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THE LONG-TERM AGRICULTURAL IMPLICATION OF CANE-GROWING[1]

by

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EXPLANATORY NOTES

Numbers in parentheses refer to the corresponding numbers in the reference list at the end of the paper.

LIST OF ABBREVIATIONS

ha	hectare
fed	feddan
m	meter
ft	foot
dm	decimeter
cm	centimeter
mm	millimeter
kg	kilogram
lb	librium
gm	gram
mg	milligram
ppm	part per million
wt	weight
hr	hour
min	minute
cu	cubic
mequiv	milliequivalent
meq	milliequivalent
avail	available
Ec	electrical conductivity
mmhos	millimhos
T.C.A.	tons of cane/acre
rat	ratoon
SA	sulphate of ammonia
BOD	biological oxygen demand
TVD	top visible dewlap
C	carbon
N	nitrogen
P	phosphorus
K	potassium
Ca	calcium
Mg	magnesium
Fe	iron
Zn	zink
B	boron
Mo	molybdenum
Al	alluminum
F	fluore
Rb	rubidium

INTRODUCTION

The long-term cropping of sugarcane is practiced in various regions of the world for economical and/or farming reasons. For instance, where it is rated as a high cash crop. The system may be also dictated from the pressure of population and/or the shortage of available land, associated with an increased demand on sugar.

Sugarcane is a heavy feeding plant. According to Van Dillewijn (44) 2.8 lb N, 1.7 lb P_2O_5, 10.5 lb K_2O, 2.3 lb CaO, and 1.6 lb MgO are the average amount of nutrients found in the whole aerial part of the plant per ton of millable cane. It is also a high water consuming crop. To attain good yields the crop requires a total rainfall of 2.0 to 2.25 m distributed over the growing period. With surface irrigation the total water required for plant cane ranges from 2.75 to 3.0 m during a growing period of 12 to 14 months, and from 2.25 to 2.75 m for ratoons during a period of 10 to 12 months.

Securing the cane crop with its needs for active and vigorous growth, notably when continuously cropped deserves special attention. Better results and appreciable consistant returns are achieved when adopting an efficient and flexible farming policy.

The characteristics, limitations, agricultural implication of planting sugarcane consecutively and some culture practices adopted in various sugar producing regions will be discussed in the following pages.

I. THE LONG TERM CANE CROPPING

The choice between a classical crop rotation system based on conventional bases, and the continual cane cropping with scheduled intercepted fallow periods depends on various attributes. Moreover the length of such rest periods, and their beneficial effects vary from a specific cane growing region to another.

Wherever cane is consecutively cropped, a rest period should be intercepted between subsequent crop cycles. The length of such a period differs according to the environment. In sub-tropical regions like Egypt it is almost six months long, the period between cutting the last ratoon in the cycle and replanting cane during the Fall. In other regions such as Sudan, where enough land for planting cane is available, the resting periods may be longer. With longer rest periods the acreage devoted to cane will increase. A limiting factor for such increase will be the available cane haulage facilities and expenses.

The length of each crop cycle and the policies adopted during the rest periods coupled with additional culture practices performed during cane growth deserve special consideration. The net gains of all these needed efforts are to maintain cane and sugar yielda within acceptable margins, taking into consideration an anticipated rate for yields variations due mainly to changing environments such as climate. Such a policy is needed to support a rational sugar production established to meet the local needs and a surplus when possible for exportation.

Judicious financial studies are indispensable when taking such decisions as crop age at harvest and the length of the crop cycle, etc... For instance, they got, in Hawaii a two-year crop, because there cane pays since it yields more heavily at the end of a longer life (Table 1). Whereas in Louisiana due to the cold winter and frost incidence, they got a 10 to 14 months cane crop.

Table 1. Plant age, cane and sugar yields in Hawaii-Barnes(8)

Age of cane months	Cane yield tons/ha	% recovery of 96% sugar	Sugar yield tons/ha	kg sugar/ month
16	137.5	11.5	15.8	40
24	200.0	11.5	23.0	38

In many instances continual cane cropping is the rule, since total yields are greatest. Nona had reported that increases following the rest periods could make up for absence of years of cane cropping. This situation is mostly serious in certain countries like Egypt, India, Taiwan, etc.., where available land for agriculture is lacking. Yet, it should be emphasized that the long term system needs improved culture practices to maintain the soil productivity at acceptable rates.

To maintain soil productivity at a desired level it is necessary to compensate the soil of the quantities of nutrients removed by the growing canes, provided that they are not found in excess; and restitute its organic matter reserves which are needed for adequate soil aeration, increased amounts and ratios of available nutrients, and improved plant-soil-water relations.

The data obtained on the long term cane cropping system, its characteristics, the circumstantial variations in cane and sugar yields, and the concomitant desired culture practices to maintain soil productivity at an acceptable level are quite abundant. The possibility of just enumerating these various studies is beyond the scope of the present paper.

A logical solution is to review the results of some specific and important studies, given here as examples, and to discuss some technical aspects of the cultural practices performed here and there.

Joshi et al (29) - Tables (2 & 3)

They claimed that whether compost was given or not, the long term sugarcane cropping resulted in a continuous decline in cane yield up to the 7th cycle. Even though there was some yield increase in subsequent cycles, the yield level did not reach the original value, indicating a permanent deterioration in soil productivity. This deterioration in cane yield, observed with time, could be arrested to some extent by the application of compost and also by the application of mineral equivalents of the compost. The beneficial effects of cake might be attributed to its P and K content (Table 2).

Table 2. The changes in cane yields of the variety Co419 during different cycles in metric tons/ha - Joshi et al (29).

Treatments[a] Main	Sub	1st cycle[c] 1939-1942	7th cycle 1957-1960 A	7th cycle 1957-1960 B	10th cycle 1966-1969 A	10th cycle 1966-1969 B	Average A	Average B
No N	no compost	43.75	33.25	72.5	41.0	69.2	33.0	73.5
	compost[b]	44.00	56.50	89.0	58.0	80.7	46.7	88.5
Groundnut cake alone	no compost	137.50	89.90	104.2	102.5	107.6	101.0	109.5
	compost	142.20	90.00	102.5	102.0	102.5	111.5	108.5
Sulphate ammonia alone	no compost	119.20	55.00	96.0	73.2	94.2	64.0	102.2
	compost	138.50	90.50	102.7	95.5	110.7	94.2	110.9
SA+ Cake	no compost	142.00	86.50	108.5	99.0	112.5	92.0	110.0
(1 : 1)	compost	147.00	89.00	104.5	112.5	108.5	108.0	108.7

A = without artificials, i.e., compost equivalents

B = with artificials, i.e., compost equivalents (120 lb N, 120 lb P_2O_5, and 650 lb K_2O/acre)

[a] types of N top dressing were adjusted so as to supply 337.5 kg N/ha (300 lb N/acre)

[b] 50 cart-loads of compost/ha

[c] a crop cycle of 3 years (plant cane + 2 ratoons) using a medium deep and fairly well drained clayey soil

Table 3. The changes in soil fertility status during different cycles - Joshi et al (29).

Treatments Main	Sub	pH 1943	pH 1969	Organic C% 1943	Organic C% 1969	Total N% 1943	Total N% 1969	C/N ratio 1943	C/N ratio 1969	P_2O_5 mg/100 gm 1943	P_2O_5 mg/100 gm 1969
No N	no compost	8.6	8.1	0.85	0.74	0.041	0.064	20.80	11.57	16.7	25.25
	compost	8.5	7.7	0.75	0.65	0.046	0.060	16.30	10.80	8.4	17.25
Groundnut cake alone	no compost	8.5	7.8	0.79	0.77	0.042	0.077	18.88	10.10	14.1	17.75
	compost	8.5	7.7	0.77	0.70	0.048	0.058	16.10	12.10	8.9	18.75
Sulphate ammonia alone	no compost	8.5	7.8	0.81	0.85	0.047	0.066	17.30	12.80	8.6	18.00
	compost	8.4	7.7	0.81	0.85	0.048	0.062	16.90	13.70	12.8	18.00
SA+Cake	no compost	8.5	7.8	0.85	0.85	0.029	0.053	29.90	16.00	8.0	16.00
(1 : 1)	compost	8.4	7.9	0.83	0.85	0.046	0.053	18.10	15.80	10.5	20.75

As regards the changes in soil fertility status (Table 3) they reported that at the end of the 10th cycle, the treatments showed in general more or less the same level of chemical fertility. This seems to indicate that the soil had reached an equilibrium in respect to chemical fertility, and explains the small differences in cane yields obtained during the 10th cycle.

To conclude, the addition of mineral equivalents of compost was found to be effective in maintaining yields at cptimum levels. However, the regular addition of organic matter in the compost series over and above the crop residues gave a slight increase even in the presence of the mineral nutrients. These results emphasize the importance of the soil organic matter status.

Tang et al (41)-Tables (4&5)

The results they reported of nine consecutive ratoons showed that normally with proper types of soil, a good cane variety and suitable culture methods, the long time ratooning system can be successfully adopted in Taiwan after each planting (Table 4).

Chemical analyses of the soils (Table 5), revealed that mulching with trash or bagasse resulted in higher organic matter contents then interplanting with Crotalaria juncea. Plots to which the spent wash concentrate which contained 7.2% K had been applied gave some increase of available K; as compared with those soils which received no spent wash concentrate.

Normally, the yield of ratoon cane decreases in the order of the numbers of ratoons. For instance, at Nag Hamadi, Egypt (Anon 4), the yield of the variety NCo310 planted in this region decreases from 39.5 tons/feddan (1 feddan = 4200 m^2) in the 1st ratoon, to 34.9 tons in the 4th ratoon. So, the usual crop cycle in most regions consists of a plant cane and 2 to 3 ratoons. Whereas in certain regions like Sudan, the high incidence of Smut in the 2nd ratoon of the variety NCo310 restrains the crop cycle to a plant cane and a ratoon, despite the partial roguing of the desessed cane stools.

Table 4. Sugar yield (tons/ha) - Tang et al (41).

Crop year treatments	1955/56	1959/60	1963/64	Combined
	1st ratoon	5th ratoon	9th ratoon	analysis
Check	11.176	9.284	7.926	9.704
Mulching with cane trash (15 cm thick)	11.936	9.344	7.860	10.088
Mulching with bagasse (15 tons/ha)	11.548	10.472	8.148	10.436**
Interplanting with green manuring[a]	10.596	8.232	7.250	8.709**
Standard fertilization[b]	10.576	9.111	7.522	9.433
Heavy fertilization[c]	12.052	9.555	8.071	10.036**
No spent wash concentrate	11.084	8.848	7.579	9.424
With spent wash concentrate[d]	11.543	9.818	8.013	10.044**

Average yield of the 1954/55 plant cane was 119.530 tons/ha, variety NCo310 grown on a sandy loam soil

a. A green manuring crop (Crotalaria juncea)

b. Standard rates N:P:K = 150:75:75 (kg elemental form/ha)

c. Heavy rates 225:112.5:112.5 kg(50% over standard)

d. Application of 75 kg/ha spent wash concentrate (7.2% K)

** Highly significant.

Table 5. Average soil analyses after harvesting the 4th, 6th, 8th and 9th ratoons-Tang et al (41).

Crop year treatments	pH	Organic matter %	Available K (ppm)	Available P (ppm)
Check	5.3	0.85	81	112
Mulching with cane trash	5.3	1.16	91	98
Mulching with bagasse	5.2	1.02	84	90
Interplanting with green manuring	5.1	0.84	83	105
Standard fertilization	5.4	0.95	82	98
Heavy fertilization	5.1	0.98	89	105
No spent wash concentrate	5.3	0.97	78	103
With spent wash concentrate	5.3	0.96	92	100

Of course the adoption of a long-time ratooning system as that practiced in Taiwan needs to devote special care and adopt all possible and adaptable culture practices which are necessary to maintain soil productivity.

It might be interesting to note that in countries like Taiwan, India and Egypt, where intensive agriculture is practiced they get appreciable yields from ratoons. There, the cane is hand-cut and almost no machinery is being used for cultivation. But with the use of machinery added factors, mainly soil compaction, depress ratoon yields, notably in the wet tropical regions.

Yeh (45)-Tables (6&7)

The effects of continuous dressings of compost and manure on some physico-chemical properties of the soils and cane yield were approached. He noted that continuous application of 30-40 tons of compost, 20 tons of solid manure or 100 tons of liquid manure per ha besides mineral fertilizers (N 200, P_2O_5 100, and K_2O 100 kg/ha) dressed to the fields during 10 crops cultivation increased the cane and sugar yields as compared to mineral fertilizer alone (Table 6).

The treatments increased the total porosity of soils while the bulk density was decreased. They also resulted in a net increase in water-stable aggregates, organic matter content, total N, P_2O_5 and exchangeable K. The improvement in these physiochemical properties of the soils elevated the NPK absorption rate (Table 6).

In addition, solid manure or compost decreased the amount of water percolation and decreased the rate of K leaching, with almost no loss of N and P (Table 7).

Singh (40)-Table 8

The data presented on the effect of long term application of three N sources to a monoculture cane rotation showed that the maintenance of high organic matter content of the soil is taken care of along with the high cane yields, provided that crop residues are

Table 6. Average cane and sugar yields (means of ten NCo310 crops grown on a loamy soil), and some physiochemical properties of the soil-Yeh(45).

Crop year treatments	Yield (tons/ha)		Soil bulk density	Total porosity %	Soil available water %	Water stable aggregates (1.0–0.25 mm%)	Total N %	P_2O_5 (ppm)	Exchangeable K (ppm)	Organic matter %
	Cane	Sugar								
F(check)	83.8	10.1	1.52	41.86	6.60	26.14	0.095	39	7.8	0.98
FC	94.3	11.4^{**}	1.38^{*}	47.99^{**}	9.89	38.27	0.122^{**}	118^{*}	15.0	1.69^{**}
FM	97.5^{**}	12.0^{**}	1.37^{**}	47.77^{**}	8.38	33.26	0.113^{*}	180^{**}	15.6^{*}	1.74^{**}
FU	93.9^{**}	11.4^{**}	1.37^{**}	47.26^{*}	6.93	27.90	0.107	78	13.0	1.89^{**}
RFC	86.9	10.7	1.40^{*}	46.44^{**}	7.41	38.26	0.107	71	10.4	1.62^{**}
RFM	86.7	10.8	1.37^{**}	47.71^{**}	7.17	34.29	0.109	113	13.1	1.48^{*}
RFU	86.2	10.7	1.46	44.09	7.78	21.58	0.104	79	8.7	1.41

F = 200 kg N, 100 kg P_2O_5, and 100 kg K_2O/ha/crop

C = 30–40 tons compost/ha/crop

M = 20 tons solid manure/ha/crop

U = 100 tons liquid manure/ha/crop

R = Amount of mineral fertilizer adjusted according to the NPK - content of the organic fertilizer (C, M, U) applied so that the total quantity of NPK corresponds to treatment F

$*$ & $**$ Significant at the 5 and 1% levels as compared to F

Table 7. Water percolation, leaching of K and absorption rate of N, P_2O_5 and K_2O - Yeh (45).

Treatments	Amounts of water leaching(lit/m^3)	Amounts of K leaching gm/m3	Absorption rate by sugarcane %		
			N	P_2O_5	K_2O
No fertilizer	976.155	22.836	-	-	-
N 200, P_2O_5 100, K_2O 100 kg/ha	958.800	38.423	52.48	9.49	94.54
NPK + 20 tons/ha solid manure	923.180	32.611	59.57	15.11	103.66
NPK + 40 tons/ha compost	880.015	30.148	60.20	15.77	113.57

The amounts of available NPK applied were equal in each treatment - a lysimeter experiment managed well. Thus, the best way to conserve organic matter in cane fields is to make them grow vigorously and yield abundantly.

Table 8: Yield of cane(tons/ha) and soil properities following long term applications of 132 kg N/ha - Singh (40)

Year crop treatments	Mean cane yield 1949-1962	Soil analyses 1962			% of aggregates > 0.25 mm
		pH	Organic C%	N%	
Control (Non)	45.4	7.8	0.27	0.033	21.6
Farmyard manure (FM)	56.7	7.8	0.32	0.042	36.8
Groundnut cake (GC)	64.0	7.8	0.31	0.038	35.8
Ammonium sulphate(AS)	66.8	7.6	0.28	0.036	30.7
AS + FM	62.0				
AS + GC	64.6				
AS + FM + GC	64.1				

The cane crop was growing on a sandy loam soil with a pH of 7.8

So, from the above formulated example it seems that appropriate and flexible culture practices should be always adopted to increase cane yields with satisfactory sugar contents. This will give rise to increased proportions of crop residues ready for decomposition. In this way the soil productivity can be indirectly maintained and even improved. This conclusion drawn from the above example and similar studies may justify the Hawaiian policy of obtaining the possible high cane yields from fertile soils. Yet, in such case a greater investment of money and diverse skill are needed.

The merits of the cane crop and sugar factory residues and the benefits which can be obtained when properly handled will be furtherly discussed.

II. IMPACTS OF LONG TERM CANE CROPPING

A. Soil Fertility

The circumstantial decline in soil organic matter content and available nutrients which normally accompanies the continual cane cropping and examples of the culture practices adopted in various sugar producing countries will be discussed along the paper.

B. Soil compaction

The continuous cropping of sugarcane accentuates compaction of soil as a consequence of perpertuated specific culture practices. This is true whether cane culture is manual or mechanized.

Compaction and loss of tilth in different cane growing areas are connected either with culture operations carried out under unfavourable conditions, or as an inevitable result of the use of heavy infield machinery. In this context, Hare (22) reported a significant negative correlation of r = -0.43 between the drop in T.C.A. and the soil porosity.

In Egypt, tillage pans frequently occur as dense soil horizons just below the average depth of tillage which amounts to 20 ± 5 cm (Anon 4). These pans have been noted to limit the free movement of water along the soil profile and root proliferation. Breaking up such pans by deep tillage or subsoiling is beneficial to cane growth and sugar yields (Table 9).

Table 9. the beneficial effect of breaking up tillage pans-Anon(4).

Yields	Check	Depth of subsoiling 50 cm			70 cm		
		1m apart	2m	2x2m	1m	2m	2x2m
Cane(tons/fed.)	33.8	39.6	39.4	40.4	53.1	43.5	41.4
Sugar(tons/fed.)	3.8	6.9	5.7	5.4	5.4	5.4	5.3

With machinery, cane yields may be greatly suppressed due to:

a. the damage encountered to the remaining underground portion of the plant. The gaps in the ratoon fields, in case of machinery damage, should be replanted whenever possible. This can be achieved either by using the top cuttings or preferably the stubble canes. An alternative method is the use of slip-setts instead of ordinary tts to save the time taken by the buds to germinate; as practiced in India, if possible? The nursery is being set up 2 to 3 months ealier.

b. the compressive effect of heavy machines on the soil, notably in the wet tropical areas, and despite the beneficial effects of the low pressure high flotation tires.

Soil compaction may reach a depth of 50 cm under moist conditions and greatly depress root development and soil-water relations. According to Trouse(42), heavy traffic on solid clay decreased the density of the soil from 108 to 160 gm/dm^3. Heavy disking reduced the infiltration rate from 330 to 5 mm/hr, and infield traffic from 77.5 to 20 mm/hr. In clayey soils, Trouse et al (43) found that there was root reduction at 70 lb/cu. ft., and no penetration of roots into soils of 115 lb./cu. ft. bulk density. Moreover Kong (31) recommended to keep bulk densities below 1.6 gm/cm^3 for optimum cane growth.

Juang et al (30) studied various aspects of soil compaction (Table 10). They placed ^{32}P and ^{86}Rb in soil cores compacted to bulk densities from 1.2 to 1.8 gm/cm^3. They noted that nutrient uptake decreased with increasing bulk density. This coincided with the decreasing root proliferation that accompanied increasing bulk density. Cane grown in pots containing soil compacted to bulk densities from 1.2 to 1.8 gm/cm^3 performed best in the 1.6 gm/cm^3. For comparable bulk densities, it performed better at the higher fertilizer level.

Where compacted horizons exist near the soil surface coupled with slower rates of water infiltration, deeper tillage or subsoiling is needed to shatter these layers. This will enhance root penetration and distribution. In Hawaii, additional amounts of rock phosphate were added when subsoiling, to build up the P reserves in the subsoils, which were defficient in this nutrient element. Filter cake can be equally beneficial.

Table 10. **Effect of bulk density on nutrient uptake, root proliferation and cane growth—Juang et al(30).**

Soil	Bulk density gm/cm3	P cpm/gm dry wt.	Root dry wt. in core (gm)	Rb cpm/gm dry wt.	Root dry wt. in core(gm)	Fertilizer level	stalk length (cm)	Dry root wt/pot (gm)
Clay loam	1.2	385 a	0.46 a	10 a	0.42 a	High	60	200
						Low	47	175
	1.4	274 a	0.24 b	12 a	0.36 a	High	60	245
						Low	56	265
	1.6	73 a	0.18 b	4.5 b	0.30 a	High	69	495
						Low	66	430
	1.8	35 a	0.15 b	5.5 b	0.05 b	High	59	320
						Low	59	265
Sandy loam	1.2	297 a	0.51 a	28 a	0.39 a	High	63	295
						Low	64	190
	1.4	202 a	0.34 a	18 a	0.61 a	High	65	290
						Low	58	420
	1.6	63 b	0.42 a	8 b	0.28	High	74	395
						Low	64	330
	1.8	22 b	0.20 b	8 b	0.27 a	High	72	190
						Low	56	280

Means followed by the same alphabetical letter are not significant at the 5% level
High fertilizer level = 300 kg N, 150 kg P_2O_5 and 200 kg K_2O/ha
Low fertilizer level = 150 kg N, 75 kg P_2O_5 and 100 kg k_2O/ha

C. Plant-soil moisture relations

Care should be advocated to allow gravitational water to percolate satisfactory through the soil, notably when adding water consecutively to supply the growing crop with its water needs. Movement of water through the soil will depend on various attributes such as the infiltration capacity of the surface soil and the moisture conductivity of the lower horizons. This briefly explains why soil compaction will restrict water movement.

In dry regions the consecutive swelling and shrinkage of the silty clay soils which accompanies the application of irrigation water may impede soil structure and reduce the rates of cane growth. According to Hare (22) the bulk density increased with decreasing soil moisture indicating the substantial shrinkage that occurred in these clayey soils. Following irrigation the clays swelled and became accordingly less compact. Increasing the organic matter level of these soils or any other culture practice needed to improve soil structure will enhance cane growth. This may necessitate a modification of the cropping system followed.

Growth of cane on soils puddled with water is greatly reduced due to the circumstantial impeded aeration. Consequently, the rate of nutrient absorption decreases, denitrification takes place rapidly with appreciable N losses, etc... This is quite true with shallow soils characterized by a high water table. In such case a bare fallow period might be beneficial. As regards water table a better cane growth was secured from a water table depth of 200 cm (Fig. 1), provided that the subsurface soil was wet whereas the surface soil was dryer, a situation needed for a suitable gaseous exchange (Menshawi 33). Similar results were obtained by Pao et al (34), and Escolar et al (15).

To improve soils puddled with water a good drainage system is needed to move the water table below the depth of the cane roots.

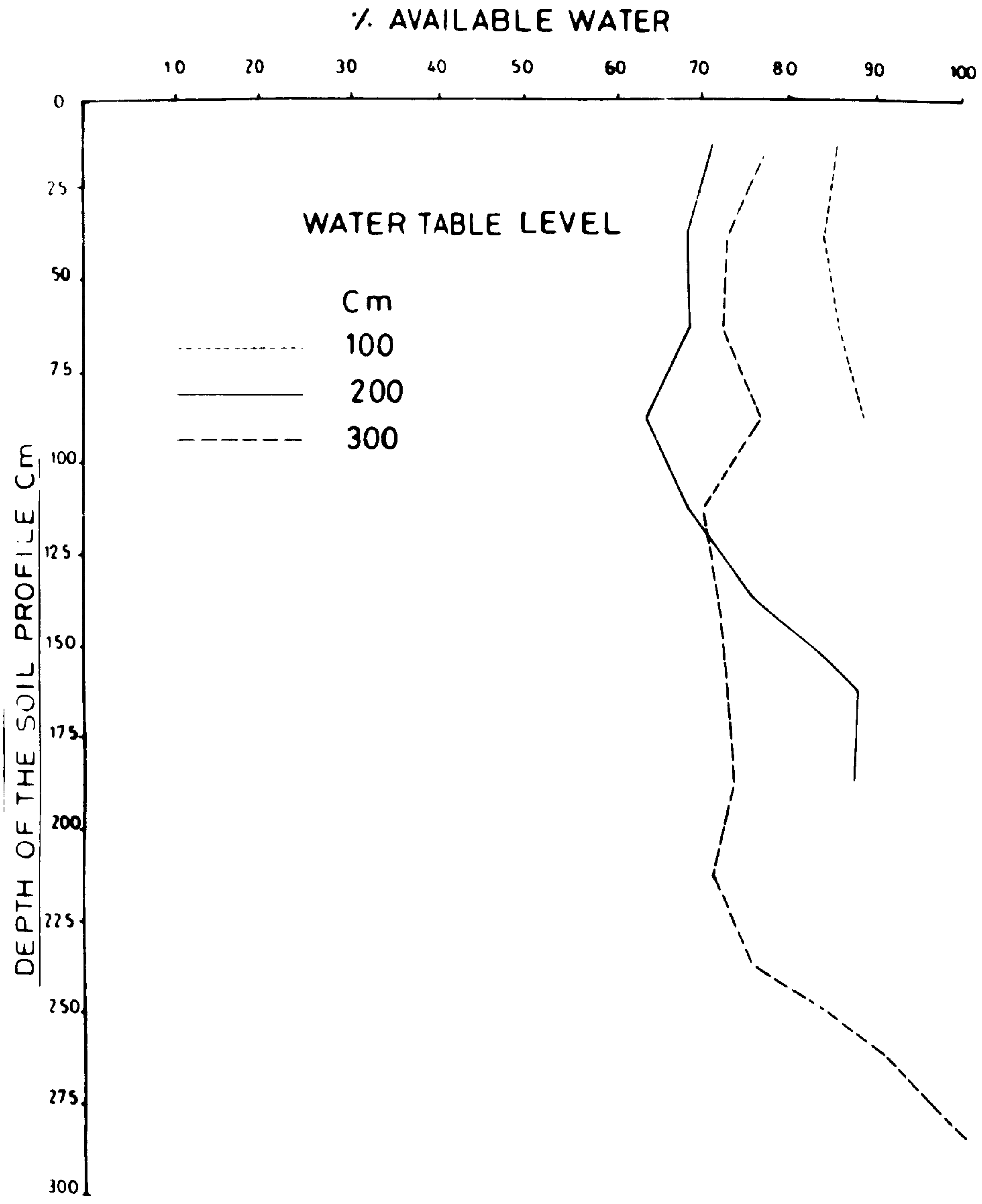

Figure 1. The moisture release curve along the soil profile in a sandy loam soil with water table levels at 100, 200, and 300 cm—Menshawi (33).

Needless to mention that with sugarcane, being an almost permanent crop, the difficulty of correcting errors in irrigation and drainage schemes imposes itself. Moreover, the incidence of salt accumulation in the surface soil due to water evaporation will impede cane growth. This situation may impose a temporary rice planting.

D . Disease incidence

The problems of disease and pest control by a suitable crop rotation has been discussed by various authors, such as Curl (11). The increasing incidence of cane diseases and pests with continual cropping results from increased pathogen populations.

For instance, in sugarcane, Fawcett (19) advised a rotation with lucerne, maize or other non-susceptible crops to control smut. Arruda (6) recommended maize, and Robinson (36) a fallow period or green manure crop. Green manuring will also help in controlling such parasitic plants as triga and Aeginetia plants. Andrews (3) claimed that legume roots would be injured, yet Striga grew for only 1 cm or so in height and died without seeding. Whereas, a fallow period notably in wet regions will increase the amounts of Striga seeds during the course of the fallow.

Moreover, Hogg et al (24) reported a decrease in the overall population of parasitic nematodes from 675/300 cm^3 soil after continuous cane to 288/300 cm^3 soil after a 3-year grass ley. The cane root system was also less vigorous in the former case. Thus, the use of a suitable crop sequence when planting cane helps in controlling soil borne pathogens.

In addition, growing cane in a cane field repeatedly will enhance the infestation of various cane pests such as borers and aphids. The latter pest will also contribute in increasing the incidence of such virus diseases as Grassy shoot and Mosaic.

Alternatively, a long term-variety monoculture of cane necessitates an adequately aerated soil and a balanced nutrition. Otherwise, the

Table 11. The incidence of cane diseases as influenced by nutrien[illegible]ilability - Egerton (13) and Hughes et al (25).

Type of disease	Disease	Causal organism	Rate of infection	
			Increased	reduced
Fungus (leaf)	Sheath rot	Cytospora sacchari	Shallow soils	N fertilization
	Eye spot	Helminthosporium sacchari	K deficiency	
	Brown stripe	Cochliobolus stenospilus		P & K fertilization
Fungus (stalk)	Wilt	Cephalosporium sacchari	increased C/N ratio	B & Mn additions
	Stem rot	Gibberella moniliformis		applying Zn
	Pokkah boeng	Fusarium moniliformis	B deficiency	
Fungus (root)	Pythium root rot	Pythium arrhenomanes	Ca & P deficiency	
	Root rot	Pythium arrhenomanes	N excess	
	a)kalimati(java)		K deficiency	
	b)pahala(Hawaii)		avail.Mn deficiency	applying S
	c)droppy - top (Queensland)		Cu & Zn deficiency	
Virus	Chlorotic streak		K deficiency	applying N

probability of nutrient deficiency notably of micro- nutrients increases, and a less vigorous cane will be growing. This situation will enhance the cane susceptibility to various diseases, as shown in table (11).

III.MAINTENANCE OF SOIL PRODUCTIVITY

Sugarcane is indeed a heavy feeding plant, yet it has got the possibility to remedy or balance its excessive needs and impact on soil fertility. As previously discussed, sugarcane as a monoculture crop can improve soil texture due to its high proportion of plant residues (Table 12). Soil productivity can be maintained when the crop is being managed properly and supplied with the needed nutrients, i.e., a balanced fertilization, coupled with adequate culture practices.

Table 12. Vegetative composition of 12 months old cane-Barnea (8)

Constituents	Green weight (Natal)		Dry weight % total dry weight	
	tons/acre	% millable cane	Natal	Hawaii
Millable cane	33.4	100	49.0	45.2
Tops	8.4	25	10.0	14.6
Trash	5.0	15	19.5	20.6
Stubble	8.4	25	13.4	11.7
Roots	2.7	8	8.1	7.3
Young shoots	-	-	-	0.6
Total plant	57.9	173	100	100
Plant residues	24.5	73	51.0	54.8

The above tabulated figures are self-explanatory. They emphasize the importance of a flexible return to field system to sustain an economical cane sugar production.

A. Rotation

The practice of continuous cropping of sugarcane would eventually reduce yield, unless as previously noted, care is being devoted to restore the soil organic matter and nutrient reserves. For this purpose rotation seems not only logical but desirable.

The beneficial effects of rotation, or the growing of different crops in sequence as a mode of farming, could be attributed to:

a. evading the exhaustion of minor elements. The special preference on one or a few micro elements by a specific variety grown continuously on a land for years would cause deficiency of these particular elements (Loh 32).

b. diminishing the probabilities of invasion and multiplication of pathogenic organisms and pests, as previously discussed.

c. evading the accumulation of toxic substances in soil which impair the normal growth of sugarcane.

Various examples of cane rotation are found in the literature. In Hawaii cane follows pineapple. In such case 30 to 120 tons/acre of pineapple trash is being ploughed in the red subsoil. An increase in sugar yield was recorded when planting cane after pineapple (Alexander et al 1), or after tobacco (Anon 5). The increase was attributed to the residual effects of heavy N and K_2O fertilizer applications of these previous crops, to lesser weeds and to the added amounts of humus which greatly improved the water holding and cation exchange capacities of the soils.

Among the interesting examples are the results achieved by Hogg et al (24), which are given in tables (13 & 14). They noted that rotating cane with Pangola grass (Digiteria decumbens) increased cane yield (Table 13). Ley fallowing, i.e., grassy intervals improved the soil moisture holding capacity and root proliferation and thus increased the amounts of water available to the cane crop. The soil pH, and exchangeable Ca^{++} increased notably after the third year ley (Table 14). Of course, the growing of grasses such as the Pangola grass during the rest period (fallow) is no problem.

The problems arising when cropping cane consecutively, i.e., planting continuously one crop after another are intensified due to

Table 13. The effect of grass leys on cane yield (tons/acre)-Hogg et al (24).

Fertilizer level per acre	0	Years under Pangola grass			
		1	2	3	Average
3 cwt. ammonium sulphate	17.01[a]	23.59	25.90	28.70	26.06
6 cwt. ammonium sulphate	21.33	24.17	26.86	32.01	27.68

a. The average cane yields of 3 varieties, grown on a gravelly clay loam soil

Table 14. The effect of grass leys on some soil properties-Hogg et al (24).

Properties	0	Years under Pangola grass			
		1	2	3	Average
a. <u>chemical</u>					
pH	5.0	4.6	4.9	5.7	5.1
Organic matter%	1.96	2.06	2.27	2.17	2.17
Available P_2O_5 (ppm)	32.0	44.0	26.0	26.0	32.0
Available K_2O (ppm)	180	168	168	202	179
exchangeable Ca^{++} (mequiv./100 gm)	8.43	7.99	8.89	11.32	9.40
b. <u>Physical</u>					
Bulk density gm/cm3	1.07	1.14	1.11	1.11	1.12
moisture content at 0.3 atm.	20.3	20.4	20.5	21.1	20.7
Moisture content at 10 atm.	14.3	13.5	13.8	14.5	13.9

the usual mono-varietal culture of cane. In Hawaii a partial rotation is being practiced, the change done is in the planted cane varieties. Selection of varieties in the plantation area helpa in chosing a variety which is more resistant to the particular fauna and flora and general environment of the area. Such a situation and solution emphasize the need of several commercial varieties auited to each particular environment. So while rotation lengthens the longevity of a given commercial cane variety, changing the variety in case of long term cropping helps in increasing the obtained yields.

B. Green manuring

Besides the appreciable amounts of N added to the soil when planting a legume crop as a green manure, generally green manuring during the rest period controls the leaching of nutrients, reduces weed infestation and limits soil erosion that may occur during a bare fallow.

According to Pearson (35) a Sunhemp crop grown between cane cycles in South Africa and turned over provided the equivalent of 600 to 800 lbs sulphate of ammonia/acre- 50 to 70 kg N/acre- with the added benefit of building up reserves of soil organic matter. Normelly, no additional N is being applied to the plant cane.Afterwards normal N dressinga are given to ratoons. The choice between adapted varieties of legumes such as cowpeas and velvet beans depends on the length of the rest period. The latter legume produces a higher tonnage of green manure and grow for longer periods (Humbert 26).

C. Trashing

Trash, i.e., all the above-ground crop constituents excluding the milleble canes participate in the addition of organic matter to the soil. Trash will also partially compensate for the amounts of nutrients removed. In many countries sugarcane waa hand-cut. Nowadays the lack of manpower and the high cost of handling the trash has unfortunately encouraged the change to burning the cane.

A logical start point for trashing is to add all possible green foliage, as is, to the soil. Hence, the practice of burning cane prior to harvest which destroys most of the trash and the loss of such a high organic matter potential deserves special attention. Despite the extensive data justifying cane burning in terms of practicability and encountered low sugar losses, the development of a green cane harvester delivering a fresh unburned cane crop of high milling quality is still a challenge.

A coordinated effort from the cane breeder is needed to incorporate the free- trashing and erect cane characters to the present commercial varieties. The success achieved in Queensland along this line deserves special attention. They substituted their former varieties which gave a forest of tangled stalks difficult to cut and load, with new varieties that give satisfactory tonnages of high sucrose cane that stand erect at harvest. Whereas, in Hawaii they are still burning, pushing and shoping a heavy two-year crop. The raw material delivered is of a comparatively lower milling quality-the trash problem-despite their efforts to clean and wash the cane.

In certain areas within the tropics where rains prior to harvest are not so excessive and where additions of organic matter to the soil are needed, it seems that better results can be achieved when cutting a crop of self-trashing erect fresh cane forced to ripe by spraying chemicals that will not greatly damage their green tops. These are classified as growth regulators that stop cane growth by impeding respiration, or antimetabolites that restrict cell division at the plant apex.

The trash problem deserves special consideration when evaluating the merits of delivering a fresh can crop. For instance, in British Guiana, Birkett (9) recorded a drop in apparent purity from 84.21 in the clean cane to 82.07 in the gross cane (84% clean cane + 11% tops + 5% trash). Trash was of far more importance in milling costs than the tops and resulted in very appreciable economic losses. In Hawaii," trash + tops" ranged from 12% with a good burn to as high as 30% with no burn. In comparison with net cane the burnt cane with 12% trash content showed 2% lower purity and with the unburnt cane with 30% trash a purity drop of 3.5% was recorded (Evans 18).

So, the situation which imposes itself is to decide whether to deliver a high tonnage per unit area of lodged burned cane obtained from longer crop cycles, or otherwise a lower tonnage of upright clean fresh cane from shorter crop cycles.

Cutting fresh cane could be restricted to the last ratoon of the crop cycle. The decomposition of the remaining trash during the rest period will cause no serious problems notably in the wet regions. These intercepted rest periods when long enough give enough time to grow an additional legume crop to be turned in as the first stages of the series of preparatory operations for replanting with cane. In certain sub-tropical areas with a cold winter, the soil temperatures under trash may be somewhat cooler and thus retard growth.

The contents of mineral elements in cane trash are given in table (15).

Table 15. Contents of mineral elements in cane trash (tops excluded)_Fogliata et al (20).

N%	P%	K%	Ca%	Mg%	C%	Organic matter	C/N ratio
0.43	0.040	0.35	0.15	0.03	20.8	35.9	48

The beneficial effects of trash addition as compared with burning trash appear in table (16). Trash addition improved the soil structural stability and resulted in an increase in organic matter, total N, hydric capacity and porosity.

Table 16. Effects of trash burning and addition (tops excluded) on soil characteristics (18 cm of surface soil)- Fogliata et al (20).

Treatments	Stability index	Organic matter %	Total N%	C/N ratio	Moisture equivalent %	Density	Porosity
Trash burning	0.256	1.29	0.105	14	24.0	1.21	54.0
Trash addition	0.498	1.74	0.123	12	29.0	1.11	57.8

Apart from improving soil properties, Fogliata et al (20) estimated the amounts of nutrients restored to the soil (Table 17). It appears that for P and K almost the same amounts were restored to the soil whereas burning the trash resulted in high N losses due to volatilization.

Table 17. Amounts of nutrients restored to the soil, variety CP34/120, trash (tops excluded)- Fogliata et al (20).

Treatments	Amounts left on the soil tons/ha		kg/ha		
	trash	ash	N	P_2O_5	K_2O
Trash unburned	5.3	-	22.7	4.85	22.4
Tresh burned	-	1.5	2.2	5.15	21.2

The presence of trash has been reported to have a negative influence on the available N and its assimilation. In Egypt, and elsewhere it appeared that unless additional N was added to the soil, when trashing (dry leaf additions), canes would exhibit various degrees of chlorosis, signs of N starvation. Also the increase in cane and sugar yields appeared in the 2nd ratoon, a year after adding trash (Table 18). Whereas trash added to the 1st ratoon resulted in a drop in cane and sugar yields (Anon 4).

Table 18. Cane and sugar yields, variety NCO310, 2nd ratoon (4).

Treatments	Cane yield tons/feddan	Sugar yield tons/feddan
Conserving trash in alternate rows	46.9	5.1
Burning trash	43.1	4.6

Similarly Hebert et al (23) reported from long term experiments in Louisiana that the treatment o trash-soybean - 40 pounds N increased yield, while trash burned or without adequate N decreased sugar yield. Moreover, Pearson (35) found that the cane yield increased only when the trash from a plant cane crop had acted as a mulch in the 1st ratoon and as an organic layer in the 2nd ratoon crop.

Of course, the benefits of cane trash as a soil amendment will greatly increase when the top portions are included. This clearly appears from the data obtained by Cross (10) who used varieties like PoJ36 and PoJ 213 (Table 19).

Table 19. Amounts of nutrients in kg/ha returned to the soil-Cross (10).

Treatments	N	P_2O_5	K_2O
Trash left without top portion	15	8	38
Trash left with top portion	50	25	115

To conclude most of the efforts were directed during the past 25 years towards developing the efficiency of harvesters that deliver burned shoped canes. A corresponding effort should be directed towards developing similarly efficient machines that deliver fresh topped millable clean canes. A part of the top portions could be directed towards replanting with cane.

In this context, the possibilities of increasing the incidence of certain cane diseases and pests may arise as an objection to such practice. In Taiwan the spreading of specific leaf diseases such as eye spot, leaf blight, and brown stripes was controlled by burning the trash. Yet nowadays the commerciel cane varieties planted in most regions ere in most cases highly resistant to almost all important diseases. Moreover, the possibility that turning over the cane trash, once at the end of each crop cycle, causes an outbreak of a specific idisease is quite improbeble.

D. Sugar factory residues

The practability of returning the factory residues to the cane fields should be given more consideration. It is easier to achieve when both the field and factory are under the control of the same organization.

According to Evans(18) the use of mill waste organic matter in the improvement of Hewaiian soils, particularly the grey hydromorphic and dark magnesium soilshad been found economical. In many sugar producing regions returning the factory residues to fields was a traditional practice, nowadays discontinued. But it seems that the present improvements in the wide range of implementation, plant diagnostic and analytic methods, etc... used for producing cane and sugar, call for a similar improvement in the techniques followed to handle such a residue as the bulky filter ceke. Such improvement will enable the re-use of this beneficial soil amendment.

1. Filter cake

Unless used to produce wax, the dried filter cake should be returned to the field when possible. The equipment used to deliver the millable cane from the field to the mill can be used to transport the stored filter mud to the field.

The filter mud varies in quantity, moisture content end composition from one place to another. Its weight percent cane varies from 2.8 in Jameica and Mauritius to 5.4 in South Africa.

Its composition (Tables 20 & 21) is not constant throughout the milling season.

Table 20. The composition of wet filter press cakes-Avice(7).

Rate	Water %	N%	P_2O_5%	K_2O%
Average	52	1.14	2.04	0.87
Extreme-low	11	0.62	0.93	0.20
Extreme-high	66	1.71	3.37	1.85

Table 21. The chemical composition and physical properties of filter press cake-Samuels et al (39).

Constituents	Dry weight %	Constituents	Dry weight %
N	2.19	B_2O_3	0.01
P_2O_5	2.77	Organic matter	39.5
K_2O	0.44	Loss ignition	45.2
CaO	3.05	Sucrose	3.0
MgO	0.49	Moisture (fresh wet basis)	61.0
MnO_2	0.17	(stored basis)	15.0
Fe_2O_3	1.05	Volume-weight cm^3/gm	0.375

Filter mud contains most of the P_2O_5 and some of N found in the cane, but is low in K. Most of K is found in the molasses. Its main advantages are its cheapness, a comperatively slower release of nutrients, minor-element content,high water-holding capacity, high cation exchange capacity and mulching properties. Its main disadvantages are its low K_2O content and large bulk.

According to Samuels et al (39) when filter press mud decomposes it releases its bulk of N as nitrates, the peak of NO_3 formation occurs about 5 months after its application. Also 10 to 15 tons of 30% moisture filter cake returned to the soil would add about 450 pounds N, 600 pounds P_2O_5 and 100 pounds K_2O.

The system of"vertical mulching" devised by Evans (18) deserves special attention. A slit 2 to 3" wide and 2' 6" deep was being cut in the heavy days and filled with a porous material such as filter mud. The addition of filter mud resulted in an increase of 10 tons cane/acre in plant cane with a visible effect in ratoons.

The beneficial effects of applying filter press mud to phosphate-deficient soils in Jamaica where 20-40 tons/acre were added (Innes 28) and in Trinidad where 2-8 tons/acre were added (Evans 16), and the benefits of returning filter mud to the fields practiced in India, should serve as example.

2 . Effluent waters

The details of composition of the various categories of effluent waters of a sugar factory in India is given in table (22). Usually the chemical composition of these effluents is not constant throughout the milling season.

Table 22. Analysis of effluent waters of a sugar factory - Sachan et al (37).

Effluents	pH	Total soluble salts mmhos/cm	Ca meq/liter	Mg meq/liter	CO_3 meq/liter	HCO_3 meq/liter	Cl meq/liter	Na ppm
Mill house water	6.5	0.7	3.8	5.4	0.20	5.0	3.0	200
Boiler water	8.0	0.6	2.0	1.6	0.10	5.1	3.1	1950
Main drain water (mixed effluents)	6.3	0.8	7.6	5.2	0.20	4.3	3.0	430
Oliver filter water	8.1	0.5	2.8	4.0	0.20	2.4	3.2	220
spray pond water	7.2	0.8	9.5	5.4	0.30	3.9	4.0	290
Well water (check)	7.6	0.4	8.2	5.7	0.40	2.2	10.0	210

The data collected by Sachan et al (37) and given in table (23) indicate that all the sugar factory effluent waters except mill house water can be used for irrigating cane.

Table 23. Effects of effluent waters on cane growth and yield on medium black loam soils - Sachan et al (37).

Effluents	A growth period of 90 days			Cane yield (tons/acre)	
	Average number of shoots/ plant	Average heights of main shoot cm	Vigour of the shoots	Plant cane	1st rat.
Mill house water	10	85	Vigourless died after 60 days)		
Boiler water	32	158	normal		
Main drain water (mixed effluents)	30	154	normal	40.7	32.2
Oliver filter water	29	154	normal		
Spray pond water	28	156	normal		
Well water (check)	34	165	normal	42.3	35.8

In practice, the effluents should first be subjected to coarse and fine screening and care should be taken to separate all oil and grease. Then, with a very small dilution it can be used for irrigation purposes since its BOD ranges from 500 to 3000 ppm and for irrigation water the maximum BOD is 500 ppm. This practice will solve the problem of disposal and prevent pollution of the environment and surface waters.

E. Inter-cropping

Raising an additional crop in the space between the cane rows is quite beneficial. In various sub-tropical regions notaly in Egypt, north-India, Taiwan, etc.... Autumn planted cane suits the practice of intercropping much more than the spring planted cane. The practice of inter-cropping was introduced as a result of various investigations undertaken to evaluate the compatibility of various crops, the cultural adaptability of the two crops, efficient use of soil amendments, irrigation water resources, and plant protection problems.

The interplanted crops must keep freely their own photosynthetic foliage with the least possible interception. Normally, the crop interplanted with cane is harvested before the closing-in of sugarcane. Or otherwise, being harvested early enough, the cultural practices needed for vigorous cane growth start immediately.

The utility of legumes which fix N and add humus to the soil should be considered, Crops such as peas, beans, peanuts, clover, wheat, barley, sugar-beet, potato, onion, garlic, redish, cotton and rice have given satisfactory results when inter-cropped with cane.

Of course, inter-cropping increases the returns per unit area (Table 24). Normally, it has no adverse residual effects on the subsequent ratoons (Anon 4).

Table 24. Yields of normal and inter-cropped Fall cane-Anon(4).

Yields (tons/feddan)	Normal Fall cane crop (check)	Fall cane inter-cropped with					
		Beans	Lentil	Onion	Garlic	Lupine	Safflower
a. Plant cane							
Yield of intercropped crop	-	1.2	3.0	2.0	1.2	3.5	10.0
Yield of cane	56.0	52.2	56.1	52.8	56.8	50.0	43.0
b. 1st ratoon							
Cane yield	52.6	52.3	48.0	48.8	50.6	52.8	50.9
Sugar yield	7.9	8.0	7.4	7.7	8.0	8.1	7.9

In this context, the success achieved when intercropping sugarbeet with Fall planted cane (Gill 21) deserves special attention. The results showed the possibility of increasing production of raw material and consequently of sugar per unit in sub-tropical areas. Both crops can be raised within 15 months in the same field with a raw material outturn of about 93^{m3} (55^{m3} from cane + 38^{m3} from beet), against 61^{m3} from October planted non-intercropped cane. The question of processing sugar-beet in a sugarcane factory does not present difficulties. It calls for only some additional machinery for slicing and diffusion of beet in the existing cane sugar factories. This practice followed with success in India and Pakistan, should serve as an example.

F. Inorganic fertilization

The replacement and maintenance of a ready supply of all elements needed for optimum cane growth is the ultimate goal of a balanced fertilization. Balanced ratios notably of the essential elements N, P and K in available forms are quite essential. Barnes (8) estimated that a cane crop of 50 tons/acre removed from the soil about 34-40 kg N, 22-28 kg P_2O_5, and 68 kg K_2O.

To a large extent the amounts of replaceable soil nutrients which are applied to sustain the cane crop demands depend on various attributes such as the nutritional status of the different soils, the length of the growing cycle, and the prevailing environmental variables. Rainfall, soil type, organic matter content, types of irrigation and drainage are rated as important factors. For instance, in Hawaii with a two-year irrigated crop, N applications vary between 125 kg and 240 kg N/acre (Evans 17). Whereas in the Dominican Republic, the annual N dressing for a one-year unirrigated crop is from 18 to 25 kg N/acre, and 36 to 45 kg for irrigated cane (Ellis 14).

Moreover , the soils in Hawaii are rather well supplied with active organic matter. There, rock phosphate, which apparently approaches fluorapatite ($3\ Ca_3\ (PO_4)_2 .\ CaF_2$) in its molecular make-up, is being used for the more acid soils to build up the soil P_2O_5 reserves and correct their cation exchange capacity.

Generally it is seldom necessary to add the other macronutrients which are not usually of prime importance and the micronutrients to soils. For instance, limestone ($CaCO_3$) is being rationally supplemented to acid soils, but the responses observed have been attributed in most cases to its control of the percentage base saturation of the soil and thereby to the correction of the pH of the soil solution, rather than to satisfying calcium deficiencies. As to the micro-nutrients, when definit foliar deficiency symptoms are observed, they should be applied preferably as foliar spray.

Another example is the fertilization of cane fields in Egypt. Planting cane in the Upper-Egypt sugarcane belt is quite an old practice. Soils there, have been continually cropped with cane notably during the last 30 years. Fertilization had been restricted to the use of 40 to 80 kg N/feddan. Tests during these early periods showed little or no response to either phosphate or potash applications, indicating the availability of adequate supplies of both nutrient elements. Applications of micro-nutrients such as B gave also negative responses.

Recently, in a survey of soil and cane crop, performed in the year 1975 at Kom Ombo plantations Egypt, Ali (2) determined the levels of P, K, Ca, Fe and Mn found in the alluvial productive soils and too in the TVD leaf lamina of the growing variety NCo310 (1st ratoon). The values obtained (Table 25), were fairly comparable to the nutrient elements indices for optimum cane yields in different countries (Samuels 38). Indeed, appreciable yields of cane and sugar were obtained (Table 26).

Thus it seems that 10 years after the erection of the High Dam in Egypt, the cane crop planted on fertile soils is still depending on the built up and still undepleted soil's reserves. Of couse, in the near future the whole fertilization policy should be changed. Besides the amounts of N added (60-120 kg N/feddan), other nutrients should be applied for optimum cane growth.

Table 25. Average data of chemical analyses of alluvial soils and TVD leaf lamina, var. NCo310 1st ratoon - 12 months old - Ali (2).

Parameter	Soil (available nutrient content)		TVD leaf lamina dry weight basis)	
	Range	Mean	Range	Mean
P%	-	-	0.08-0.18	0.11
K%	0.011-0.061	0.034	0.50-1.46	0.91
Ca%	0.14-0.92	0.66	0.11-0.52	0.25
Fe ppm	1.8 - 6.5	2.7	97-269	200
Mn ppm	0.5 - 3.0	0.6	12-92	34
$CaCO_3$%	0.9 - 16.0	5.9	-	-
pH	7.15-8.20	7.65	-	-
Ec. mmhos/cm	0.16-1.50	0.30	-	-

Table 26. Mean millable cane and sugar yields, and juice analyses at harvest_Ali (2).

	Stalk height cm	Cane yield ton/feddan	Juice purity	Ec. Juice mmhos/cm	Sugar yield ton/feddan
Range	83-248	18.50-73.26	76.9-91.9	2.7-8.0	2.72-10.78
Mean	173	47.15	88.2	4.6	6.94

Each value (Tables25 & 26) represents the mean of 65 samples of soil and cane at harvest collected at random, Daraw - Idfu area, Kom Ombo cane plantations, Asswan Province, Egypt.

The objectives of a balanced fertilization programme, notably when cropping cane continuously, should be to supplement the growing cane crop with sufficient resources of easily available nutrients, besides improving the fertility status of the soil for succeeding crops.

This principle is being realised in the following examples. For instance, heavier doses of phosphates are required not only to meet the growing crop needs and to enhance the effectiveness of other nutrients such as N and K, but also to limit the phosphate fixing capacity of the soil. This is specialy true with clayey to loamy soils which contain appreciable amounts of Ca^{2+} ions. There, the initialbuild-up dressings will benefit subsequent crops and the levels of applications are later progressively reduced. Also limestone when added to the soil increases Ca levels, and corrects soil acidity, increases the availability of P and Mo, reduces Fe, Al, and Mn toxicities, and improves the physical structure of the soil. A similar complex change occurs when applying gypsum ($CaSO_4$) to alkali soils. Moreover, the organic fertilizers previously discussed, with their extended nutrient yielding potentials are a further example. They supply their nutrients notably N at slower rates and improve the organic matter status of the soil.

Yet it should be noted that the concept of returning to the soil what has been taken out should be followed with certain precautions. Its systematic adoption under any circumstance is unadvisable, since it may only perpetuate any state of imbalance. For instance, the idea of applying K fertilizers to increase the sucrose content of cane even where no potash deficiency exists and no growth response occurs is quite wrong. Sucrose increases were only obtained, where growth responses occured asaresult of K applications (du Toit 12). Obviously excessive applications of nutrients are not only wasteful but can lower the sucrose and purity of the cane juice.

To conclude the best policy to adopt is to withhold a nutrient application when an excess is definitely existing. Also, maintenance dressings should be applied long before actual deficiency symptoms develop, or likely responses are indicated by foliar analyses.

IV. A BALANCED FERTILIZATION

To sustain the growing cane with a balanced fertilization it is necessary to evaluate the changes in soil fertility and to determine the nutrient status of the crop, in order to make advantageous fertilizer recommendations. In other words, to carry out periodical analyses of the soil and plant.

To reap appreciable sugar, foliar diagnosis should be considered among the beneficial agricultural tools at hand and thus used efficiently. It is the most logical solution for the necessity of early detecting any forthcoming nutrient deficiency in order to regulate the mineral nutrition of the subsequent crop.

The utility of the crop-logging, defined as a graphic record of the foliar values and related indices, taken periodically throughout the life of the cane crop, is unquestionable. It integrates all the factors that influence cane growth and sugar production.

Soil analyses to determine the available P and K, coupled with either foliar diagnosis or the more elaborated system of crop-logging are now practiced in various sugar producing centers. Slight differences are found among the various procedures adopted here and there.

Besides the above formulated example of soil analysis coupled with leaf diagnosis, the following one (Innes 28) gives the optimum values for N, P, and K% in cane leaves in Jamaica (Table 27).

Table 27. Optimum nutrient concentrations in cane leaves in Jamaica - Innes (28)

% in dry matter	Age of cane in months at sampling					
	3	4	5	6	7.5	9
N	2.25	2.02	1.93	1.85	1.75	1.65
P	0.22	0.21	0.20	0.19	0.18	0.18
K	1.37	1.34	1.33	1.29	1.20	1.15

Maintaining nutrients at such levels is of vital importance for a continual cane cropping system. Moreover, appropriate field records of the past and present soil and crop status may be used as a forecast of future changes. This is quite true where no regular compensatory culture practices are being performed during the intercepted rest periods, and where sugarcane agriculture is fully mechanized.

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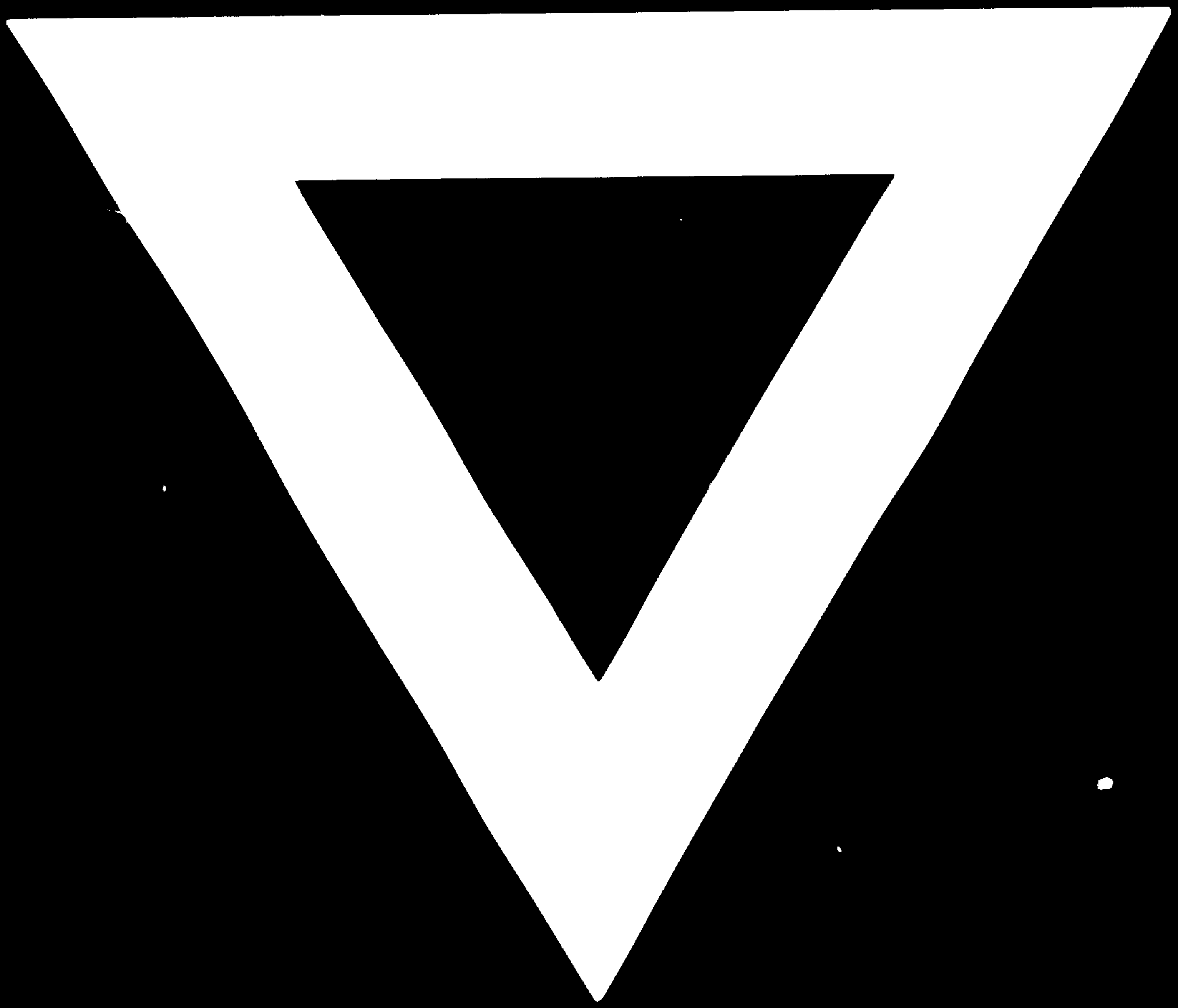

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