

SUGARCANE RESPONSE TO DEPTH OF SOIL COVER AT PLANTING AND HERBICIDE TREATMENT

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ABSTRACT

Reducing the depth of soil cover at planting may enhance the rate of sugarcane emergence in Louisiana, but the effects of reducing soil cover on the potential for herbicide injury has not been studied. Sugarcane response to depth of cover at planting in combination with several herbicide treatments used to provide at planting and spring preemergence weed control was evaluated. LCP 85-384 sugarcane was planted on August 26, 1997 and October 4, 1998 on a Commerce silt loam soil. In a split-plot treatment arrangement, sugarcane seedcane (whole stalks) was covered with 5- or 10-cm of soil, and herbicides (metribuzin, pendimethalin + atrazine, pendimethalin + diuron, terbacil, terbacil + pendimethalin, terbacil + diuron, azafenidin, and clomazone + atrazine) were applied after planting and in spring of the plant-cane, first ratoon, and second ratoon crops. In plant-cane, reducing soil cover reduced cane yield, TRS, and sugar yield. Terbacil, azafenidin, and terbacil + diuron reduced cane yield, and terbacil and terbacil + diuron reduced sugar yield comparing 5- with 10-cm of soil. In the first ratoon crop, cane yield was reduced by terbacil, and sugar yield was reduced by terbacil, pendimethalin + diuron, and terbacil + diuron, comparing 5- with 10-cm of soil. In the second ratoon crop, there was no response to depth of cover at planting. The objective of reducing soil cover at planting is to reduce emergence time to improve sugarcane production. The results of this study did not support this hypothesis. In contrast, reducing soil cover left sugarcane more vulnerable to injury from certain herbicides and, even in the absence of injury, sugarcane production was not increased by reducing planting depth.

INTRODUCTION

Sugarcane in Louisiana is planted on raised beds with 1.8 m centers and is cultured as an annually-harvested perennial. Sugarcane planted in late-summer or fall has been traditionally and is currently recommended to be covered with 8- to 10-cm of packed soil following planting to buffer from freezing winter temperatures and soil-applied herbicides and to reduce uprooting of underground buds during mechanical harvesting (Silliman, 1833; Legendre, 2001; Ricaud, 1994). However, research conducted on sugarcane response to depth of planting in Louisiana has been limited.

The predominant sugarcane cultivar in Louisiana, 'LCP 85-384', produces a high number of small diameter stalks (Milligan et al., 1994). Following planting, it is relatively slow to emerge. To decrease time of emergence, many growers have reduced soil cover at planting to as little as 5-cm, especially in lighter textured soils. Growers have also reduced the amount of soil added to row tops at layby, the final spring cultivation, so as to keep row tops flat to improve harvestability when using a chopper-type mechanical harvester. Hence, soil cover continues to

be somewhat lower when herbicides are re-applied in the spring during the ratoon crop years as well.

Many preemergence herbicides used in sugarcane are safe due to the soil acting as a buffer that prevents sugarcane roots and underground buds from coming into contact with high concentrations of herbicide. Effective rates for several of these soil-active preemergence herbicides are increased when applied to soils with high clay content or high organic matter or to attain acceptable control of certain difficult to control weeds (Anonymous, 2006). Although the depth of soil cover at planting varies in Louisiana, the influence of covering depth on herbicide selection and rate is not considered in current weed control recommendations.

While a shallower depth of soil cover at planting may allow for quicker emergence in the newly planted crop, it is unknown what effect this has on sugarcane yield, ratoon performance, or herbicide tolerance. Research was conducted to evaluate the effects of depth of soil coverage at planting on sugarcane yield and response to preemergence herbicide treatments from the plant-cane through the second ratoon crop cycle which is common to Louisiana.

MATERIALS AND METHODS

Studies were conducted at the Welcome Farms Plantation in Vacherie, LA, on a Commerce silt loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquents)¹. Permeability in Commerce soils is moderately slow, however, it is more permeable than surrounding common agricultural soil series, such as Sharkey (very slowly permeable), Mhoon (slowly permeable), or Vacherie (very slowly permeable). The location was selected because it was a relatively coarse soil type with less clay content (11 to 13% sand and 14 to 15% clay) which would be more susceptible to herbicide leaching than a fine textured clay soil (such as 3 to 4 % sand and around 61% clay in a Sharkey clay soil). Treatments were arranged in a split-plot fashion with whole plots being depths of soil cover at planting and sub-plots being herbicide treatments. Entire stalks were machine-planted (three to four stalks placed lengthwise in the planting furrow) and covered with either 5- or 10-cm of soil in the whole plots. Sub-plots consisted of three adjacent 1.8-m wide rows which were 15-m in length. Sugarcane cultivar 'LCP 85-384' was planted on August 26, 1997 (Study A) and October 4, 1998 (Study B). The later planting date in 1998 was due to availability of the grower who cooperated in this research having the desired field available and personnel available to plant the study. Four replications were used in both studies.

The herbicide treatments for this study were selected because all were capable of controlling weeds present, are commonly used in at-planting and spring to provide broad-spectrum preemergence control of seedling grass and broadleaf weeds, and have varying degrees of potential to injure sugarcane. The experimental herbicide azafenidin was also included in this study as attempts were being made at the time to register it in the U.S. for use in sugarcane and other crops. Although azafenidin was never registered for use in the U.S., results are still reported. Metribuzin is not known to injure sugarcane at recommended use rates (Hilton et al.,

¹ Soil Survey of St. James and St. John the Baptist Parishes, Louisiana. National Cooperative Soil Survey. Soil Survey Division, Natural Resources Conservation Service, United States Department of Agriculture.

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1974; Millhollon, 1977; Richard, 1989), and was used as the standard to compare all other herbicide treatments in this study. This study was not intended to be inclusive of all herbicides available for use in sugarcane and there is no intended implication that the herbicides used in this study are being recommended over those not included in this study.

Within five days of planting, eight herbicide treatments: metribuzin ($1.7 \text{ kg ai ha}^{-1}$), pendimethalin + atrazine ($3.4 + 3.4 \text{ kg ai ha}^{-1}$), pendimethalin + diuron ($3.4 + 2.9 \text{ kg ai ha}^{-1}$), terbacil ($1.5 \text{ kg ai ha}^{-1}$), terbacil + pendimethalin ($0.9 + 2.2 \text{ kg ai ha}^{-1}$), terbacil + diuron ($0.9 + 2.9 \text{ kg ai ha}^{-1}$), azafenidin ($0.7 \text{ kg ai ha}^{-1}$), and clomazone + atrazine ($1.7 + 3.4 \text{ kg ai ha}^{-1}$) were applied to sub-plots. These same herbicide treatments were repeated the following spring (March 27, 1998 in Study A; March 10, 1999 in Study B), and again in spring during the first ratoon (March 10, 1999 in Study A; March 24, 2000 in Study B) and second ratoon crops (March 24, 2000 in Study A, and April 4, 2001 in Study B). While spring applications are termed preemergence, they were made preemergence to weeds, but postemergence to the sugarcane crop. During spring applications, sugarcane ranged from 5- to 9-cm in height from the soil surface to the leaf collar of the uppermost mature leaf. Herbicides were applied using a tractor-mounted compressed air sprayer calibrated to deliver 190-L ha^{-1} using flat fan 8002 nozzles², except the fall treatment of Study B that, due to wet conditions, was applied using a hand-held boom sprayer using flat fan 8001 nozzles².

Conventional management practices were employed in both studies. Cultivation and fertilization of the crop were conducted by the cooperating grower. Cultivation included off-barring of the row (cultivation of all but the 90-cm row top with shields to prevent soil from being deposited on the row top) in March, row side cultivation in conjunction with fertilizer application, and layby cultivation in May or early-June. During the layby cultivation of the row sides, disks were pitched to deposit 2- to 3-cm of soil onto the row top. After the layby cultivation, all plots received an application of pendimethalin + atrazine ($2.2 + 2.2 \text{ kg ai ha}^{-1}$) to control late-emerging weeds.

Sugarcane injury was visually rated at 14 days after the spring treatment (DAT) in the plant-cane and first ratoon crops. Injury was rated on a scale of 0 to 100% with 0% being no injury, and 100% being complete death. Sugarcane stalk population (number per plot) and height (12 stalks measured per plot) of harvestable stalks (at least 1.4-m in height) were determined in August of each year excluding the first year of Study A because excessive lodging prohibited accurate measurements.

Sugarcane, beginning in 1999, was harvested using a chopper harvester³, with weights of harvested cane from each plot being measured using a dump wagon fitted with electronic load cells³ (Johnson and Richard, 2005). In Study A, sugarcane was harvested on December 9, 1999 (first ratoon), and December 12, 2000 (second ratoon). No yield data were obtained from the plant-cane crop of Study A as it was excessively lodged and could not be harvested with equipment available at the time (a whole-stalk harvester) without leaving excessive scrap that would have skewed results. In Study B, sugarcane was harvested on December 9, 1999 (plant-

² Teejet Spraying Systems Company, North Avenue, Wheaton, IL 60189-7900

³ CAMECO[®] Industries, Inc., 244 Highway 3266, Thibodaux, Louisiana, 70301-1602

cane), November 28, 2000 (first ratoon), and November 21, 2001 (second ratoon). Samples were collected from each plot using a sampler built into the wagon capable of randomly collecting an approximately 10-kg sample of billets. Billets were crushed using a three-roller mill and expressed juice was analyzed for Brix and pol using a refractometer and saccharimeter, respectively. Theoretically recoverable sugar (TRS) was determined from these analyses using standard methodologies (Chen and Chou, 1993). Sugar yield (kg ha^{-1}) is the product of TRS (kg Mg^{-1}) and cane yield (Mg ha^{-1}).

All data were analyzed using the PROC MIXED procedure in SAS (SAS, 2003). Block x study, block x study x depth of cover, and block x study x depth of cover x herbicide were designated as random factors. Year within crop cycle was analyzed as a repeated measure. Due to interactions with year within a crop cycle, all data were again analyzed separately by crop-year as before without a repeated measure term for year within crop cycle for each crop and without the random term for block x study x depth of cover x herbicide. Means of significant effects ($P > 0.05$) were separated using the PDIFF option along with the Saxton Macro ($P > 0.05$) (Saxton, 1998). Means were averaged across studies when there were no significant interactions.

RESULTS AND DISCUSSION

In the first month following herbicide application to planted sugarcane, there were 3- and 30-mm of rainfall in Study A and Study B, respectively. In the second month there were 60- and 65-mm of rainfall in Study A and Study B, respectively. In the third month there were 107- and 90-mm of rainfall in Study A and Study B, respectively. While Study B was planted later in the year than Study A, the pattern of rainfall following herbicide application to these studies was similar in that the amount of rainfall increased each month with the difference in total rainfall for the three months following herbicide application being only 14-mm greater in Study B than in Study A. The greatest difference is that there was insufficient rainfall in the first month following herbicide application at planting in Study A to move herbicides off of the soil surface into the soil profile and thereby activating their herbicidal properties. It was not until October 19, 1997 (54 days after treatment), when 53-mm of rainfall occurred that these herbicides would have become active. In study B, herbicides were applied to a wet soil surface, which may have activated their herbicidal properties to some extent, however, rainfall did not occur until 22 days after herbicide treatment when 28-mm of rainfall occurred on November 1, 1998.

For visual injury ratings, there was no response to depth of cover at planting and no interaction between depth of cover at planting and herbicides treatment; however, there was a response to herbicide treatment. Due to interactions between study and herbicide treatment, means for Studies A and B are presented separately (Table 1). Clomazone + atrazine caused the greatest visual injury (32 to 59%) at 14 DAT, with azafenidin also causing serious injury (27 to 41%) when compared to the metribuzin standard. Clomazone has previously been shown to cause high levels of visual injury which generally lessen with time (Esqueda, 1999; Richard, 1996). Injury symptoms due to postemergence applications of clomazone are quite visible due to the bleaching of treated leaves. Injury lessened with time, and leaves emerging after applications generally showed little or no signs of injury (data not shown). All other treatments showed low to moderate levels of injury when compared to the metribuzin standard. Injury in these treatments included leaf necrosis and/or stunted growth. Depth of soil coverage at planting did

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not affect visual injury ratings (Table 1). In plant-cane, only pendimethalin + atrazine caused more injury in Study B than in Study A. In the first ratoon, pendimethalin + atrazine, pendimethalin + diuron, and clomazone + atrazine all caused more injury in Study A than in Study B (Table 1). Visual injury ratings are highly dependent on environmental conditions following treatment and can vary from one year to the next. However, the treatment causing the greatest injury each year and in each crop was clomazone + atrazine.

Table 1. The effect of depth of soil covering planted sugarcane on herbicide injury 14 days after spring application^a in plant and first ratoon crops and stalk populations at Vacherie, LA (Studies A and B).

Herbicide treatment (kg ai/ha)	Injury 14 DAT-PC ^b		Injury 14 DAT-FR		Stalk population		
	Study				Crop		
	A	B	A	B	PC ^c	FR	SR
	—————(%)—————				—————1000 stalks ha ⁻¹ —————		
Metribuzin (1.7)	0 eA ^d	0 eA	0 fA	0 eA	208	230 a	195a
Pendimethalin+atrazine (3.4+3.4)	5 eB	12 dA	23 cA	1 eB	193	216 c	189bc
Pendimethalin+diuron (3.4+2.9)	13 dA	18 cdA	14 dA	8 dB	202	225 ab	186bc
Terbacil (1.5)	6 eA	11 dA	4 eA	0 eA	195	227 ab	186bc
Terbacil+pendimethalin (0.9+2.2)	14 dA	10 cdA	3 efB	7 dA	201	225 ab	185c
Terbacil+diuron (0.9+2.9)	28 cA	19 cA	14 dA	15 cA	194	220 bc	189bc
Azafenidin (0.7)	39 bA	41 bA	36 bA	27 bB	198	226 ab	186bc
Clomazone+atrazine (1.7+3.4)	53aA	59 aA	54 aA	32aB	199	219 bc	191ab
PR > F Study	0.4132		0.0011		0.0002 1.000		
PR>F Depth	0.3374		0.6727		0.6484	0.5977	0.1587
PR > F Study*Depth	0.9079		0.6353		0.9283 0.6512		
PR>F Herbicide	<0.0001		<0.0001		0.8418	0.0113	0.0156
PR > F Study*Herbicide	0.0081		<0.0001		0.6791 0.9127		
PR>F Depth*Herbicide	0.0753		0.9825		0.6920	0.2378	0.6324
PR > F Study*Depth*Herbicide	0.7637		0.4031		0.7070 0.1062		

^a Herbicides were fall-applied at planting and again in spring (March or early-April) during each crop.

^b Abbreviations: DAT, days after treatment; PC, plant-cane; FR, first ratoon; SR, second ratoon.

^c PC Means are from Study B only as measurements could not be taken from Study A.

^d Means within rows followed by the same upper case letter and within columns followed by the same lower case letters and means within rows within specified parameters are not significantly different using the Saxton means separation macro of the PDIFF option of the lsmeans statement ($P > 0.05$) in SAS.

Study B was not planted until much later in the fall (October 4) than Study A (August 27). While rainfall in the three months following herbicide application was similar for both studies, this could potentially have led to differences in injury in the plant-cane of Studies A and B. However, differences in injury between these two studies were minor and in all but one case (pendimethalin + atrazine) were similar to those in Study A (Table 1). Therefore, we assume that the later planting date in Study B did not result in greater crop injury.

Stalk height was not affected by herbicide treatment in any of the crop years (data not shown). Number of harvestable stalks was affected by herbicide treatment in the first and second ratoon crops, but not in the plant-cane crop (Table 1). Stalk number was not affected by depth of soil cover planting, and there were no interactions between depth of cover at planting and herbicide. Therefore, data were averaged over depth of planting. In the first ratoon crop, pendimethalin + atrazine (216,000 stalks ha⁻¹), terbacil + diuron (220,000 stalks ha⁻¹), and clomazone + atrazine (219,000 stalks ha⁻¹) all had less stalks ha⁻¹ than the metribuzin treatment (230,000 stalks ha⁻¹). Richard (1996) also reported a reduction in stalk population due to applications of clomazone (2.2 kg ha⁻¹) and terbacil (1.8 kg ha⁻¹). Atrazine has been proven safe in sugarcane at recommended application rates, and stalk population reductions in herbicide mixes were attributed to the herbicide mix-partner rather than to atrazine. In the second ratoon, sugarcane treated with metribuzin had significantly greater numbers of stalks ha⁻¹ (195,000) than all other treatments with the exception of clomazone + atrazine (191,000 stalks ha⁻¹). The treatment with the lowest stalk population was terbacil + pendimethalin (185,000 stalks ha⁻¹), which was similar to all treatments other than metribuzin and clomazone + atrazine.

Pendimethalin is generally considered safe to sugarcane when applied at recommended doses (Richard and Griffin, 1993; Griffin and Lencse, 1992). Pendimethalin is a mitotic inhibitor that inhibits root and shoot development, which may have been responsible for the reduction in stalk population in this study. However, this has not been previously reported. Pendimethalin affects root development causing roots to be short and thick or clubbed (Dissanayake et al., 1998) but is highly immobile in soil (WSSA, 1994). Therefore, it is important that pendimethalin treated zones remain separated from developing sugarcane roots by maintaining adequate soil cover of roots. Current recommendations for the use of pendimethalin do not consider depth of planting; however, a planting depth of 4-cm is recommended for corn when pendimethalin is to be used for weed control (Anonymous, 2006). While 4-cm is less than the soil cover depth used for planting sugarcane (5- to 10-cm) the use rate of pendimethalin in corn (0.6 – 1.7 kg ai ha⁻¹) is also much lower than what is used in sugarcane (2.2 – 3.4 kg ai ha⁻¹) (Anonymous, 2006). The reason that the use rates in sugarcane can be higher is at least partially due to deeper depth of soil cover when planting sugarcane.

Reductions in stalk populations in sugarcane treated with clomazone + atrazine and terbacil + diuron were likely related to herbicide treatments (Table 1). Clomazone injury was primarily due to foliar absorption of this herbicide (both of treated leaves and emerging shoots) as it has low mobility in soil (WSSA, 1994) and would not have leached to a large extent into the root zone. Terbacil is highly mobile in soils, while the mobility of diuron decreases with increases in soil organic matter (Marriage, 1977; Hogue et al., 1981). Therefore, it is likely that these two herbicides would have leached into the sugarcane root zone where they are both readily absorbed.

As mentioned previously, no yield data were obtained for the plant-cane crop of Study A. In the plant-cane crop of Study B, cane and sugar yields and TRS were all reduced (5 Mg ha⁻¹, 1,100 kg sugar ha⁻¹, and 4 kg Mg⁻¹, respectively) when 5-cm of soil was used to cover sugarcane at planting compared with 10-cm of soil (Table 2). When averaged across depth of cover, cane yield was reduced compared to metribuzin by all herbicide treatments except terbacil alone, and

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azafenidin. Sugar yield was reduced compared to the metribuzin treatment only by terbacil + diuron and clomazone + atrazine.

Table 2. The effect of depth of soil cover on planted sugarcane on plant-cane cane and sugar yield and theoretically recoverable sugar (TRS) using various herbicides at Vacherie, LA, 1999 (Study B).

Herbicide treatment (kg ai/ha) ^a	—Cane yield—			—TRS—		—Sugar yield—			
	Depth of coverage								
	5-cm	10-cm	Mean	5-cm	10-cm	5-cm	10-cm	Mean	
	Mg ha ⁻¹			- kg Mg ⁻¹ -		100 kg sugar ha ⁻¹			
Metribuzin (1.7)	124 Aa ^b	127 Aa	125 ab	107	107	147 Aa	152 Aa	150 a	
Pendimethalin+atrazine (3.4+3.4)	118 Aab	121 Aabc	119 b	106	112	139 Aa	151 Aa	145 a	
Pendimethalin+diuron (3.4+2.9)	118 Aab	120 Abc	119 b	105	113	138 Aab	151 Aa	145 a	
Terbacil (1.5)	115 Bb	127 Aa	121 ab	97	109	125 Bb	155 Aa	140 abc	
Terbacil+pendimethalin (0.9+2.2)	117 Aab	119 Abc	118 bc	110	110	144 Aa	146 Aa	145 a	
Terbacil+diuron (0.9+2.9)	107 Bc	116 Ac	112 d	104	111	125 Bb	144 Aa	134 bc	
Azafenidin (0.7)	118 Bab	126 Aab	122 ab	108	106	142 Aa	150 Aa	146 a	
Clomazone+atrazine (1.7+3.4)	114 Abc	114 Ac	114 cd	104	104	133 Aab	132 Aa	133 c	
Mean	116 B	121 A		105B	109A	137 B	148 A		
PR>F Depth		0.0006			0.0243		0.0039		
PR>F Herbicide		0.0002			0.2436		0.0246		
PR>F Depth*Herbicide		0.2187			0.2637		0.0891		

^a Herbicides were applied sequentially; initially at planting (Oct 9, 1998), and subsequently on March 10, 1999.

^b Means within rows followed by the same upper case letter and within columns followed by the same lower case letters and means within rows within specified parameters are not significantly different using the Saxton means separation macro of the PDIFF option of the lsmeans statement ($P > 0.05$) in SAS.

While interactions between depth of cover at planting and herbicides were not significant, slicing of the data into simple effects to provide F-tests for means within main effects revealed significant differences ($P > 0.05$) in cane yield due to herbicides within both depths of cover and sugar yield within the 5 cm depth of cover, as well as significant differences in cane yield response to depth of cover at planting within several herbicide treatments. At the 5-cm depth, compared to the metribuzin treatment, cane yield was reduced by terbacil, terbacil + diuron, and clomazone + atrazine, and sugar yield was reduced by terbacil and terbacil + diuron, while at the 10-cm depth cane yield was reduced by pendimethalin + diuron, terbacil + pendimethalin, terbacil + diuron, and clomazone + atrazine (Table 2). Sugarcane covered with 5-cm of soil at

planting had lower cane yields when terbacil (9 Mg ha⁻¹ less), terbacil + diuron (17 Mg ha⁻¹ less), or azafenidin (6 Mg ha⁻¹ less) were applied compared to equivalent treatments covered with 10-cm of soil. Sugar yield was significantly reduced comparing 5- with 10-cm of soil cover at planting when terbacil (3000 kg ha⁻¹ less) and terbacil + diuron (1900 kg ha⁻¹ less) were applied, and was numerically less in five of the six other herbicide treatments (Table 2).

In the first ratoon crop, there were significant interactions between depth of cover at planting and herbicide treatment for sugar and cane yields, and TRS (Table 3). When terbacil was applied to sugarcane covered with 5-cm of soil at planting there was a reduction in cane (13 t ha⁻¹) and sugar (2000 kg ha⁻¹) yields compared with sugarcane covered with 10-cm of soil. There was also a reduction of 1400 kg sugar ha⁻¹ when pendimethalin + diuron were applied to sugarcane covered with 5-cm compared with 10-cm of soil. TRS was significantly reduced in the pendimethalin + diuron (10 kg Mg⁻¹ less) and azafenidin (7 kg Mg⁻¹ less) treatments compared to similar treatments covered with 10-cm of soil. At the 5-cm depth of cover at planting, only terbacil + diuron (124 Mg ha⁻¹) reduced cane yield compared to metribuzin (129 Mg ha⁻¹). At the 10-cm depth, only azafenidin (124 Mg ha⁻¹) yielded less than metribuzin (133 Mg ha⁻¹). When sugarcane was covered with 5-cm of soil, terbacil, terbacil + diuron, and azafenidin yielded less (each at 137 kg sugar ha⁻¹) than the metribuzin treatment (148 kg sugar ha⁻¹). With 10-cm of soil cover, the pendimethalin + atrazine (143 kg sugar ha⁻¹) and clomazone + atrazine (142 kg sugar ha⁻¹) treatments both had lower cane yields than the metribuzin treatment (154 kg sugar ha⁻¹).

Table 3. The effect of depth of soil covering planted sugarcane on first ratoon cane and sugar yield and theoretically recoverable sugar (TRS) using various herbicides at Vacherie, LA (Studies A and B).

Herbicide treatment (kg ai/ha) ^a	Cane yield		TRS		Sugar yield	
	Depth of coverage					
	5-cm	10-cm	5-cm	10-cm	5-cm	10-cm
	Mg ha ⁻¹		kg Mg ⁻¹		-100 kg sugar ha ⁻¹	
Metribuzin (1.7)	129 Abc ^b	133 Aab	114 Aab	117 Aab	148 Aab	154 Aab
Pendimethalin+atrazine (3.4+3.4)	130 Ab	130 Abc	109 Ab	110 Ac	144 Aabc	143 Ac
Pendimethalin+diuron (3.4+2.9)	129 Abcd	133 Aab	108 Bb	118 Aa	140 Bbc	154 Aab
Terbacil (1.5)	125 Bcd	138 Aa	110 Ab	115 Aabc	137 Bc	157 Aa
Terbacil+pendimethalin (0.9+2.2)	137 Aa	133 Aab	112 Aab	114 Aabc	154 Aa	152 Aabc
Terbacil+diuron (0.9+2.9)	124 Ad	126 Abc	111 Aab	117 Aab	137 Ac	148 Aabc
Azafenidin (0.7)	126 Abc	124 Ac	109 Bb	116 Aabc	137 Ac	144 Abc
Clomazone+atrazine (1.7+3.4)	125 Acd	129 Abc	117 Aa	111 Abc	146 Aabc	142 Ac
PR > F Study	0.0043		0.0115		0.0039	
PR > F Depth	0.1498		0.0995		0.0993	
PR > F Study*Depth	0.8523		0.7206		0.6142	
PR > F Herbicide	<0.0001		0.2774		0.0202	
PR > F Study*Herbicide	0.0044		0.2853		0.3236	
PR > F Depth*Herbicide	0.0071		0.0353		0.0190	
PR > F Study*Depth*Herbicide	0.0505		0.3996		0.2907	

^a Herbicides were applied on March 10, 1999 (Study A) and March 24, 2000 (Study B).

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^b Means within rows followed by the same upper case letter and means within columns followed by the same lower case letter are not significantly different using the Saxton means separation macro of the PDIFF option of the lsmeans statement ($P > 0.05$) in SAS.

In the second ratoon crop, cane yields, averaged across depth of soil cover at planting, were lower when sugarcane was treated with pendimethalin + diuron (7 Mg ha⁻¹ less), clomazone + atrazine (7 Mg ha⁻¹ less), or azafenidin (6 Mg ha⁻¹ less) compared to sugarcane treated with metribuzin (Table 4). There were no significant differences in TRS or sugar yield, and there were no significant difference due to depth of soil cover at planting. Lack of response in the second ratoon to depth of soil cover at planting is probably related to the depth of sugarcane roots and underground shoots becoming more similar as years progressed due to conventional tillage practices used in this study, which deposited some soil onto the row top each year during the layby cultivations.

Table 4. The effect of depth of soil covering planted sugarcane on second ratoon cane and sugar yield and theoretically recoverable sugar (TRS) using various herbicides at Vacherie, LA (Studies A and B).

Herbicide treatment (kg ai/ha) ^a	Cane yield			TRS			Sugar yield		
	5-cm	10-cm	Mean	5-cm	10-cm	Mean	5-cm	10-cm	Mean
	Mg ha ⁻¹			kg Mg ⁻¹			-100 kg sugar ha ⁻¹		
Metribuzin (1.7)	119	116	117 a	103	103	125	147	147	146
Pendimethalin+atrazine (3.4+3.4)	116	112	114 ab	105	104	127	148	142	145
Pendimethalin+diuron (3.4+2.9)	110	112	110 b	104	109	130	138	148	143
Terbacil (1.5)	114	116	116 ab	107	105	129	149	148	147
Terbacil+pendimethalin (0.9+2.2)	114	112	113 ab	104	110	130	143	148	149
Terbacil+diuron (0.9+2.9)	116	116	117 a	103	104	126	147	149	146
Azafenidin (0.7)	112	112	111 b	106	105	128	142	141	142
Clomazone+atrazine (1.7+3.4)	110	112	110 b	104	106	127	137	144	140
Mean	114	114		105	106		143	146	
PR > F Study		0.0008			0.2652			0.0038	
PR > F Depth		0.8614			0.2956			0.6745	
PR > F Study*Depth		0.1990			0.7033			0.3938	
PR > F Herbicide		0.0162			0.5913			0.5673	
PR > F Study*Herbicide		0.7210			0.9845			0.5995	
PR > F Depth*Herbicide		0.9121			0.5982			0.6943	
PR > F Study*Depth*Herbicide		0.1544			0.7844			0.8930	

^a Herbicides were applied on March 24, 2000 (Study A) and April 4, 2001 (Study B).

^b Means within columns followed by the same letter are not significantly different using the Saxton means separation macro of the PDIFF option of the lsmeans statement ($P > 0.05$) in SAS.

While sugarcane response to depth of soil cover at planting was affected by herbicides such as terbacil, azafenidin, and combinations of diuron with terbacil and pendimethalin, it was not affected by the herbicide treatment that gave the greatest visual injury response, clomazone + atrazine. Clomazone tends to be moderately absorbed to soil particles and thus has low mobility in sandy loam, silt loam, and clay loam soils. In this study, it is likely that most of the injury to

the sugarcane was caused by foliar absorption of clomazone with little reaching the root zone. Hence, deeper soil cover would not be expected to prevent injury when using this herbicide.

Terbacil applied alone and in combination with diuron reduced sugar yields in both the plant-cane and first ratoon crops when sugarcane was covered with 5-cm of soil, but not when sugarcane was covered with 10-cm of soil at planting compared to sugarcane treated with metribuzin. Herbicides with high soil mobility such as terbacil (Hogue et al., 1981; Marriage et al., 1977) and moderate mobility such as diuron (Hogue et al., 1981) would be more likely to leach into the root zone of shallow-planted sugarcane than less soil mobile herbicides, such as clomazone and pendimethalin. Shallow soil cover at planting could increase injury resulting in yield losses when using soil-mobile herbicides with known potential to injure sugarcane (Millhollon, 1975). The mobility of metribuzin is dependent on soil type. Metribuzin is highly mobile in sandy soils with low organic matter, but is readily adsorbed to clay and organic matter (Savage, 1976). Although metribuzin is readily absorbed by sugarcane roots, it is rapidly metabolized into non-phytotoxic metabolites (Hilton et al., 1974) and thus does not injure sugarcane at recommended use rates.

The purpose of reducing planting depth would be to promote earlier shoot emergence and increased fall growth following planting, in hopes of producing higher yields. This study does not support the hypothesis of higher yields due to reduced planting depth. In no case was there an increase in any of the yield components due to reducing soil cover at planting. During the plant-cane season, yield components were reduced by adopting a shallower coverage at planting. In the first ratoon crop, certain herbicides again caused significant yield reductions when sugarcane was covered with 5- compared with 10-cm of soil. There were no significant differences due to depth of cover in the second ratoon crop. Perhaps depth of coverage would have influenced yields in the second ratoon crop if there would have been a deep frost during the crop cycle.

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