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Evaluation of Candidate Chemical Ripeners with Early-Juvenile Sugarcane[1]

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ABSTRACT

Ripening activity of seven candidate materials was examined in sugarcane plantlets propagated by sand culture. Test compounds included Polaris[3] and CP 70139 (Monsanto), RH 1622 and C-9550 (Rohm and Haas), JF 4380 (ICI, Plant Protection Ltd.), PP 757 (ICI United States, Inc.), and Ripenthol (Pennwalt). Polaris served also as a standard ripener. All materials were administered as aqueous foliar sprays containing 3000 p/m active ingredient. Activity parameters included net growth (total green weight), sucrose content, and the enzymes acid invertase, acid phosphatase, ATP-ase, *beta*-amylase, and trehalase. CP 70139 activity surpassed that of Polaris while PP 757 equalled or moderately exceeded Polaris. Other compounds were relatively inactive. The significance of plantlet screening is discussed in terms of diminishing resources for ripener research, field problems to be solved by chemical means, and physiological requirements of candidate materials at the regional level.

INTRODUCTION

The advent of Polaris[4] as a commercial plant growth regulator (8) offers genuine promise for the control of sugarcane ripening by chemical means. This reflects in part the recent emergence of plant growth regulation as a tool of modern agriculture (9), and the intensified efforts by chemical manufacturers to provide suitable regulatory materials (9, 10).

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[3] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment or materials not mentioned.

[4] N,N-bis (phosphonomethyl) glycine. Monsanto Agricultural Products Co.

A formidable task remains, however, in the discovery of new ripeners and the defining of physiological conditions needed for them to operate with optimal efficiency. This has always been so because of inherent differences in climate, varieties, and cultural conditions among regional sugar industries. Ethrel[5], for example, has produced negative results in Puerto Rico (3), variable results in Hawaii (11), and highly favorable responses in South Africa (12, 10). Moreover, in none of the leading candidate materials is the mode of action understood sufficiently well to assure an efficient or even positive response in any given situation.

Since the early 1970's an added problem has been the drastic curtailment of resources needed for sugarcane ripener research. In the present report, early-juvenile sugarcane is utilized as a rapid and inexpensive means for evaluating growth, quality, and enzymic effects of seven candidate compounds.

MATERIALS AND METHODS

Plantlet methodology was developed between 1970 and 1972 (1, 2) following the emergence of Polaris as the first reliably consistent material suitable for use as a standard cane ripener. It is predicated upon young leaf and meristematic parameters showing characteristic sensitivities to chemicals from the early-juvenile stage onward.

One-eye cuttings of the interspecific hybrid PR 980 were propagated by sand culture in the greenhouse using controlled water and nutrient regimes as previously described (3). Test compounds were administered as aqueous foliar sprays containing 3000 p/m active ingredient. Five-week old plants were treated between 0700 and 0730 h. There were two experiments, each employing Polaris as a second control or standard reference material. Candidate ripeners included RH 1622 and C-9550 (Rohm and Haas Co.), JF 4380 and PP 757 (ICI, Plant Protection Ltd., and ICI United States, Inc.), CP 70139 (Monsanto Agricultural Products Co.), and Ripenthol (Pennwalt Corp., Agchem-Decco Division). JF 4380 was administered as a suspended powder. PP 757 was dissolved in methyl cellosolve and dispersed in water prior to application. All preparations contained 0.1% Tween 20 as wetting agent. Control plants were sprayed with water and Tween 20. There were four replications.

Samples consisting of six uniform plantlets per replicate were harvested at "0" days, ie., just prior to chemical application, and at the same hour 21 days thereafter. Green weight measurements were taken for whole plantlets. Appropriate leaf and immature storage tissues were frozen for sugar and enzyme analyses as described in a previous paper (3). Trehalase, a hydrolytic enzyme thought to be active in sugar utilization, was assayed in the second experiment using methods adapted

[5] 2-chloroethyl phosphonic acid. Amchem Products, Inc.

for *Saccharum* spp. (4). Other enzymes included acid invertase, ATP-ase, acid phosphatase, and *beta*-amylase. All replicated data were submitted to statistical analysis by the Duncan New Multiple Range Test.

RESULTS

The main objective was the discovery of materials having ripener activity equal to or exceeding that of Polaris. Of the compounds tested in experiment 1, including RH 1622, C-9550, and JF 4380, none equalled Polaris in their effects on growth (table 1), sugar content (table 2), or enzyme activity (table 3).

In the second experiment the Monsanto product CP 70139 exceeded Polaris in growth restriction, sucrose accumulation, and enzymic

TABLE 1.—*Growth responses of sugarcane plantlets treated with candidate chemical ripeners*

Treatment[1]	Green wt (g/plant) at day—	
	0	21
Control	15.6 a[2]	48.1 a
Polaris	18.8 a	19.7 b
RH 1622	19.1 a	45.9 a
C-9550	18.1 a	42.8 a
JF 4380	16.3 a	47.7 a

[1] All materials were applied as aqueous foliar sprays containing 3000 p/m active ingredient.

[2] Mean values in the same column bearing unlike letters differ significantly ($P < .05$).

TABLE 2.—*Sugar content of sugarcane plantlets treated with candidate chemical ripeners*

Tissue	Treatment[1]	Mg sugar/g dry wt, at 0 and 21 days, for—			
		Sucrose		Total reducing	
		0	21	0	21
Leaf	Control	47.5 a[2]	55.0 a	14.0 a	10.9 a
	Polaris	51.0 a	73.6 b	14.7 a	14.7 b
	RH 1622	54.2 a	53.8 a	14.2 a	11.5 a
	C-9550	50.5 a	56.3 a	14.1 a	11.1 a
	JF 4380	46.9 a	54.8 a	14.1 a	10.4 a
Immature storage	Control	74.4 b	127.8 b	84.6 a	95.4 a
	Polaris	96.0 ab	192.0 a	87.6 a	91.2 a
	RH 1622	108.0 a	159.6 ab	78.4 a	91.2 a
	C-9550	93.0 ab	146.4 b	89.4 a	96.0 a
	JF 4380	70.8 b	127.8 b	95.2 a	95.4 a

[1] All materials were applied as aqueous foliar sprays containing 3000 p/m active ingredient.

[2] Mean values in the same column bearing unlike letters differ significantly ($P < .05$).

changes (tables 4, 5, and 6, respectively). Growth repression was excessive and the plantlets were near death at 21 days. A second material, PP 757, equalled or moderately exceeded Polaris without destroying the plants. The Pennwalt product, Ripenthol, showed comparatively little activity. Enzymic effects of Polaris, CP 70139 and PP 757 were pronounced in immature storage tissue where significant repression of acid invertase, ATP-ase, *beta*-amylase and trehalase was produced by each compound (table 6).

DISCUSSION

Initial screening with plantlets will not give final answers relative to a candidate ripener's potential. However, such data have considerable value when placed in proper perspective. Important considerations

TABLE 3.—*Enzymic responses of sugarcane plantlets treated with candidate chemical ripeners*

Tissue	Treatment[1]	Mg product/g tissue/h, at 0 and 21 days, for enzyme—					
		Beta-amylase		ATP-ase		Acid phosphatase	
		0	21	0	21	0	21
Leaf	Control	85 a[2]	90 a	2.3 a	2.3 a	2.1 a	1.5 a
	Polaris	89 a	63 c	2.4 a	2.3 a	1.8 a	1.6 a
	RH 1622	91 a	78 ab	1.8 a	2.2 a	1.5 a	1.4 a
	C-9550	84 a	71 b	2.0 a	2.3 a	2.1 a	1.4 a
	JF 4380	93 a	80 ab	3.6 a	2.3 a	2.0 a	1.5 a
						Acid invertase	
Immature storage	Control	238 a	388 a	7.4 a	7.0 a	10.4 a	6.3 a
	Polaris	268 a	416 a	9.0 a	8.4 a	11.1 a	3.6 b
	RH 1622	260 a	380 a	7.8 a	8.6 a	8.8 a	5.6 ab
	C-9550	304 a	344 a	7.7 a	7.1 a	10.2 a	5.3 ab
	JF 4380	280 a	372 a	7.5 a	7.5 a	11.8 a	5.0 b

[1] All materials were applied as aqueous foliar sprays containing 3000 p/m active ingredients.

[2] Mean values in the same column bearing unlike letters differ significantly ($P < .05$).

TABLE 4.—*Growth responses of sugarcane plantlets treated with candidate chemical ripeners*

Treatment	Total green wt, g/plant, at day—	
	0	21
Control	16.7 a[2]	49.4 a
Polaris	15.8 a	16.7 c
CP 70139	15.0 a	11.1 c
Ripenthol	14.7 a	39.4 b
PP 757	15.6 a	18.1 c

[1] All materials were applied as aqueous foliar sprays containing 3000 p/m active ingredient.

[2] Mean values in the same column bearing unlike letters differ significantly ($P < .05$).

include: a) Resources available for continued ripener research; b) nature of the chemical's field work requirements at the regional or plantation level; and c) nature of the chemical's physiological work requirements at the regional level.

IMPLICATIONS FOR FIELD TESTING

Where resources for field testing are limited, priority should be given to materials such as CP 70139 or PP 757—compounds seemingly a match for Polaris. The possibility remains that less active candidates might excel when field tested on other varieties or at different concentrations, yet the likelihood of their surpassing Polaris in outright growth control and sucrose accumulation is considerably lessened by the plantlet results.

Some indication of regional suitability and optimal field usage may

TABLE 5.—*Sugar content of sugarcane plantlets treated with candidate chemical ripeners*

Tissue	Treatment[1]	Mg sugar/g dry wt, at 0 and 21 days, for—			
		Sucrose		Total reducing	
		0	21	0	21
Leaf	Control	26.2 a[2]	41.7 bc	26.9 a	18.1 d
	Polaris	22.9 ab	33.6 c	28.5 a	36.0 a
	CP 70139	20.8 b	64.2 a	26.4 a	37.1 a
	Ripenthol	23.1 ab	45.7 b	26.9 a	23.4 c
	PP 757	21.4 b	61.9 a	29.3 a	31.3 b
Immature storage	Control	72.4 ab	117.6 c	62.3 a	114.5 a
	Polaris	68.1 b	149.7 b	70.5 a	77.6 b
	CP 70139	72.0 ab	243.8 a	66.0 a	55.3 b
	Ripenthol	78.8 a	132.6 bc	61.0 a	111.4 a
	PP 757	73.2 ab	227.0 a	73.5 a	72.0 b

[1] All materials were applied as aqueous foliar sprays containing 3000 p/m active ingredient.

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also be gleaned from plantlet data. The very powerful action of Monsanto's CP 70139 should justify field tests at 10 or 20 percent of the standard Polaris level, both as a means of preventing plant injury and of lowering treatment costs. This is particularly true where crop conditions are normally favorable for chemical administration. Alternately, higher levels might be used where climate or crop conditions are otherwise prohibitive for chemical ripening. The use of exceptionally powerful growth inhibitors is also consistent with crop planning that stresses higher tonnage via extended use of nitrogen and late irrigations.

PHYSIOLOGICAL CONSIDERATIONS IN RIPENER SCREENING

In a physiological sense sugarcane ripening is correctly viewed as a series of interrelated processes operating with variable efficiency along

TABLE 6.—*Enzymic responses of sugarcane plantlets treated with candidate chemical ripeners*

Tissue	Treatment[1]	Mg product/g tissue/h, at 0 and 21 days, for enzyme—							
		Acid phosphatase		ATP-ase		β-amylase		Trehalase	
		0	21	0	21	0	21	0	21
Leaf	Control	5.5 a[2]	4.0 b	7.5 a	2.5 b	273 a	348 a	0.060 a	0.102 b
	Polaris	5.5 a	5.2 ab	7.8 a	7.5 a	286 a	236 b	.065 a	.102 b
	CP 70139	5.9 a	4.1 b	8.3 a	3.1 b	298 a	209 b	.043 a	.127 b
	Ripenthol	6.5 a	4.7 b	8.8 a	5.6 ab	320 a	401 a	.088 a	.107 b
	PP 757	5.6 a	6.3 a	7.9 a	5.4 ab	300 a	395 a	.097 a	.213 a
		Acid invertase							
Immature storage	Control	8.7 a	13.3 a	15.9 a	18.3 a	309 a	584 a	.74 b	3.12 a
	Polaris	10.9 a	3.5 b	16.5 a	15.3 b	285 ab	442 b	1.13 a	.73 b
	CP 70139	9.7 a	1.4 b	17.5 a	11.9 c	262 ab	336 b	1.02 ab	.20 b
	Ripenthol	9.1 a	13.1 a	13.4 b	15.4 b	222 b	454 ab	.72 b	1.11 ab
	PP 757	9.4 a	3.1 b	16.9 a	14.7 b	285 ab	383 b	.93 ab	.85 b

[1] All materials were applied as aqueous foliar sprays containing 3000 p/m active ingredient.

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an extended source-to-sink system. The extent to which individual stages in sucrose production, translocation, and storage may become rate-limiting, and thereupon subject to improvement by chemical means, is largely unknown. However, the existence of multiple "weak links" in the chain of ripening processes has long been implied by the inconsistencies in response to confirmed growth regulators (5, pp. 443–52). For Polaris, chemical action appears to include light-utilization and transport processes spatially divorced from growth regulation (6, 7). The physiological system is almost certain to become more complicated as hybridization programs yield increasingly sophisticated genomes bearing a wider spectrum of *Saccharum* germplasm.

VALIDITY OF RIPENER SCREENING PROGRAMS

Within the context of ripening physiology, negative results from chemical screening with plantlets or adult cane must be viewed with caution, for it is always possible that the candidate material was never presented with a suitable problem. For example, the key question in the present experiments was whether or not new candidate materials could restrict growth as effectively as Polaris. However, at our present level of understanding, there is no reason to believe that growth repression is the best attribute these materials have to offer, or whether in fact this attribute is a necessary feature of chemical ripening. The validity of ripener screening programs will eventually improve as local physiological conditions needed for optimal ripener action are defined for local varieties as locally cultured. Our present limitations in material selection are classically illustrated by gibberellic acid and Ethrel; each compound has undeniably powerful influences over plant physiological processes, yet the roles that each can perform in the improvement of cane quality have never been defined.

RESUMEN

La eficiencia madurativa de siete compuestos se observó en plantitas de caña de azúcar sembradas en arena. Los compuestos fueron: Polaris y CP 70139 (Monsanto), RH 1622 y C-9550 (Rohm and Haas), JF 4380 (ICI, Plant Protection, Ltd.), PP 757 (ICI United States, Inc.) y Ripenthol (Pennwalt). Polaris también se usó como agente madurativo tipo. Todos los compuestos se administraron en aspersiones foliares acuosas que contenían 3000 p.p.m. del ingrediente activo. Los paramedtros estudiados fueron: crecimiento (peso fresco total), contenido en azúcar y los enzimas invertasa ácida, fosfatasa ácida, ATP-asa, *beta*-amilasa y trehalasa. La actividad de CP 70139 sobrepasó a la de Polaris, mientras que PP 757 la igualó o superó ligeramente. Los otros compuestos fueron relativamente inactivos.

La importancia de la eliminación selectiva mediante el uso de plantitas se discute en términos de la disminución de los recursos para la investigación relacionada con agentes madurativos, los problemas de campo que deben resolverse por medios químicos y los requisitos fisiológicos al nivel regional de nuevos reguladores del crecimiento.

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