomic NCH was obtained; measurement by using digital caliper of the diameter of the middle third of 10 stalks sampled randomly. The variable agronomic DMC and cutting of all stalks of the useful area (at ground level and at the height of the apical bud), and its weighing by a "roman scale" type (weighing capacity of 150 ± 0.5 kg) to obtain s cane productivity variable (TCH). After weighing, the 10 randomly sampled stalks were bunched, identified with labels and sent to the laboratory of technological analyses at USACUCAR - Usina Santa Terezinha- in Ivaté-Paraná, for technological analysis (Brix, PC and TRS).

The results were submitted to analysis of variance, in which harvest period were submitted to regression analysis to check effect of ripeners. Tukey test at 5% level of probability was used when there was significantly effect ($FC_{al} > F_{Tab}$). The software System of Statistical Analysis and Genetics was used (SAEG) to perform the statistical analysis (Ribeiro Júnior, 2001).

RESULTS AND DISCUSSION

The study of the application of different ripeners and sugarcane ratoon harvests at different times showed that in number of stalks per hectare (NCH) and average diameter of stalks (ADC) there were not statistically difference ($p > 0.05$). Therefore, it was obtained an average of 59797 stalks per hectare with an average diameter of 25.30 mm measured in middle third of the stalks. Similarly, these results were also observed by Leite and Crusciol (2008).

The result of the cane productivity (TCH) demonstrates that there were significant effects ($p \leq 0.05$) of ripeners and harvest time interaction. However, it can be seen that even in harvest time increasing, when sugar cane ratoon is not submitted to the application of ripeners, it did not show significant differences ($p > 0.05$) in the cane yield (TCH) with 67,220 kg ha^{-1}. Under the same condition, the agronomic variable TCH also showed no significant difference ($p > 0.05$) when submitted to the application of sulfometuron methyl, with a cane yield of 78,380 kg ha^{-1}. Meschede et al. (2010) found no significant effect ($p > 0.05$) of sulfometuron methyl in any of the analyzed harvest periods, similar to the results of this study. When KNO_3 was applied, it was observed that there was an average 43 p.c of increase in TCH compared to control and that the best harvest time was within 60 to 120 days after application (DAA) in comparison to the other harvest times (Table 1).

Rodrigues (1995) and Crusciol et al. (2010) report on the significant increase ($p \leq 0.05$) of TCH at 60 DAA with the application of KNO_3, confirming only the harvest period found in this study. Glyphosate, paraquat, fluazifop-p-butyl, methyl and sulfometuron ethephon did not provide significant yield gains ($p > 0.05$) compared with the control at 60 and 120 DAA, not corresponding to the results obtained by Meschede et al. (2009). Ethyl-trinexapac provided significant gains ($p \leq 0.05$) of 43 p.c compared to the control at 120 DAA, which was confirmed by observations of Viana et al. (2008).

With the application of glyphosate and ethyl trinexapac, an increase in productivity by 70 and 52 p.c respectively was observed with ratoon sugar cane harvested at 120 DAA, compared to 15 DAA, but there were no significant differences ($p > 0.05$) between the two types of products and the other harvest periods. Concerning to glyphosate, Meschede et al. (2009) reported on significant results ($p \leq 0.05$) of productivity at 30 DAA, not confirming the response of this study. But Viana et al. (2008) observed a significant result ($p \leq 0.05$) with ethyl-trinexapac at 120 DAA, corroborating the response observed in this study.

Although the applications of paraquat, fluazifop-p-butyl and ethephon did not cause significant increases ($p > 0.05$) of TCH compared to the control and other ripeners, at least they provided 59, 68 and 64 p.c more yield when the ratoon sugar cane was harvested at 60, 30t and 30-60 DAA, respectively. Meschede et al. (2009) did not confirm the result obtained in this study at 30 DAA by the action of fluazifop-p-butyl. Concerning ethephon, Silva et al. (2010) corroborate the significant result ($p \leq 0.05$)

Table 1. Ratoon sugar cane Productivity (TCH) as a function of the application of ripeners and harvest times (DAA), in the crops 2009/2010 at Icaraíma, State of Paraná, Brazil.

Harvest Time (DAA)	Ripeners								Mean	LSD
	Control	Glyphosate	Paraquat	Fluazifop-p-butil	Ethephon	Etyl-trinexapac	Sulfometuron methyl	KNO_3		
	TCH									
15	56.10[aA]	53.12[bA]	60.79[bA]	55.54[bA]	56.65[bA]	63.63[bA]	67.90[a]	53.27[bA]	58.38	27.20
30	74.86[aA]	75.57[abA]	79.40[abA]	93.75[a]	90.62[aA]	78.98[abA]	76.99[a]	74.29[abA]	80.56	
60	70.31[aB]	80.40[abAB]	96.85[aAB]	75.14[abAB]	96.17[aAB]	85.65[abAB]	77.99[aAB]	100.5[a]	85.39	
120	67.62[aB]	90.49[aAB]	80.68[abAB]	81.82[abAB]	86.38[abAB]	96.73[a]	90.62[aAB]	97.16[a]	86.40	
Mean	67.22	74.90	79.43	76.56	82.46	81.25	78.38	81.32		
CV (%)	15.94									
LSD	31.59									

[1]/Means followed by the same capital letters in the rows and the same lower case letters in the columns do not differ significantly at the level of 5% of probability by the Tukey test.

Table 2. Ratoon sugar cane Brix as a function of ripener application and harvest times (days after application DAA) in 2009/2010 crop at Icaraíma, State of Paraná, Brazil.

Harvest time (DAA)	Ripeners								Mean	LSD
	Control	Glyphosate	Paraquat	Fluazifop-p-butil	Ethephon	Etyl-trinexapac	Sulfometuron methyl	KNO_3		
	BRIX (%)									
15	18.45[bA]	18.83[cA]	17.28[bA]	18.64[cA]	18.36[bA]	18.37[cA]	18.69[cA]	18.55[cA]	18.40	1.62
30	19.34[abA]	19.88[bcA]	16.38[b]	19.83[bcA]	18.70[bA]	19.47[bcA]	18.88[cA]	19.06[cA]	18.94	
60	19.29[abB]	20.50[bAB]	20.20[aAB]	20.92[abA]	19.61[bAB]	20.68[bAB]	20.97[bA]	20.71[bAB]	20.36	
120	20.40[aC]	22.68[aAB]	21.54[aBC]	22.08[aAB]	23.07[aAB]	23.49[a]	23.40[a]	23.61[a]	22.53	
Mean	19.37	20.47	18.84	20.37	19.94	20.50	20.49	20.48		
CV (%)	3.67									
LSD	1.34									

[1/] Means followed by the same capital letters in the rows and the same lower case letters in the columns do not differ significantly at the level of 5% of probability by the Tukey test.

obtained in this study at 30 DAA, and Caputo et al. (2007) confirm the significant response ($p \leq 0.05$) in this study for the yield of stalks at 60 DAA.

The result of the Brix of the ratoon sugarcane showed that the significant effects ($p \leq 0.05$) of the interaction between the application of different ripeners in relation to control and the harvest period 30, 60 and 120 days after application (DAA) of ripeners. On the other hand, the results of Brix were statistically similar ($p > 0.05$) when ripeners worked- compared to the control - at 15 DAA, presenting an average value of 18.40%. Viana et al. (2008) observed results statistically similar ($p > 0.05$) for the control, glyphosate and sulfometuron methyl at 15 DAA, partially corroborating the response in this study (Table 2).

Ratoon sugarcane not submitted to the application of ripeners presented the technological variable Brix at 120 DAA with a significant increase ($p \leq 0.05$) of 10% compared to the initial period of 15 DAA, with no significant difference ($p > 0.05$) provided to the variable at 30 and 60 DAA compared to 15 DAA. Paraquat, ethephon and fluazifop-p-butyl provided significant increases ($p \leq 0.05$) by 23, 22 and 12% to the variable Brix at 120 DAA compared to 15 DAA, respectively. Similarly, applications of glyphosate and etyl-trinexapac, and sulfometuron methyl and KNO_3 as well, gave average significant increases ($p \leq 0.05$) of 20 and 18% for the Brix compared to 15 DAA, respectively. Castro and Christoffoleti (2005) found significant responses ($p \leq 0.05$), but contradictory to the results of this study on the action of paraquat and glyphosate, fluazifop-p-butyl, sulfometuron methyl and ethefon, respectively, on the Brix of the ratoon sugar cane. Leite et al. (2008) inferred on the inducing action of etyl- trinexapac on the Brix of the sugar cane, just as Silva et al. (2007) reported a significant result for the Brix at 120 DAA, confirming the response in this study. On the other hand, Viana et al. (2008) and Crusciol et al. (2010) inferred on the

Table 3. Sugar cane Pol (PC) of sugar cane ratoon as a function of ripeners appliaction and harvest times (days after application DAA) in 2009/2010 crop at Icaraíma, State of Paraná, Brazil.

Harvest time (DAA)	Ripeners								Mean	LSD
	Control	Glyphosate	Paraquat	Fluazifop-p-butil	Ethephon	Etyl-trinexapac	Sulfometuron methyl	KNO_3		
	SP (%)									
15	13.81^{bA}	13.73^{cA}	12.63^{bA}	13.67^{cA}	13.44^{cA}	13.48^{cA}	13.85^{cA}	13.77^{cA}	13.60	
30	14.52^{abA}	14.89^{bcA}	11.84^{b}	14.90^{bA}	13.88^{bcA}	14.54^{bcA}	14.14^{cA}	14.68^{bcA}	14.20	1.48
60	14.50^{abB}	15.84^{bAB}	15.22^{aAB}	16.01^{abA}	14.91^{bAB}	15.69^{bAB}	16.00^{bA}	15.86^{bAB}	15.50	
120	15.35^{aC}	17.20^{aAB}	16.26^{aBC}	16.51^{aABC}	17.52^{aAB}	17.77^{a}	17.79^{a}	17.95^{a}	17.00	
Mean	14.54	15.42	13.99	15.27	14.94	15.37	15.45	15.57		
CV (%)	4.46									
LSD	1.22									

[1/] Means followed by the same capital letters in the rows and the same lower case letters in the columns do not differ significantly at the level of 5% of probability by the Tukey test.

significant effect ($p \leq 0.05$) of KNO_3 at 60 DAA, compared with 15 DAA, but which does not support the result in this study.

The other products used as ripeners did not differ significantly ($p > 0.05$) regarding the Brix compared to control. Rodrigues (1995), Castro and Christoffoleti (2005), Leite and Crusciol (2008), Viana et al. (2008) and Crusciol et al. (2010) confirm that they obtained significant results ($p \leq 0.05$) until 45 DAA with the ripeners in this experiment, overall, not corroborating the observations of this study.

At 60 DAA, fluazifop-p-butyl and sulfometuron methyl provided significant increase ($p \leq 0.05$) of 9% to the Brix, compared to the control. The other ripeners showed similarity ($p > 0.05$) with the control. Meschede et al. (2009) reported on getting significant results ($p > 0.05$) of Brix by applying the product at 60 DAA, corroborating the results of this study.

At 120 DAA, glyphosate, fluazifop-p-butyl and ethephon showed similarity ($P < 0.05$) among themselves, but with significant differences ($p \leq 0.05$) of 11% of increase in Brix compared to control. Just as the etyl-trinexapac, sulfometuron methyl and KNO_3 showed similarities ($p > 0.05$) among themselves, but resulting in a significant increase ($p \leq 0.05$) by 15% to the technological variable compared to 15 DAA.

The most appropriate harvest time to the Brix of ratoon sugarcane was at 120 days after applying the ripeners (DAA), and the performance of etyl-trinexapac, sulfometuron methyl and KNO_3 on the technological variable under study stood out.

The study on the application of different chemical ripeners, compared with the control, and harvesting of sugarcane ratoon at different times resulted in a significant difference ($p \leq 0.05$) for the sugar cane Pol (PC) at 30, 60 and 120 days after application (DAA) of ripeners. So that the variable showed a significant effect ($p \leq 0.05$) of the interaction between harvest time and each of the ripeners and control (Table 3).

On the other hand, ripeners' action did not present significant effect ($p > 0.05$) on PC at 15 days after application (DAA) in comparison to the control, resulting in 13.60% of the sugar cane Pol.

Ratoon sugarcane not submitted to the application of ripeners presented the PC variable with significant increases ($p \leq 0.05$) of 11% at 120 DAA, compared to 15 DAA. However, it did not provide significant gain ($p > 0.05$) to PC at 30 and 60 DAA, in the same comparison.

The action of the ripeners conferred significant gain ($p \leq 0.05$) of 23% at 120 DAA, compared to 15 DAA. Viana et al. (2008) inferred on significant responses ($p \leq 0.05$) of the main ripeners on PC from 30 to 60 DAA, partially corroborating the response of this study. Authors like Crusciol et al. (2010) and Meschede et al. (2009) specifically cited the significant response ($p \leq 0.05$) resulting from the individual actions of sulfometuron methyl, and KNO_3 on the variable at 60-120 DAA also partially confirms the response observed in this study.

At 30 DAA, the action of ripeners did not confer significant responses ($p > 0.05$) to the variable PC, and paraquat gave significant response ($p \leq 0.05$) by 20% less for the technological variable. The responses observed in this study contradict the results obtained by Rodrigues (1995), Leite et al. (2008) and Meschede et al. (2009).

At 60 DAA, applications of fluazifop-p-butyl and sulfometuron methyl caused an average significant increase ($p \leq 0.05$) by 10% on the variable PC compared to the control with similarity ($p > 0.05$) between the control and the other ripeners.

But, in relation to the action of fluazifop-p-butyl, Almeida et al. (2005) inferred on the significant responses ($p \leq 0.05$) of the ripener at 60 DAA compared with the control, confirming the result of this study.

At 120 days after application (DAA) of glyphosate and ethephon, significantly increases ($p \leq 0.05$) of 12 and

Table 4. Total recoverable sugar (TRS) of ratoon sugar cane as a function of ripener application and harvest times in days after application (DAA) in 2009/2010 crop at Icaraíma, State of Paraná, Brazil.

Harvest time (DAA)	Ripeners								Mean	LSD
	Control	Glyphosate	Paraquat	Fluazifop-p-butil	Ethephon	Etyl-trinexapac	Sulfometuron methyl	KNO_3		
	TRS (kg t^{-1})									
15	137.02^{bA}	136.70^{cA}	126.47^{bA}	136.12^{cA}	133.97^{cA}	134.36^{cA}	137.72^{cA}	136.91^{cA}	134.91	13.64
30	143.42^{aA}	147.08^{bcA}	119.24^{b}	147.35^{bcA}	137.81^{bcA}	143.83^{bcA}	141.13^{cA}	145.27^{bcA}	140.64	
60	143.20^{abB}	155.70^{bAB}	149.88^{aAB}	157.27^{abA}	147.02^{bAB}	154.22^{bAB}	157.15^{bA}	155.84^{bAB}	152.54	
120	151.30^{aC}	168.29^{aAB}	159.11^{aBC}	161.96^{aABC}	171.29^{aAB}	173.65^{a}	173.73^{aA}	175.46^{a}	166.85	
Mean	143.74	151.94	138.68	150.68	147.52	151.52	152.43	153.37		
CV (%)	4.18									
LSD	11.24									

[1/] Means followed by the same capital letters in the rows and the same lower case letters in the columns do not differ significantly at the level of 5% of probability by the Tukey test.

14% respectively, were observed for the variable PC, compared to control. The other ripeners showed similarity ($p > 0.05$) in comparison with sugarcane ratoon not submitted to the application of ripeners. Almeida et al. (2005) observed significant results ($p \leq 0.05$) for sugar cane Pol until 60 DAA after application of glyphosate and ethephon, respectively, not confirming the response observed in this study.

The study of the application of different chemical ripeners, compared to ratoon sugar cane control, and the harvest times resulted in a significant difference ($p \leq 0.05$) for the technological variable total recoverable sugar (TRS) at 30, 60 and 120 days after application (DAA) of chemicals (Table 4).

Similarly, the variable TRS showed significant effect ($p \leq 0.05$) of interaction between harvest periods of ratoon sugarcane and each ripener and control. On the other hand, the variable showed significant similarity ($p > 0.05$) in the action of ripeners at 15 DAA, compared to the control, resulting in 134.91 kg t^{-1} of TRS.

Ratoon sugarcane not submitted to the action of the ripeners presented technological variable TRS with a significant increase ($p \leq 0.05$) of 10% at 120 days after application (DAA), compared to the initial harvest at 15 DAA. When sugar cane is submitted to normal weather conditions, it is ready for harvest under low temperature and low rainfall conditions (Deuber, 1988).

Glyphosate and sulfometuron methyl gave significant gains ($p \leq 0.05$) by 24 and 12% TRS at 120 and 60 days after application (DAA), respectively, compared to harvest at 15 DAA. On the other hand, paraquat, fluazifop-p-butyl, ethephon, trinexapac etyl and KNO_3 provided a significant increase ($p \leq 0.05$) by 26% TRS at 120 DAA. Caputo et al. (2008) and Meschede et al. (2010) corroborate the responses of this study until 60 DAA by the action of glyphosate and sulfometuron methyl. Almeida et al. (2005) and Leite et al. (2009) inferred on responses of action of fluazifop-p-butyl, ethephon and KNO_3 which did not corroborate any responses of this study.

At 30 days after application (DAA), ripeners showed no significant differences ($p > 0.05$) between itself and the control. The responses observed by Rodrigues (1995), Leite et al. (2008) and Crusciol et al. (2010) did not corroborate the results found in this study.

At 60 DAA, fluazifop-p-butyl and methyl sulfometuron provided individually, an average significant gain ($p \leq 0.05$) of 10% for total recoverable sugar (TRS), and the other ripeners showed similarity ($p > 0.05$) between itself and the control. Meschede et al. (2009) and Caputo et al. (2008) inferred on significant results ($p \leq 0.05$) by the action of fluazifop-p-butyl and methyl sulfometuron, respectively, on the technological variable total recoverable sugar at 60 days after application (DAA) of ripeners, confirming the responses observed in this study.

At 120 days after application (DAA) the actions of glyphosate and ethephon resulted in significant responses ($p \leq 0.05$) of 11 and 13% on TRS, compared to the control. Similarly, action mode of etyl-trinexapac, methyl sulfumeturon and KNO_3 resulted in an overall gain of 15%, also in comparison to control. The other ripeners showed similarities ($p > 0.05$) compared to control. Meschede et al. (2009) inferred on the ripeners previously mentioned, noting significant responses ($p \leq 0.05$) until 60 DAA, compared to the control, not corroborating the results of this study.

The best harvest period was at 120 days after application (DAA), and the ripeners which provided the significant increase ($p \leq 0.05$) of the TRS were etyl - trinexapac, sulfometuron methyl and KNO_3.

Harvest times 15, 30, 60 and 120 days after application (DAA) of ripeners were also assessed by regression analysis to determine the effect of ripeners on the technological variable total recoverable sugar (TRS), pol and brix of ratoon sugar cane compared to the respective

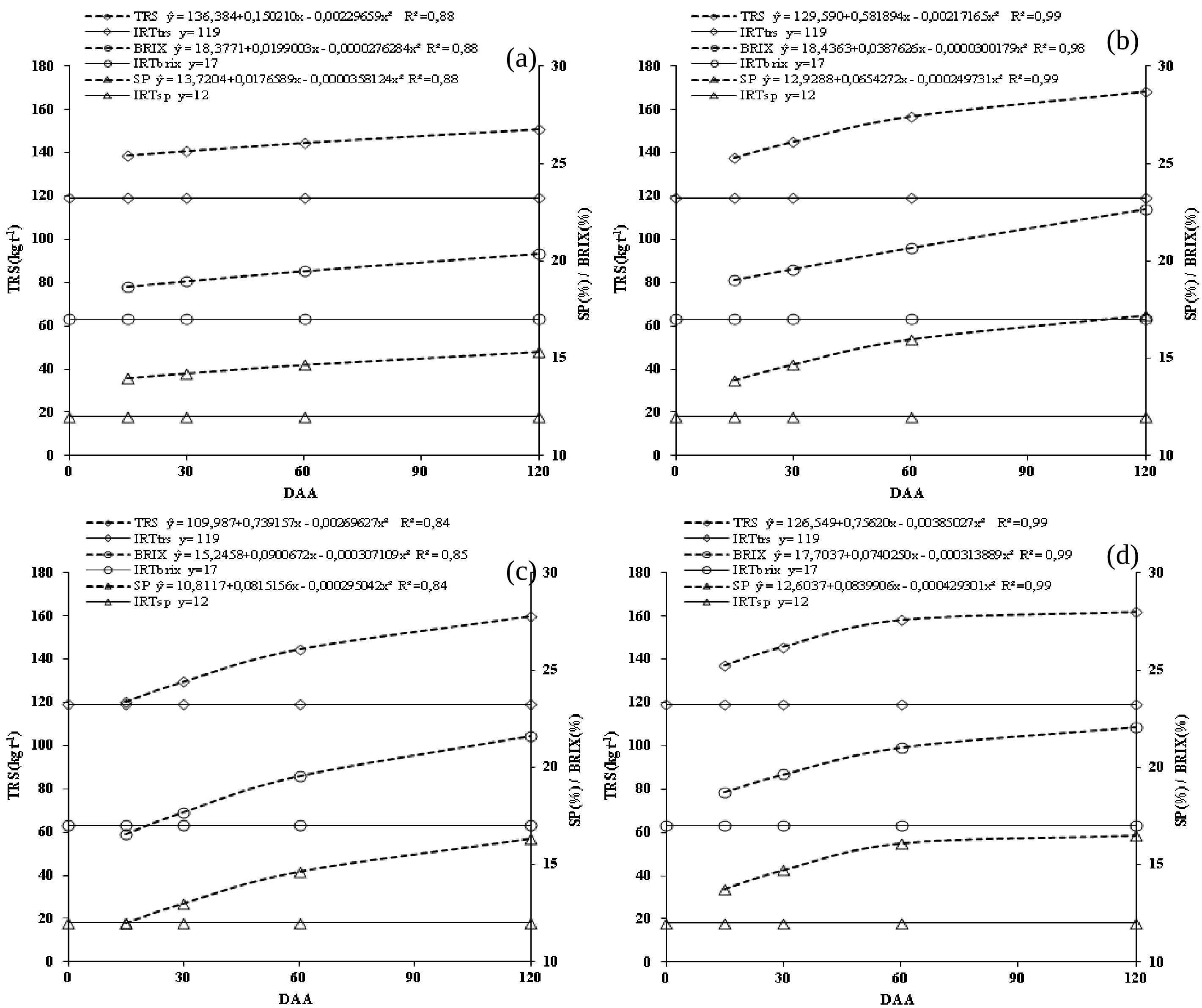

Figure 2. Total recoverable sugar (TRS), sugarcane Pol (SP) and ratoon sugar cane BRIX submitted to application of control (a), glyphosate (b), paraquat (c) and fluazifop-p-buthyl (d) harvest time at 15, 30, 60 and 120 days after application (DAA) of the treatments in comparison to the initial reference times IRT_{TRS}, IRT_{SP} and IRT_{BRIX}, in 2009/2010 crop, Icaraíma, State of Paraná, Brazil.

initial periods of reference IR_{TRS}, IR_{PC} and IR_{BRIX} which were evaluated prior to application of ripeners and whose corresponding values are 119 kg t^{-1}, 12 and 17%. Quadratic adjustment was determined for all treatments.

Control has provided significant increases ($p \leq 0.05$) for the technological variables TRS, PC and Brix of 27, 28 and 20% for the respective initial reference periods (Figure 2a) were observed in ratoon sugar cane. Rodrigues (1995) mentions on the natural action of environmental conditions - cool temperatures and reduced precipitation - on the maturation of cane sugar, also similar on the ratoon sugarcane.

Glyphosate (Figure 2b) has provided significant gains ($p \leq 0.05$) of 41, 43 and 33% for the variables in the study, compared to the respective initial reference periods IR_{TRS}, IR_{PC} and IR_{BRIX} at 120 days after application (DAA), considered the best time for harvest. Meschede et al. (2010) inferred on similar results, corroborating the responses obtained in this study.

The result of the technological variables TRS, PC and Brix showed significant effect ($p \leq 0.05$) in the action of paraquat (Figure 2c), resulting in increases of 34, 36 and 27% in relation to their initial reference periods, being the best time of harvest at 120 DAA. Netto (2006) mentions

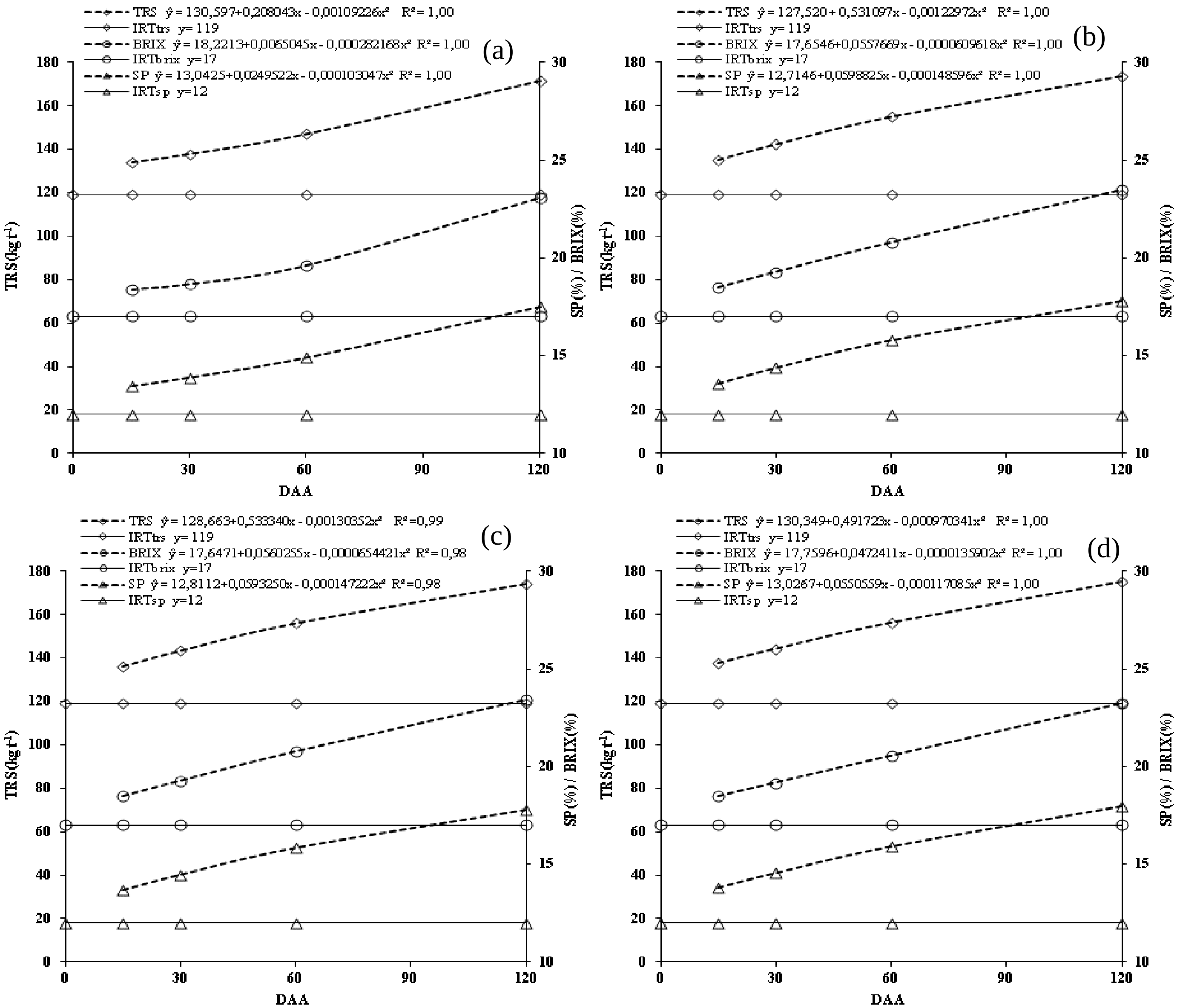

Figure 3. Total recoverable sugar (TRS), sugarcane Pol (SP) and ratoon sugar cane BRIX submitted to application of ethephon (a) Etyl-trinexapac (b) Sulfometuron methyl (c) and KNO_3 (d) harvest time at 15, 30, 60 and 120 days after application (DAA) of the treatments in comparison to the initial reference times IRT_{TRS}, IRT_{SP} and IRT_{BRIX}, in 2009/2010 crop at Icaraíma, State of Paraná, Brazil.

that the best time of harvest by using this ripener was observed at 30 DAA, which is a result that does not support the response in this study.

Fluazifop-p-butyl (Figure 2d) contributed to the improvement of technological quality of ratoon sugarcane by significantly increasing ($p \leq 0.05$) by 36, 38 and 30% for the variables in the study in relation to the respective reference periods EI_{ATR}, EI_{PC} and EI_{BRIX}. Castro and Christoffoleti (2005) and Meschede et al. (2009) inferred on the significant responses ($p \leq 0.05$) that the ripener gave to the variables in the study at 60 DAA, a result that does not corroborate the responses observed in this study.

Ethephon (Figure 3a) contributed to the improvement of sugarcane ratoon by providing significant increases ($p \leq 0.05$) of 44, 46 and 36% for technological variables ATR, PC and Brix at the best time of harvest, 120 days after application (DAA) of the chemical agent in relation to the reference initial periods EI_{ATR}, EI_{PC} and EI_{BRIX}, respectively. Leite et al. (2009) inferred on the significant effect ($P \leq 0.05$) of ethephon on the sugar cane Pol (PC) on anticipation of the harvest by up to 25 days, a result that does not corroborate the responses obtained in this study. However, Meschede et al. (2009) and Leite et al. (2009), inferred from the effect significantly differentiated ($p \leq 0.05$) from the chemical agent on the PC and ATR

60 DAA and on the PC until 90 DAA, respectively. In both cases, the responses found by the authors do not corroborate the results found in this study.

Etyl-trinexapac (Figure 3b) contributed to the improvement of technological quality of ratoon sugarcane by providing significant increases ($p \leq 0.05$) of 45, 47 and 38% for ATR, PC and Brix at the best time to harvest the ratoon sugar cane submitted to chemical agent, at 120 days after application (DAA) compared to the corresponding initial periods of reference EI_{TRS}, EI_{PC} and EI_{BRIX}. Viana et al. (2008) say that the mode of action of this chemical agent favors technological variables of sugar cane under study, inferring on the significant responses ($p \leq 0.05$) of TRS between 46 and 117 DAA, corroborating the responses found in this study related to this variable.

Sulfometuron methyl (Figure 3c) contributed to the improvement of ratoon sugarcane by increasing ($p \leq 0.05$) by 46, 48 and 38% the technological variables under study at 120 days after application (DAA) - considered the best harvest time - compared to the corresponding initial reference periods EI_{ATR}, EI_{PC} EI_{BRIX}. Meschede et al. (2010) found that ATR presented significant increases ($p \leq 0.05$) in treatments with this chemical agent in the sugarcane harvest period until 120 DAA, corroborating the results of this study, which was also confirmed by Caputo et al. (2007) for the same condition and technological variable. On the other hand, Silva et al. (2010) inferred on significant responses ($p \leq 0.05$) to the variable PC due to the action of this chemical agent until 45 DAA. The results presented by the authors do not confirm the responses found in this study.

At the most suitable harvest time, at 120 days after application (DAA), KNO_3 action (Figure 3d) conferred a significant increase ($p \leq 0.05$) of 47, 50 and 37% for technological variables TRS, PC and Brix of ratoon sugar cane compared to the reference periods EI_{TRS}, EI_{PC} and EI_{BRIX}, respectively. Crusciol et al. (2010) confirm that this chemical agent induces maturation by chemical injury caused by its mode of action, releasing endogenous ethylene and temporarily reducing growth rate, favoring qualitative storage quality of sucrose in the stalks. Leite et al. (2008) confirmed that they obtained significant results ($p \leq 0.05$) for the variables PC and TRS until 30 DAA, a result that corroborates the responses obtained in this study.

Conclusions

KNO_3 contributed to improving the agronomic quality by increasing the productivity of the stalks (TCH) by 43% compared to control and the most favorable harvest period was from 60 to 120 days after application (DAA) of ripeners, compared to other harvest periods.

The application of etyl-trinexapac, sulfometuron methyl and KNO_3 resulted in an increase of 12, 13 and 14% for TRS variables, Brix and PC, respectively, compared to the control and the best harvest period was 120 days after application (DAA) of those ripeners.

Thus, the most suitable harvest period was 120 days after application (DAA) of ripeners and control, as it provided gains of 40, 32 and 42% for technological variables TRS, Brix and PC, in relation to their initital reference periods IR_{TRS}, IR_{BRIX} and IR_{PC}.

Conflict of Interests

The authors have not declared any conflict of interests.

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