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Response of Eight Sugarcane Cultivars to Glyphosine and Glyphosate Ripeners

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Abstract. Studies were conducted on eight sugarcane (*Saccharum* spp. hybrid) cultivars during the 1982–83 (plant crop) and 1983–84 (ratoon crop) growing seasons to determine the effects of glyphosine (Polaris) (N,N-bis (phosphonomethyl) glycine) and glyphosate (Polado) (sodium-N-(phosphonomethyl) glycine) on stalk sucrose content and yield. Difference due to crops (plant vs. ratoon) for sugarcane quality, kilograms of sugar per ton of cane (S/T), sugarcane yield, tons of cane per hectare (TCH), and sugar yield, tons of sugar per hectare (TSH) were significant. Significant differences were found in quality for the ratoon crop and cane and sugar yield in both crops due to ripener treatment. Cultivars in both crops differed significantly in quality and yield. Harvest dates were significantly different for all plant characteristics. Interactions of cultivar by treatment for the plant crop, harvest date by treatment for the ratoon crop, and cultivar by harvest date for both crops for cane quality also were significant. Time from ripener application to achievement of maximum sugar concentration also depended on cultivar. This is important in determining the economic benefits of a ripener treatment. Climatic conditions may also affect the benefits of such applications.

Since Florida has a relatively long (5-month) harvest season, excellent commercial management is needed to continuously harvest sugarcane (*Saccharum* spp.) that is at its peak sugar concentration. In Florida, chemical ripeners are often applied to sugarcane to be harvested during the first 2 months of the harvest season to hasten maturity. Ripening is considered one of the most im-

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portant management aspects of sugarcane production. Ripening is the accumulation of sucrose in the internodes of the stalk (Legendre 1975) and is induced by low temperatures (Brodie et al. 1969, Legendre 1975), water stress (Humbert et al. 1967), nutrient stress (particularly nitrogen (Nickell 1972)), physiological maturity of the plant, and shortening day length (Humbert et al. 1967). During the first portion of the Florida sugarcane harvest season on organic soils, both moisture and nitrogen levels are high and temperatures are warm. Thus, natural sucrose accumulation is limited and chemical ripening is relied upon (Orsenigo 1977). Potential chemical ripeners have been evaluated worldwide since 1949 (Nickell 1979). The response of sugarcane to chemical ripeners may vary with the rate of application of the chemical, the cultivar, the physiological stage of the crop at the time of application, and the growing conditions before and after application (Nickell 1982, Rostron 1974).

The use of glyphosine (Polaris) in Florida has increased dramatically from 72 ha in 1972 since its registration to more than 18,000 ha in 1979 (Rice et al. 1980). Glyphosine has been reported to provide about a 10% increase in sucrose yield with maximum increases of up to 30% (Ahlrichs and Porter 1972, Selleck et al. 1974), particularly under conditions unfavorable to natural ripening. Under prevailing field conditions, a number of cultivars have not responded to glyphosine (Hilton et al. 1980, Holder and DeStefano 1979, Nickell 1983, Rice et al. 1980, Selleck et al. 1974, Zschoche 1977). Glyphosate (Polado) has been found to provide greater activity than glyphosine (Hilton et al. 1980, Nickell 1983). Glyphosate also improves the sucrose content over a wider range of climatic conditions, is less cultivar-specific, and provides a ripening response that is more consistent and rapid than that obtained with glyphosine (Hilton et al. 1980, Selleck et al. 1974). Orsenigo (1977) evaluated 35 compounds in Florida and reported that significant sucrose enhancement was obtained only with glyphosine and glyphosate. Dusky (1984) also reported significant sucrose enhancement only with glyphosine and glyphosate when 16 other compounds were evaluated. Besides sucrose enhancement, other benefits of chemical ripeners may be (1) increased purity (ratio of sucrose to nonsucrose solutes in the juice), (2) increased recoverability of sugar at the mill, and (3) reduction of the ratio of tons of cane to tons of sugar. Reduction in this ratio results in improved economy of transporting and milling the cane. The use of ripeners also results in desiccation of spindles and leaves, causing an improved burn and reduced trash at harvest. Nickell (1982, 1983) recently reviewed the use of plant growth regulators in sugarcane production. However, little information is available on the effect of commonly used sucrose enhancers on new sugarcane cultivars in Florida.

The objectives of this study were to evaluate the effectiveness of glyphosine and glyphosate on eight sugarcane cultivars and to determine the time interval between application and harvest that optimizes the response.

Materials and Methods

Eight sugarcane cultivars were planted on December 30, 1981, in a split-split-plot arrangement with four replications at A. Duda and Sons, Belle Glade, FL, on a Pahokee muck (Euic hyperthermic Lithic medisaprist). Years were the main plots, ripener treatments and control the subplots, and cultivars the subsub plots. The cultivars used were CP63-588, CP69-1052, CP70-1133, CP72-1210, CP72-2086, CP73-1547, CP74-2005, and CL54-378. Cane seed pieces were planted as two running lines in furrows with rows 1.5 m apart. Individual cultivar plots were four rows wide and 7.9 m long. The following nutrients were applied in the furrows prior to planting at the indicated rates (kg ha^{-1}): K, 326; Mn, 0.86; B, 0.36; and Zn, 0.78. Other cultural practices such as cultivation and pest control were the same as used in the commercial field in which the test was located. The same was true for the following ratoon crop.

Applications of glyphosine (Polaris) and glyphosate (Polado) were made using a helicopter moving at 21.5 m s^{-1} and operated at 0.4 Pa to deliver 187 L ha^{-1}. The rates of application were 3.36 kg ai ha^{-1} and 0.56 kg ai ha^{-1}, respectively, for glyphosine and glyphosate. Applications were made on October 5, 1982, in the plant crop and on October 19, 1983, to the same plots in the first ratoon crop.

For juice quality analysis, a 10-stalk sample per plot per sampling date was hand cut at random, stripped, topped at the top visible dewlap, and weighed. Juice was expressed with a three-roll mill. The juice was analyzed for Brix (% soluble solids) and percent sucrose at 1 day prior to ripener application, and at 4, 8, and 12 weeks after application for both the plant and first ratoon crops. Entire plots were weighed at harvest (ca. 16 weeks after application), and 10-stalk subsamples were removed for juice analyses. Kilograms of sugar per ton of cane (S/T) were calculated using Arceneaux's modification of the Winter-Carp-Geerligs formula (Arceneaux 1935). Tons of sugar per hectare (TSH) were determined by multiplying tons of cane per hectare (TCH) by S/T. Analyses of variance were completed on the data, and LSDs were determined for comparisons.

Results and Discussion

Significant differences due to crop rotation (plant vs. ratoon), treatment, cultivar, and harvest date for S/T, TCH, and TSH were observed (Table 1). The crop effect was confounded with year. Although data were collected on several traits, mainly sugarcane quality and yield data will be discussed, because the other traits are components of either cane quality or yield. Crop by cultivar, treatment by cultivar, crop by date, treatment by date, and cultivar by date interactions were also significant for various sugar characters (Table 1).

The 1983–84 season was cooler in November (Table 2) than in the previous year. The average minimum temperature in November of 1982 was 16.0°C with a mean temperature of 21.6°C, whereas in 1983 the average minimum temperature was 13.7°C and the mean temperature was 19.9°C. In 1983, a hard freeze occurred on December 26. After a killing freeze such as this, the stored sucrose starts to break down into other sugars and degradation products. The freeze affected cane quality at the final harvest. In addition, in December 1983, there was reduced incident radiation, reducing the rate of photosynthesis and subsequent stored sugars. For these reasons, data for S/T, TCH, and TSH were also analyzed for plant and ratoon crops separately (Table 3).

There were significant differences in cane yield and sugar yield due to treat-

Table 1. Mean squares for kilograms of sugar per ton of cane (S/T), tons of cane per hectare (TCH), and tons of sugar per hectare (TSH) for plant (1982–83) and ratoon (1983–84) crops.

		Mean squares		
Sources of variation	df	S/T (kg t^{-1})	TCH (t ha^{-1})	TSH (t ha^{-1})
Main plots	(7)			
Replication (R)	3	252.6	736.1	0.8
Crops (Y)	1	32,549.1**	<1.0	5.4*
Error a	3	145.3	144.5	0.2
Subplots	(23)			
Treatments (T)	2	2,111.4**	1,151.1**	3.7**
Y × T	2	249.9	14.6	0.1
Error b	12	108.9	75.2	0.3
Subsub plots	(191)			
Cultivars (C)	7	2,294.9**	10,878.1**	43.4**
Y × C	7	728.3**	1,049.7**	4.9**
T × C	14	212.5	332.9**	1.7
Y × T × C	14	84.3	95.9	0.5
Error c	126	120.4	147.8	1.0
Subsubsub plots	(959)			
Harvest dates (D)	4	37,538.8**	—	—
Y × D	4	2,624.0**	—	—
T × D	8	425.3**	—	—
Y × T × D	8	225.3*	—	—
C × D	28	281.1**	—	—
Y × C × D	28	72.4	—	—
T × C × D	56	119.6*	—	—
Y × T × C × D	56	63.9	—	—
Error d	576	79.5	—	—

Significance at the *5% and **1% levels of probability, respectively.

Table 2. Average minimum, maximum, and mean temperatures and incident radiation summary during 1982–83 and 1983–84 seasons.

	Temperature (°C)			
Crop year	Min	Max	Mean	Solar radiation (J M^{-2} (× 10^7))
1982–83				
October	18.0	28.6	23.3	1.50
November	16.0	27.2	21.6	1.24
December	13.4	25.4	19.4	1.20
January	10.4	22.2	16.3	1.14
1983–84				
October	18.4	30.0	24.2	1.50
November	13.7	26.1	19.9	1.22
December	13.8	24.4	19.1	0.95
January	10.8	23.4	17.1	1.16

Table 3. Analyses of variance for kilograms of sugar per ton of cane (S/T), tons of cane per hectare (TCH), and tons of sugar per hectare (TSH) for the plant crop (PC) and ratoon crop (RT).

		Mean squares					
		S/T ($kg\ t^{-1}$)		TCH ($t\ ha^{-1}$)		TSH ($t\ ha^{-1}$)	
Sources of variation	df	PC	RT	PC	RT	PC	RT
Main plots							
Replication (R)	3	141.3	255.5	473.3	407.3	0.8	1.2
Treatments (T)	2	468.2	1,893.0**	584.7**	586.0*	1.9**	1.7*
Error a	6	139.7	78.1	45.8	104.6	0.1	0.3
Subplots							
Cultivars (C)	7	1,914.3**	1,108.9**	3,712.7**	8,215.1**	12.9**	36.2**
C × T	14	205.0*	89.2	249.9	178.9	1.4	1.0
Error b	63	113.1	127.8	145.2	150.4	1.2	0.9
Subsubplots							
Harvest dates (D)	4	28,355.7**	11,807.2**	—	—	—	—
D × T	8	128.5	522.1**	—	—	—	—
C × D	28	193.9**	159.6**	—	—	—	—
C × D × T	56	84.7	98.8	—	—	—	—
Error c	288	81.9	77.1	—	—	—	—

Significance at the *5% and **1% levels of probability, respectively.

Table 4. Effect of glyphosine (3.36 kg ai ha^{-1}) and glyphosate (0.56 kg ai ha^{-1}) on sugarcane yield and quality for the plant (1982–83) and ratoon (1983–84) crops.

	S/T (kg t^{-1})		TCH (t ha^{-1})		TSH (t ha^{-1})	
Treatment	PC	RT	PC	RT	PC	RT
Check	112.6	126.9	123.4	122.5	7.7	8.0
Glyphosine	112.0	126.6	122.1	123.1	7.6	7.9
Glyphosate	115.2	132.6	115.4	115.4	7.2	7.6
LSD (0.05)	NS	2.8	4.1	6.3	0.5	0.4

Table 5. Analyses for significance for cultivars by ripener treatment (T), date of harvest (D), and treatment (T) × date (D)

	(T)		(D)		(T × D)	
Cultivar	PC	RT	PC	RT	PC	RT
CL54-378	**	NS	**	**	NS	NS
CP63-588	NS	NS	**	**	NS	**
CP69-1052	NS	NS	**	**	NS	NS
CP70-1133	NS	**	**	**	NS	*
CP72-1210	NS	*	**	**	NS	NS
CP72-2086	NS	NS	**	**	NS	NS
CP73-1547	**	NS	**	**	*	NS
CP74-2005	NS	NS	**	**	NS	NS

Significance at the *5% and **1% levels of probability, respectively.

ment in both crops and cane quality in the ratoon crop (Table 4). The TCH and TSH were significantly reduced by glyphosate treatment when compared to the check and glyphosine treatment. The S/T was significantly increased by the glyphosate treatment only in the ratoon crop (Table 4). There was no effect of treatment on S/T in the plant crop. Sugar yield significantly decreased with glyphosate treatment because of the decreased tons of cane in both crops. In the ratoon crop, even though there was a significant increase in S/T with glyphosate treatment, TSH was still significantly decreased owing to the reduction in TCH. Other researchers have reported decreased tons of cane with glyphosate treatment (Rice et al. 1980, Selleck et al. 1974). For this reason, at the present time, glyphosate is registered for use only on the last ratoon crop in Florida, Louisiana, and Texas.

Cultivar differences for S/T, TCH, and TSH were significant. CP70-1133 produces high TCH with a low sucrose content, whereas CP63-588 has high sucrose content but less TCH. The cultivar by treatment interaction (C × T) for S/T was also significant for the plant crop. This indicated that not all cultivars responded similarly to treatment with a ripener in the plant crop. In the ratoon crop year, all cultivars responded to treatment in the same manner, as C × T was not significant. Conditions were more favorable for natural ripening in the ratoon crop because of decreased temperatures and incident radiation (Table 2). Chemical ripening is more effective under conditions that do not favor natural ripening (Ahlrichs and Porter 1972, Selleck et al. 1974). Glyphosate has also been found to be more effective over a wide range of climatic

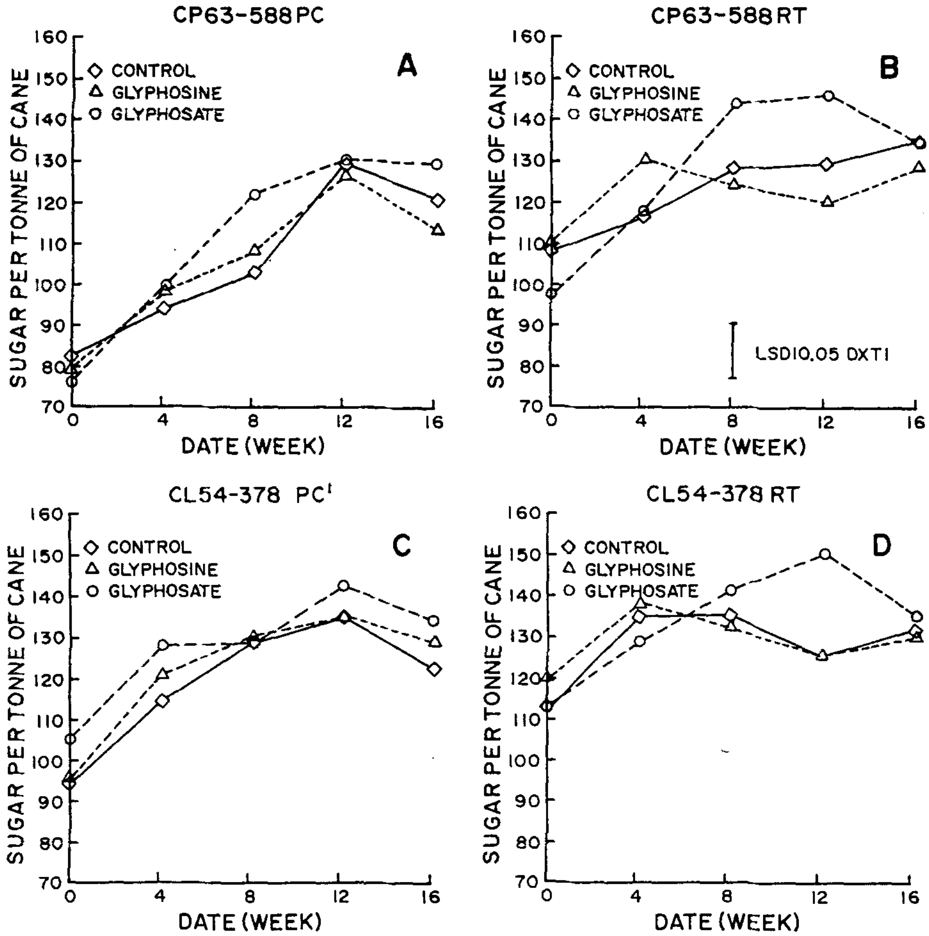

Fig. 1. (A–D) Response of sugarcane cultivars CP63-588 and CL54-378 for plant crop (PC) and first-ratoon crop (RT) for two ripeners at five sampling dates. [1]LSD (0.05) equals 2.9 for treatments across all harvest dates.

conditions (Hilton et al. 1980, Selleck et al. 1974). This is supported by the data of the present study, as the cultivars in the ratoon crop, even though under more favorable conditions for natural ripening, responded uniformly to glyphosate treatment with increasing cane quality (Table 3).

Significant differences due to date of harvest were also observed for S/T for both plant and ratoon crops. The harvest date by treatment interaction was significant for S/T in the ratoon crop. The cultivar by harvest date interaction for S/T was significant for both crops. It was apparent that the time period after application of a ripener to obtain maximum S/T varied among cultivars and that there were cultivar-maturity differences (Table 5).

Some cultivars responded differentially to ripeners. A cultivar treated with a ripener may need to be harvested at a different time from if it had not been treated. For these reasons, S/T for each cultivar was analyzed by treatments and harvest dates.

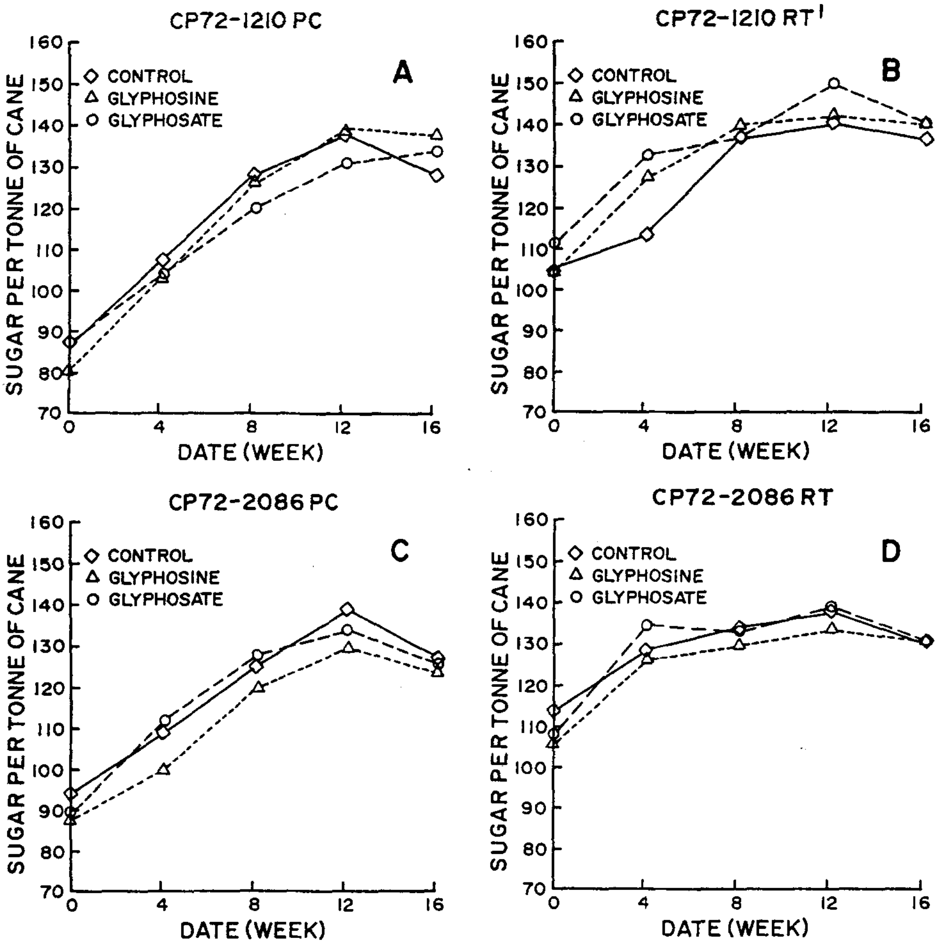

Fig. 2. (A–D) Response of sugarcane cultivars CP72-1210 and CP72-2086 for plant crop (PC) and first-ratoon crop (RT) for two ripeners at five sampling dates. [1]LSD (0.05) equals 2.5 for treatments across all harvest dates.

There were significant differences in sugarcane quality due to treatment across all harvest dates for the cultivars CL54-378 (Fig. 1C) and CP73-1547 (Fig. 3C) in the plant crop. The same was true for CP70-1133 (Fig. 3B) and CP72-1210 (Fig. 2B) in the ratoon crop. Sugar quality was significantly different for harvest dates across all treatments for all the cultivars. Treatment by harvest date interactions was significant for CP73-1547 (Fig. 3C) in the plant crop and for CP63-588 (Fig. 1B) and CP70-1133 (Fig. 3B) in the ratoon crop.

Figures 1–4 for S/T indicate differences in cultivar response to treatment with a ripener. The plant crop of CP63-588 indicated no response to treatment with a ripener (Fig. 1A). In the ratoon crop, 4 weeks after application of glyphosine, there was a significant increase in S/T above that of the control and the glyphosate treatment, after which there was no further increase. The glyphosate treatment exhibited increased S/T at 8 and 12 weeks after treatment.

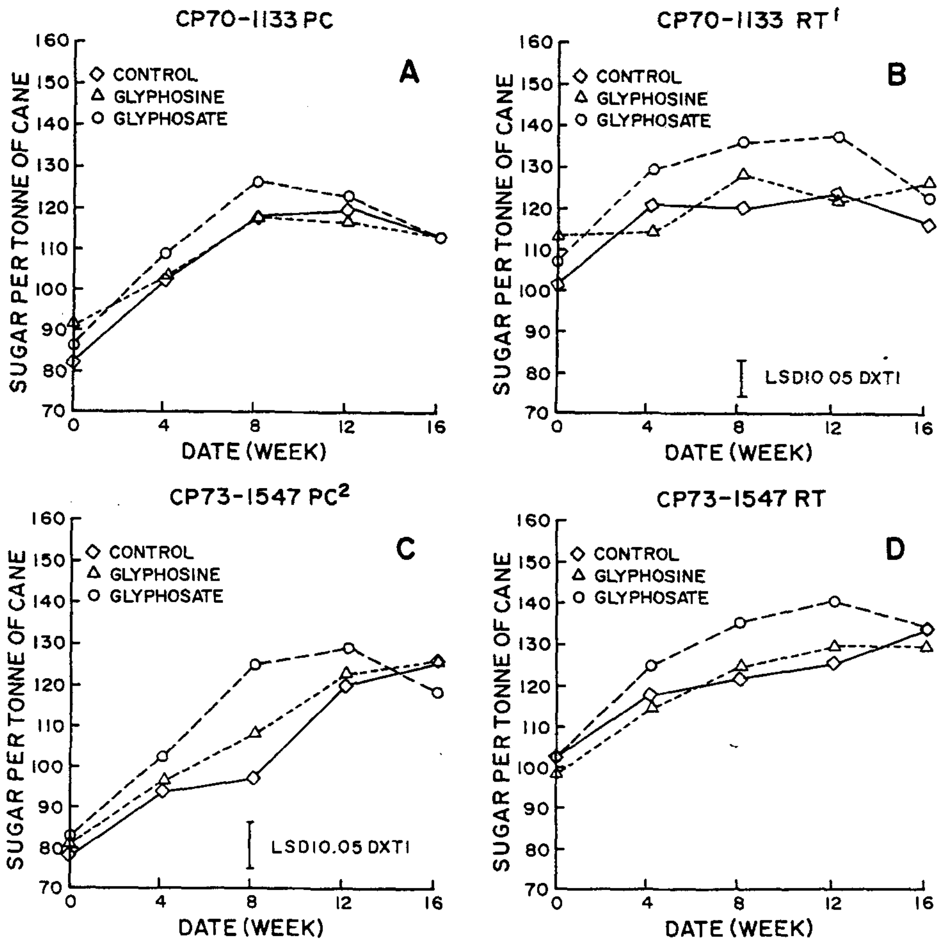

Fig. 3. (A–D) Response of sugarcane cultivars CP70-1133 and CP73-1547 for plant crop (PC) and first-ratoon crop (RT) for two ripeners at five sampling dates. [1]LSD (0.05) equals 2.4 for treatments across all harvest dates. [2]LSD (0.05) equals 2.5 for treatments across all harvest dates.

Sugarcane is normally harvested 4–8 weeks after application of the ripeners evaluated in this test. In the plant crop of CL54-378 (Fig. 1C), there was a significant response to glyphosate treatment as shown by the increased mean S/T over all dates. However, there was no specific date at which S/T was significantly increased with a ripener treatment. There were no significant difference due to glyphosate treatment in the ratoon crop (Fig. 1D). CP72-1210 (Fig. 2A,B) and CP72-2086 (Fig. 2C,D) were very similar. There was a significant response to treatment over all dates for the ratoon crop of CP72-1210 (Fig. 2B). Both cultivars reached maximum S/T ca. 12 weeks after treatment. CP70-1133 (Fig. 3A,B) did not respond to ripener treatment in the plant crop; however, it showed a significant harvest date by treatment interaction in the ratoon crop, as only glyphosate treatment significantly increased S/T at 4, 8, and 12 weeks after treatment. It should also be noted that maximum S/T was obtained ca. 8

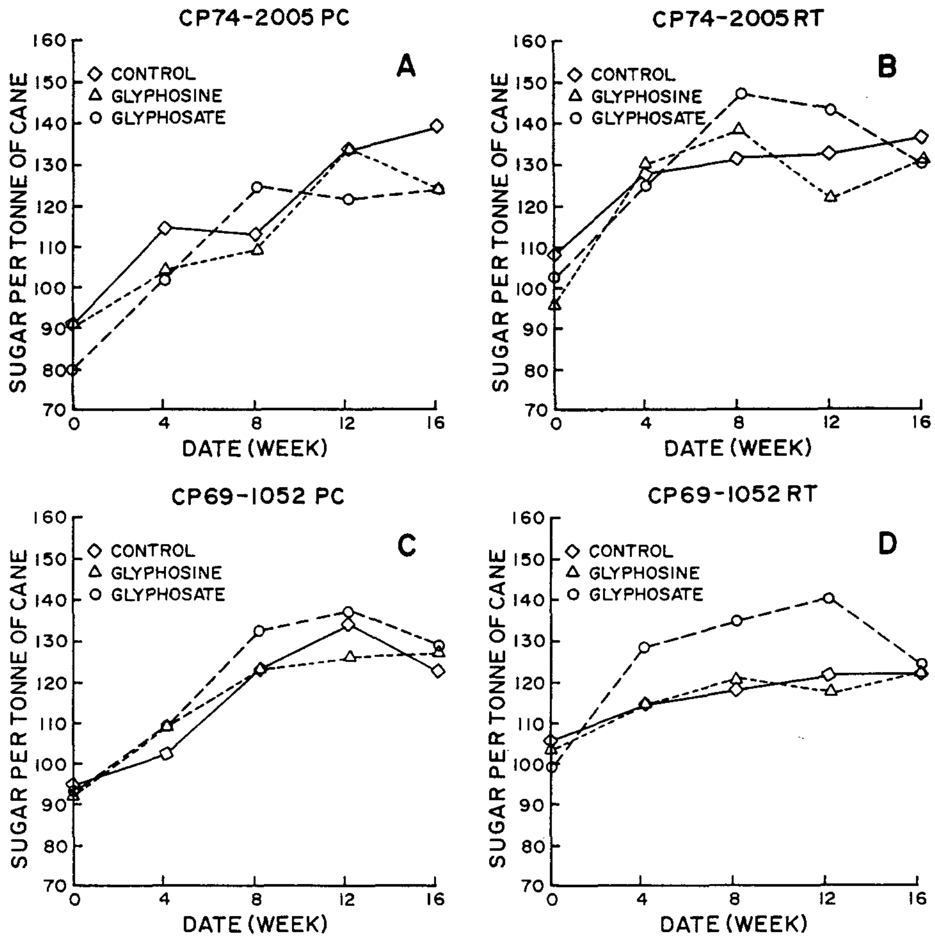

Fig. 4. (A–D) Response of sugarcane cultivars CP74-2005 and CP69-1052 for plant crop (PC) and first-ratoon crop (RT) for two ripeners at five sampling dates.

weeks after the treatment. CP73-1547 (Fig. 3C,D), on the other hand, showed a significant increase in S/T 8 weeks after glyphosate treatment in the plant crop but none in the ratoon crop. CP74-2005 (Fig. 4A,B) and CP69-1052 (Fig. 4C,D) showed no response to ripener treatment.

Cultivars such as CP63-588, CP70-1133, and CP73-1547 responded to the application of glyphosate. None of the cultivars exhibited increased S/T with glyphosine treatment. The choice of a growth regulator depends on the cultivar. Determination of the number of days between application and harvest is also important. Even though maximum S/T might be obtained 12 weeks after treatment, it may be prudent to harvest 4–8 weeks after treatment because TCH may not be increased as much as with longer exposure times. It is essential to screen newly developed cultivars at specific localities to determine if the cost and returns of ripener application are economically practical.

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