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HIGH-GROWTH SUGARCANE AS AN ORGANIC CONTROL SYSTEM FOR WEEDS AND SOIL EROSION

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ABSTRACT

Certain Saccharum forms managed as high-growth systems produce multiple salable products in addition to sugar and fermentable solids. Aside from these are organic residues amounting to some 8-18 tons air-dry matter per acre year. Since 1987, studies in Puerto Rico have indicated highly favorable potentials of these residues as control systems for weeds and seedbed erosion. Chemical weed control, together with its costs, soil compaction and potential contamination, is deferred entirely beyond month 4 of the plant crop. Erosion of ratoon-crop seedbeds is essentially eliminated. Longer-term benefits are under investigation, including nutrient and organic matter reincorporation into soils, and deferment of conventional replanting and crop-rotation operations thru periodic reincorporation of an entire cane crop. Such residues also indicate promise as inexpensive compost for food-crop seedbeds. Aside from their technical and economic benefits, the production and on-farm application of such materials is consistent with environmental and conservation interests that are increasingly affecting U.S. agriculture. The work since 1987 is presented in overview with the aid of color slides.

INTRODUCTION

Since the mid-1980's, sugarcane has been studied in Puerto Rico as a "high-growth" system offering new opportunities for survival as an economic farm commodity (Alexander, 1989a,b; 1990a; 1984; 1990b). Cane that is botanically oriented to growth has evidenced remarkable potentials for survival, productivity, and resource conservation that were underappreciated or unknown in historic sugar planting (Alexander, 1989b, 1990b; 1986-87, 1987-88). Particularly notable are botanic aptitudes for self-sufficiency with minimal human intervention and environmental disturbance (Taylor, 1990; Zarley, 1989).

Such features have increasingly special meaning in the context of new challenges to sugarcane and to tropical agriculture in the late twentieth century. High costs of farming alone would dictate drastic economies of purchased production inputs (Alexander, 1989b; Halas-Steel, 1989). But in addition to these are powerful pressures for change from environment- and conservation-oriented legislation (Taylor, 1990; Zarley, 1989; Shellenbarger, 1989; Flynn, 1988; Halas-Steel, 1989). These derive from mainstream valid concerns for preservation of atmosphere and water quality, and the conservation of land, soils, water, and wildlife. Peripheral interests are actually opposed to farm and forest industry in their concern for land and wildlife preservation (Mooney, 1989; Christensen, 1990; Anon., 1989). Some activists would restore productive "wetlands" to their pristine state as wildlife preserves, irrespective of the impact on farming and consumers (Anon., 1989; Pankowski, 1989). At the very least, farmers in the new decade will be pressured to produce more with less land, less water, less energy, and restrained use of chemical fertilizers and pesticides (Halas-Steel, 1989; Smith, 1989; Anon., 1981; Anon., 1989; Smith, 1990; Brandes, et al., 1936).

The massive organic matter yields of high-growth sugarcane has favorable implications for its economic planting as a dual sugar and conservation commodity. The nature and applications of such materials are described herein and illustrated with color slides in the public presentation.

SUGARCANE AS A GROWTH SYSTEM

1. Origin And History For Sugar

The genus Saccharum appears to bear an enormous but largely unexplored potential for growth, and for survival as a growth-oriented system. In correct botanic context its sugar is a source of carbon and energy to sustain growth processes. Authoritative studies on sugarcane's extant wild species noted the high-growth aptitude (Brandes, et al, 1936, 1947; Brander, 1956; Grassl, 1967; Arceneaux, 1967). However, greater attention was directed to its species taxonomy, relationships to related tropical grasses, prehistoric introgression, and evolution of a remarkable aptitude for sugar accumulation. Prehistoric aborigines appear to have recognized its growth capabilities as early as 20,000 B.C., utilizing wild canes for construction purposes (Brandes et al., 1936; Brandes, 1956). The perceptively high sugar contents of select S. officinarun forms were appreciated as well (Brandes, 1956; Arceneaux, 1967). This feature possibly contributed to the competitive survival of sugarcane among other wild plant forms (Bull et al., 1963). By the fourth century B.C., cane sugar planting was a well-established practice in the Indus Valley of India (Irvine, 1981). Sugarcane was a marginal sugar crop in southern Europe by the twelfth century. It was brought to the Caribbean area by Columbus in 1493 (Deere, 1911).

2. Sugar System vs. Growth System Features

Internode expansion is the quantitatively-dominant growth activity in sugarcane (Van Dilliwijn, 1952; Alexander, 1973).

approximately 26 to 30 internodes (joints) are formed per stem in a 12-month interval. In primitive Saccharum forms the expanded internodes are typically long and thin (Figure 1). The sugar-oriented canes of commerce have thickened internodes that function as vehicles for sugar storage. The most authentic cane growth system studied in Puerto Rico, the S. spontaneum hybrid US 67-22-2, combines expansive internode elongation and thickening in a powerful growth surge of comparatively brief duration (Alexander, 1990a).

Plotted graphically (Figure 2), the stem profile of a sugar-oriented variety prescribes a plateau of intermediate-length internodes. These are forced over a time-course of 10 to 12 months. Alternatively, a growth oriented cultivar such as US 67-22-2 produces remarkably-elongated internodes in an early growth surge that is essentially completed within 5 to 6 months (Figure 2). The stem internode profile does not form a plateau; rather, it depicts a botanic characteristic to slacken early a stem's initial elongation, while the crown continues with production of newer stems within the same stool complex (Alexander, 1990a; 1986-87, 1987-88).

Relative to sugar-forming potentials, our interpretation is that sugar- and growth-oriented canes have at least comparable photosynthetic capabilities. A high growth system such as US 67-22-2 could be a superior sugar producer by virtue of its large numbers of green-leaf ranks (Alexander, 1989b,c). However, proportionately more sugar is thought to be utilized in sustaining its high-growth processes.

High-growth features have been observed in cultivar US 67-22-2 since 1984. They were compared directly with select P.R. hybrid sugarcanes in a 3-year study from 1986 to 1989 (Alexander, 1986-87, 1987-88; 1990c). Typical differences between a growth system (US 67-22-2) and a sugar system (P.R. 57-13-55) are presented in Table 1. Features of special significance include whole-plant yields per acre, stems per acre, root profile expansion, green-leaf ranks, moisture stress tolerance, and residual trash yields. Residual trash offers immediate benefits in weed control and conservation of soil and water.

Growth System Benefits

1. Weed Control With Trash

Cultivar US 67-22-2 produces exceptionally large quantities of foliar "trash" as a function of its deep, expansive canopy. By month 12, a layer of field-dry leaf and leaf-sheath tissues occupies the inter-row and intra-row space to a depth of 18-30 inches. During harvest activities this material forms a contiguous matt some 8-12 inches thick covering the entire field surface (Figure 3). During the 1970's and early 1980's our intent was to bale and remove such materials as a component of the total cane biomass harvest (Alexander, 1985; Alexander, et al., 1982). Its comparatively clean, dry, and compactable condition encouraged such views. In recent years it has found a more useful and economic role as a biodegradable surface matt left in the field (Alexander, 1989a,c).

The newly-formed trash matt is materially heavier than that of conventional sugarcane. However it is readily penetrated by ratoon regrowth within 2-5 weeks. Overhead canopy closure is complete within about 16 weeks (Figure 4). Weed species, both broadleaf and grasses, are severely repressed (Table 2). The few weeds that survive are delayed or weakened and further constrained by canopy shading.

For US 67-22-2 ratoon crops, correctly managed, the use of herbicides has become an anachronism (Alexander, 1986-87, 1987-88). Benefits of weed control with cane organic matts include the following:

- Costs of chemicals and fuels are avoided
- Costs of chemicals administration are avoided
- Costs of trash collection, transport and storage are avoided
- Groundwater contamination is avoided
- Crown destruction ("Cultivar Blight") is avoided
- Seedbed compaction is avoided
- Conservation of moisture, minerals, organic matter
- Compatibility with compliance farming precepts

Such benefits are consistent with the botanic aptitudes of high-growth sugarcane. They are further consistent with the grower's need to economize his operations (Alexander, 1989b; 1986-87, 1987-88), and to comply with environment-oriented legislation (Taylor, 1990; Zarley, 1989; Anon., 1989; Smith, 1990).

2. Erosion Control

An important benefit of uncollected trash matts has been their curtailment of seedbed erosion (Alexander, 1986-87, 1987-88). A potential for major soil loss is created in the seedbed preparation for high-growth cane, particularly by use of a deeply-set land rotavator. This implement produces a pulverized, friable soil condition ideal for plant germination and root-zone establishment, but the soil is rendered vulnerable to wash-off during periods of heavy rainfall, flooding runoff, and irrigation. Such erosion potentials would remain for several crop years when trash is removed from the seedbed surface.

Some advocates of seedbed rotavation regard this practice as a justified risk. Soil losses via the Santa Rosa drainage system were severe in plant-crop years. However, wash-off losses were reduced to nil when the trash matts were left in the field. Both rain and irrigation water pass rapidly through this material but emerge in a clear state with no suspended soil (Alexander, 1989a; 1986-87, 1987-88).

An indication of the degree of soil stabilization by residual trash is seen in the annual cleaning costs of the Santa Rosa drainage system (Table 3). Major improvements in the farm's ditches were accomplished in 1984-86, employing supervised labor with minimal disturbance of newly-established cane plantings (Figure 5). Soil loss via these drains was nonetheless extensive thru the plant-crop year. Significant costs were incurred to keep them functional. By 1990 the cleaning costs were lowered to about 6 percent of original levels by the presence of cane trash matts (Table 3). The costs at present are mainly for removal of leaves and dead-grass debris -- a less serious factor than soil run-off losses.

3. Water and Nutrients Conservation

(a) <u>Canopy Closure ("Twilight Zone")</u>: An important feature of high-growth cane is its ability to conserve surface moisture beneath a dense overhead canopy. Our experience has been that a botanic "twilight zone" is created that virtually excludes light and air movement and perceptively retards evaporation (Figure 5). This is particularly true in extended-longevity crops of 18 months or more duration (Alexander, 1986-87, 1987-88). The moisture content of subtending trash is consistently higher at harvest than that of conventional sugar crops. Evidence of the higher humidity and trash dampness was demonstrated in a 1988 dry period when fires set by vandals failed to burn the high-tonnage stands.

(b) <u>Trash Residue Matts</u>: A contribution of the high-tonnage residue matts to moisture conservation is clearly evident but difficult to measure. The severe cracking (fissuring) of clean interrow surfaces in dry periods does not develop beneath the matted-trash layer. Alternatively, the presence of such residues has not impeded the flow velocity of surface irrigation water. Water administered by surface flooding, on seedbed surfaces originally leveled and land-planned, maintained an intended flow velocity of 600 to 800 feet per hour. As noted above, both irrigation and rain water emerging from the matts is essentially free of soil sediment. Moisture absorbed by the matts from passing irrigation water and rainfall can be estimated from changing moisture-percentage values when the air-dry tonnage of trash residue is known (Alexander, 1986-87, 1987-88). The retained moisture at 24 hours post-irrigation has been estimated in the order of 4.5 to 7.0 tons per acre (roughly 1,100 to 1,800 gallons per acre).

(c) <u>Root Profile Efficiency</u>: A remarkable feature of high-growth cultivar US 67-22-2 is an expansive root profile.

Both vertical and lateral development materially exceeds that of a commercial sugar hybrid such as P.R. 67-13-55 (Table 4). Perennial roots extend to a depth of at least 5-6 feet, and easily penetrate at least four soil Series layered one above the other. The accessibility thus afforded to permanent subsoil moisture probably contributes to the low-moisture stress tolerance of US 67-22-2 (Figure 6). Similarly, such elaboration of the root profile is thought to assist productivity under constrained fertilization regimes (Alexander, 1989d), and to minimize recumbency (lodging) in mature crop stands (Alexander, 1990a).

4. Deferred Replanting and Crop Rotation

The high-growth cultivar US 67-22-2 has displayed a remarkable aptitude for survival (Alexander, 1986-87, 1987-88; 1989a). The botanic mechanism is self-renewal via underground expansion of an original parent crown (Figure 7). Given correct management, it is thought that an established planting could remain productive without need of replanting for at least 10 years (Alexander, 1989a).

Such deferment of replanting costs has highly-favorable implications for economic cane planting (Alexander, 1989b). It is further consistent with conservation precepts of low-till agriculture and minimized human intervention in crops production (Anon., 1981, 1989; Smith, 1990). Alternatively, the deferment of replanting and crop rotation is also a deferment of opportunities for reconditioning of soils and their replenishment with organic matter and minerals (Alexander, 1989a,c), a new challenge to cane planting. It has been suggested that periodic reincorporation of an entire cane crop would comply with seedbed needs while conserving land, soils, water and production costs (Alexander, 1989a,b,c). Studies with US 67-22-2 in 1988 and 1989 have established the feasibility of whole-crop reincorporation. Up to 135 tons of whole cane per acre have been reincorporated effectively without injury to the established crowns or emerging ratoon growth (Figure 8).

5. Whole-cane Mulches

Correctly managed, high-growth cane routinely yields over 90 tons of green organic matter per acre year. Its post harvest residues alone are in the order of 8 to 18 tons of air-dry materials. Organic matter production at this level of magnitude is rarely accomplished with agricultural commodities. Its potential as an inexpensive source of organic mulches, for alternative farm crops or soil surfaces conservation, is therefore of special interest. Composting trials were performed with field-chopped whole stands of US 67-22-2 in 1987-88. The harvest, stacking, and partial breakdown of the chopped whole cane was accomplished with notable ease and at low cost (Figure 9). The mature cane stems posed no special problems in field chopping or in postharvest behavior within its stack.

Table 1

PERFORMANCE OF HIGH-GROWTH CULTIVAR US 67-22-2 AND THE SUGAR HYBRID P. R. 67-13-55: 1987-1989

Growth Parameter[a]	Mean Value (3-Crop Ave.) For Cane— US 67-22-2	P.R. 67-13-55
1. Whole Plant Yield (Tons/A)	113.4	65.8
2. Stems/Acre[b]	58,430	31,303
3. Stem Wt. (lbs.)	3.47	3.63
4. Stem Length (ft)	9.73	7.62
5. Joints/Stem	24.97	27.51
6. Joint Length (in)	4.68	3.54
7. Green-Leaf Ranks[c]	12.40	6.59
8. Top/Stem Ratio	0.40	0.23
9. % O.D. Matter	26.40	27.08
10. % Recumbency	7.5	27.0
11. % Tasseling	85.0	0
12. Trash (Tons/Acre)[d]	8.7	4.7
13. Rendiment[e]	8.24	9.26

[a] Month 12, manually harvested. [b] Postharvest stubble counts.
[c] 80% or more unblemished blade surface. [d] Oven-dry. [e] 1988-89 crop.

Table 2

WEED SUPPRESSION BY MATTED SUGARCANE TRASH[a b]

Treatment	Weeds/A, For Species— Broadleaf	Grasses	Total
Control	7,740	31,460	39,200
Trash	2,432	2,240	4,672
% Suppression :	68.6	92.9	88.1

[a] US 67-22-2, first ratoon, week 7.
[b] Reproduced from reference (1).

Table 3

SEDIMENTATION REMOVAL COSTS: 1986-1990[a]

Crop Year	Soil Removal By Hired Labor— Man-Days	Cost ($US)
1986-87	36.0	1,080.00
1987-88	5.5	165.00
1988-89	3.5	105.00
1989-90[b]	2.5	75.00

[a] Hacienda Santa Rosa drains for 25 acres.
[b] Up to Hurricane "Hugo" (Sept. 19, 1990)

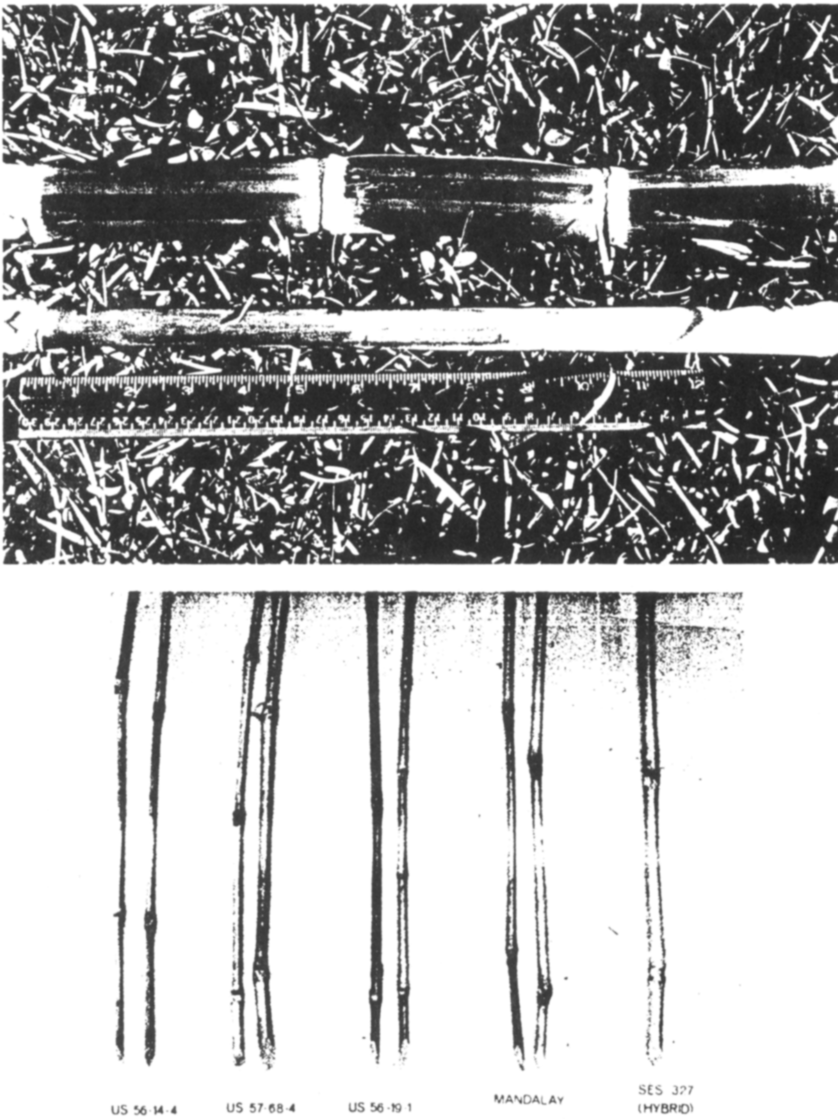
Table 4

ROOT EXPANSION PROFILES: US 67-22-2 AND PR 67-1355[a]

Cane	Maximum Expansion (Inches)— Vertical[b]	Lateral	Root Mass[c]	Soil Series Penetrated
US 67-22-2	60	32	18	4-5
PR 67-13-55	24	21	10	1-2
PR Variance:	-36	-11	- 8	-3

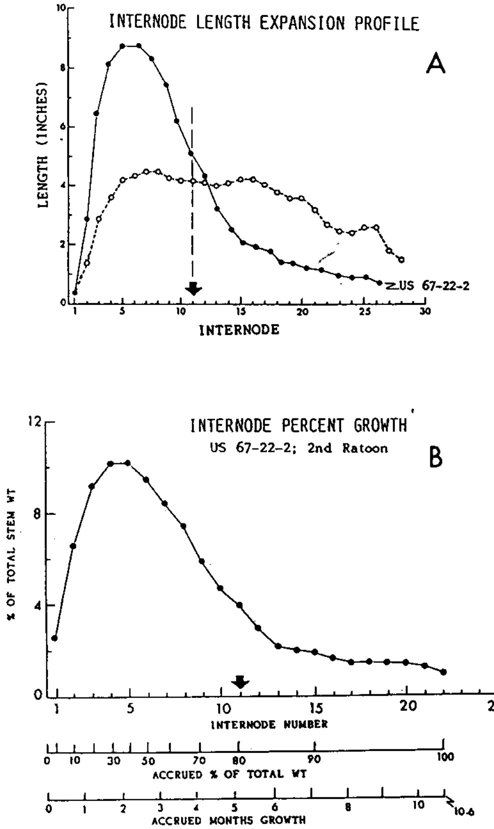
[a] First ratoon crops. [b] Leading primary roots.
[c] Zone of visible concentration, approximate vertical limit.

Figure 1



Prominent growth features in a "wild" Saccharum species, including thin, highly-elongated internodes.

Figure 2



Internode-expansion profiles for the high-growth cultivar US 67-22-2, and the commercial sugar hybrid P.R. 67-13-55 (A). Graphic depiction of "internode-percent growth" in US 67-22-2, with a single early growth surge largely completed within the first 11 to 13 internodes (B).

Figure 3

Manual harvest of cultivar US 67-22-2, with foliar "trash" deposited as a protective surface matt during the cutting and loading processes.

Figure 4

Postharvest weed control by surface foliar trash, cultivar US 67-22-2, second ratoon crop.

Figure 5

Cross-section of US 67-22-2, gran-cultura crop, illustrating a damp, trash-covered and light-restricted "twilight zone" at the seedbed surface and immediately above.

Figure 6

Growth performance under moisture stress of high-growth cultivar US 67-22-2 (left) and commercial sugar hybrid P.R. 67-13-55 (right). First-ratoon crop.

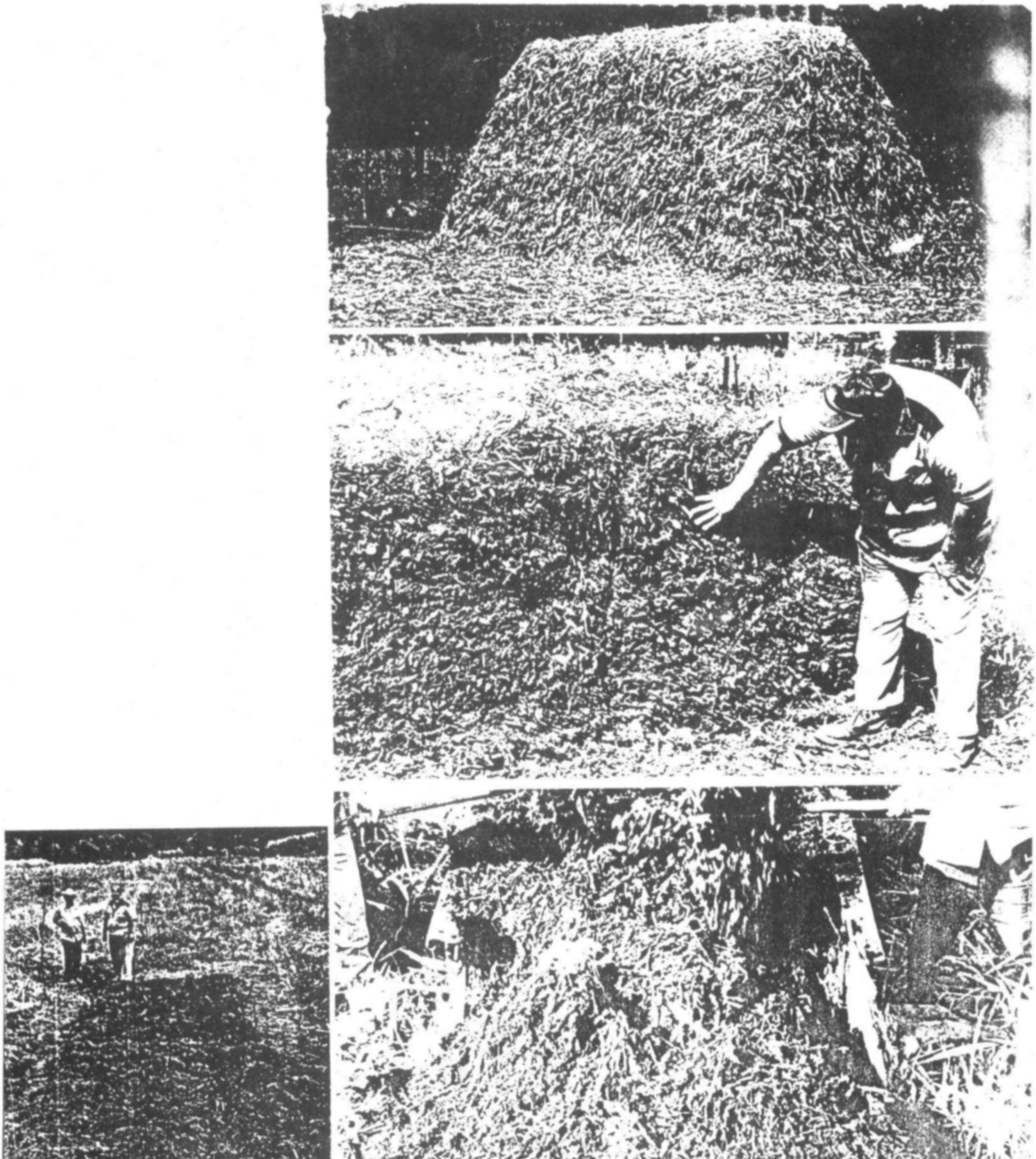
Figure 7

Shoot regrowth in the ninth ratoon crop of cultivar US 67-22-2, depicting proliferated crown development by underground expansion (inset) over an extended time-course.

Figure 8

Reincorporation of an entire crop of US 67-22-2, with penetration of the heavy biomass cover by ratoon-crop shoots, plus eventual canopy closure by highly-vigorous new plants.

Figure 9



Compost production from field-chopped whole cane plants, cultivar US 67

Stacking was by necessity performed manually but the materials were well suited for mechanical transport, off-loading, piling, and compaction. Considerable settling or self-compaction occurred over a time-course of about 4-6 months owing to biological processes within the stack. Internal heating was notable but not excessive, and no off-odors were produced. There were faint odors akin to those of raw sugar and molasses.

The final compost product was also easily manageable in stack removal and loading, and in off-loading and distribution on seedbed surfaces. The quantities needed for a given crop or application remain to be determined. It appears to have significant potential as an inexpensive organic substitute for non-biodegradable plastic mulches.

CONCLUSIONS ON HIGH-GROWTH CANE

1. Economic Compatibility

As recently as the early 1980's, the author felt that high production costs per acre were justified so long as yields were commensurately high (Alexander, 1985; Alexander et al., 1982). It now appears that respectably-high yields are possible thru attentive management of native Saccharum hardiness. Botanic features such as high growth propensity, self-renewal, moisture-stress tolerance, and root zone efficiencies are all in close alliance with the grower seeking to reduce his farming costs. Moreover, organic residue management concerns, incident to insufficient supply, irregular supply, and USDA-SCS conservation plan compliance, would be simplified materially with high-growth cane (Anon., 1988; Jewell, 1975; Smith, 1990).

2. Environmental Compatibility

The intensive input expenditures of a decade ago are similarly too costly in terms of modern environmental and conservationist precepts. Yet, a high-growth cane that displays a massive green canopy (for CO_2 consumption and O_2 emission), high trash yields for weed repression and erosion control, and sustains itself well without much need of men and machines, is in equally close alliance with environment and conservation interests.

Future sugarcane management thus inherits a dual function: First, the preservative of sugarcane an an economic farm commodity, and second, to incorporate new products and benefits for the environment not previously recognized in cane sugar planting.

3. Generic Basis of "High Growth" Cane

The growth-oriented cane herein described is a not a form of the "energy cane" described some years ago in Puerto Rico

(Alexander, 1985; Alexander et al., 1982). The energy cane consisted of commercial sugarcane hybrids, bred and selected for their sugar-planting attributes, but managed for maximum growth. Cultivar US 67-22-2 is botanically oriented for growth in its own right. It is not a new "type" of sugarcane. Rather, it appears to combine in one cultivar numerous growth aptitudes always present in *Saccharum* but underappreciated in historic sugar planting.

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