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IMPROVEMENT OF THE YIELD POTENTIAL IN CARIBBEAN SWEET POTATO CULTIVATION

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INTRODUCTION

Tropical root crops, including sweet potato, yams, edible aroids and cassava are fairly extensively cultivated in the Caribbean for domestic consumption and small quantities are exported to U.K. and U.S. markets. The demand for tropical tubers for processed human foods (e.g. instant yam flakes) and for livestock feeds, as well as for starch for industrial utilization (e.g. in bauxite, textile and adhesive industries) is likely to increase rapidly in the next decade. However, root crop cultivation in the Caribbean is characterised by unestablished systems of production, with high labour inputs, which result in low and inconsistent yields and seasonal availability of tubers. In addition, uncertain market requirements and poor marketing arrangements for fresh tubers often lead to wastage and low profitability to the farmer. As a result, the number of farmers engaged in root crop cultivation is steadily declining (Rankine, 1972). Moreover, the inherently poor storage capacity of tropical tubers limits the economic possibilities of the fresh tuber trade.

In these circumstances, a more stable market based on processed end-products would seem to be necessary to ensure more efficient utilization of root crop tubers, in the expectation that such efficient utilization will not only stimulate root crop production, but also increase the profitability of root crop enterprises. However, the demands for raw material in prospective processing industries far exceed current root crop production levels. It is suggested, therefore, that systems designed to achieve massive increases in root crop production through increase both in the productivity and acreage of root crop cultivation are urgently required, if current decline in the number of practising root crop farmers is to be reversed and root crop cultivation in the Region is to survive and expand. The major inputs to such systems are

(a) availability of superior cultivars with increased yield potential

(b) established packages of cultural practices for individual root crops.

In this paper, existing levels of productivity in sweet potato and biological constraints to increasing them are discussed, and sweet potato compared with other tropical root crops as staple sources of carbohydrate in the Caribbean.

RESULTS AND DISCUSSION

A COMPARATIVE ACCOUNT OF SWEET POTATO TUBER PRODUCTIVITY.

Data (Table 1) shows that sweet potato productivity in Japan (20 m.tons/ha) is from four (x4) to ten (x10) times that of the level for Caribbean farmers at 2 - 5 m.tons/ha, if considerations of relative cropping periods, daily radiation and other climatic factors are ignored.

Productivity on the Texaco Farm in Trinidad (Haynes and Wholey, 1971) under semi-commercial conditions was, however, much higher (x2.8 - x4.5) than that for commercial farms. Record experimental yields (e.g. in Uganda), which more precisely reflect the yield potential of the species, are some 2.5 times higher than commercial yields in Japan. The highest yielding Caribbean cultivar so far studied (A28/7) gave an experimental yield of 35 m.tons/ha and single plants of this cultivar produced yields equivalent to 46 m.tons/ha (Table 1), but plant to plant yield variability precludes consistent achievement of such yield performance either in experimental or commercial production.

On the basis of calculations for more efficient light utilization, de Vries et al (1967) predicted that the genetic potential for tuber yield in the sweet potato species is in the region of 140 m.tons/ha. However, the terminal components of yield in tuberous crops are the mean weight and number of tubers per plant at a defined plant spacing, and increased yield could be achieved only by increasing one or both of these components. Thus data (Table 2) shows that a 5-fold increase in sweet potato yield (9-46 m.tons/ha) is achieved by approximately 1.7 and 3.0-fold increases in mean tuber weight and tuber number, respectively. Realization of the predicted genetic potential of the species (140 m.tons/ha) at the highest tuber number recorded (11) and at a spacing of 50×10^3 plants/ha, necessitates a 1.4-fold increase in the highest recorded mean tuber weight in our experiments.

Removal of the constraints to yield improvement in sweet potato requires an understanding of the inter-relationships between terminal components of yield, so that they may be manipulated to achieve increased yields. These constraints will be considered in terms of the existing gap between commercial and experimental yields as well as that between record single plant yields and experimental yields. Strategies for achieving the predicted yield potential of the species are excluded from this presentation.

CONSTRAINTS TO YIELD IMPROVEMENT

The three types of biological constraints to sweet potato yield improvement chosen for discussion are related to different aspects of yield determination. Thus, agronomic constraints are defined as those which preclude realization of experimental yields in commercial production. Physiological constraints refer to those factors which limit the yield potential of experimental plots compared with that of single plants, and genetic constraints are the problems involved in first defining individual heritable characteristics associated with high yield and then combining these characteristics in a single superior cultivar. Although these constraints are discussed separately, it is only by the collective solution of the problems resulting from all constraints to yield improvement that highest yield performance will be obtained.

Agronomic Constraints

Agronomic constraints generally result from the more precise cultural practices that can be applied to the small experimental plot compared with larger commercial acreages. However, the proper selection of available cultivars and adoption of established practices also seem to be major agronomic constraints in Caribbean sweet potato cultivation. Evidence for the existence of yield constraints in the following aspects of sweet potato cultivation is presented:

TABLE I. Comparison of commercial experimental and predicted yields in sweet potato.

	Yield (m.tons/ha)	Reference	
Commercial			
West Indies (farmers)	2-5	Rankine	(1972)
(U.W.I.)	9-14	Haynes & Wholey	(1971)
Japan (country average)	20	Tsuno	(1971)
Experimental			
West Indies (c.v. A28/7)	35	Lowe & Wilson	(1974)
Single plant	46	Lowe & Wilson	(1974)
In coconut fibre dust	65	Wilson	(1964)
Congo	41	DeVries et al	(1967)
Uganda	50	T.P.I.	(1973)
Predicted Yield	140	de Vries et al	(1967)

TABLE 2. Components of total yield in sweet potato at different levels of tuber yield.

Cultivar	Yield (m.tons/ha)*	Yield (gm/plant)	Mean tuber (wt.gm/plant)	Tuber No.	Reference
049	9	180	67	2.7	1
049	14	281	88	3.2	1
049	22	454	142	3.2	2
049	30	600	140	4.3	2
C9/9	32	670	105	6.4	2
A28/7	35	722	150	4.8	2
A28/7 (single plant)	46	950	119	8.0	2
Predicted	140	(2850)	(259)	(11)	3a
	140	(2140)	(195)	(11)	3b

* at a population of 50×10^3 plants/ha. (approx.)
1 calculated from Haynes & Wholey (1971)
2 Lowe & Wilson (1974)
3a based on calculated productions from de Vries et al (1967)
3b calculated at spacing of 75×10^3 plants/ha. (approx.)

(1) Planting Material

Variety

Vine cuttings

(2) Management of the soil/crop/environmer

Soil type and land preparation

Fertiliser application

Water regime

Spacing

(3) Crop Protection

Weed control

Pest control.

Planting Material

Although several high yielding cultivars with a range of morphological and physiological characteristics likely to make them suitable to different niches in the Caribbean ecosystem have been selected at UWI (St. Augustine), local varieties still to a large extent form the basis of sweet potato cultivation e.g. Black vine in St. Vincent and Nylon in Jamaica. Thus, extensive trials are necessary to establish the best variety for a particular environment. Preliminary work (Haynes 1969; Baynes 1972) suggests that the following cultivars are suitable for specific soil types in the listed territories:

049	- Trinidad
A26/7, T.25	- St. Vincent
A26/7, 06/56/23 Cricket Gill	- Grenada
A26/7	- Barbados.

In St. Vincent, A26/7 gave yields which were 585% that of the commercial variety (Black vine). Data is not available for similar trials in Jamaica. It is significant to note that high performance cultivars produced in Trinidad (e.g. 049) do not always outyield local varieties in other regions.

Godfrey-Sam-Aggrey (1974) demonstrated 41% and 54% increases in tuber yield with increasing length of vine cuttings, in the range 23 to 61 cm in two sweet potato varieties with low and high vine/tuber ratios respectively, (Table 3), thus illustrating the importance of cutting length as a determinant of tuber yield. Longer cutting lengths resulted in reduced vine/tuber ratios. Twelve to fifteen in.(30-38 cm) cuttings are normally used for cultivation in the Caribbean. Although in these experiments (Table 3) the length of vine cutting buried in the soil at planting was kept constant at 5 cm., Lowe and Wilson (1974) showed that from 80% - 100% of total yield was normally produced on the first four subterranean nodes (Table 4), and that small unmarketable tubers produced at lower nodes (5-8) were responsible for considerable plant-to-plant variability in tuber yield. Conversely, occurence of plants with less than four subterranean nodes in normal cultivation led to reduction in yield.

It is concluded, therefore, that both the choice of variety and the length of stem cutting could be important agronomic constraints to sweet potato yield improvement.

TABLE 3. Effect of length of vine cutting on yield and vine/tuber ratio of two sweet potato varieties.

Cutting length (cm)	Yield (tons/ha)		Vine (tuber/ratio)	
	Missis	Madam	Missis	Madam
23	2.08	7.50	8.16	2.70
31	2.74	7.63	6.29	2.73
46	2.91*	9.79*	6.58*	2.11*
61	3.21**	10.57**	6.99**	2.08**

After Godfrey-Sam-Aggrey (1974)

* and ** indicate significantly different from 23 cm value.

TABLE 4. Distribution of tuber yield on subterranean nodes of six sweet potato cultivars.

Node No.	Yield (gm/plant)						
	049	A28/7	C9/9	I62	AI6/15	03/62	Mean
Node 1	72	84	120	124	87	22	85
Node 2	218	62	176	97	105	37	116
Node 3	56	118	57	49	76	26	64
Node 4	76	90	68	26	38	28	54
Total (Nodes 1-4)	422	354	421	296	306	113	319
Total Yield	472	443	363	353	343	114	348
% total yield at Nodes 1-4	89	80	100	84	89	100	92

After Lowe and Wilson (1974)

Soil Type and Land Preparation

The important soil constraint to sweet potato tuber yield is the mechanical resistance to tuber expansion and growth effected by heavy clay soils. Yields are generally higher on lighter loams which in addition ensure an adequate oxygen supply, known to be critical for sweet potato tuberisation. Accordingly, low yields (1.8 m.tons/ha) on the Micoud Gritty clay in St. Lucia indicate the unsuitability of this soil type for sweet potato cultivation. Comparable experiments on the Balambouche Gritty Clay Loam gave yields of up to 11 m.tons/ha i.e. a 520% increase over the Micoud Gritty Clay (Baynes 1974). Moreover, the highest sweet potato yields recorded in the Caribbean (65 m.tons/ha) were achieved in a coconut fibre waste artificial medium where resistance to tuber growth is reduced to a minimum and maximal oxygen supply to the root system ensured (Wilson 1964). The physical soil constraint to sweet potato tuber yield is therefore quite considerable. However, the adverse effects of soil type may be to some extent overcome by adequate soil preparation, including deep ploughing, harrowing, rotavating and use of ridges at least 46 cm (18 in.) deep, separated by furrows for rapid drainage in the wet season. Thus, although similar experiments have not been conducted with sweet potato, ploughing, harrowing and rotavating air-dry soil gave a 10% increase in White Lisbon Yam (Dioscorea alata) yields over that from soils which were only ploughed and harrowed (Ferguson & Gumbs 1974).

Fertilizer Application

Although precise fertilizer recommendations must be developed for each soil type, it has been adequately demonstrated that yield responses to NPK are obtained for sweet potato on many Caribbean soils. Generally, levels of N-application (36 kg/ha) and high levels of K-application (180 kg/ha) give best yields (Haynes 1968). Cross (1964) and Baynes (1974) also obtained significant yield responses to P-applications of 45 kg/ha. In these experiments, sweet potato yields were shown to be increased some 100% by NPK fertilizer application. However, supra-optimal levels of N-application are known to reduce sweet potato yield at normal harvest dates by postponing the advent of tuber bulking (Haynes et al. 1967). There is also some evidence for differential responses to N-application by different sweet potato varieties. Thus, Tsunoda (1965) claimed that low leaf area types were N-responsive but yield was reduced by nitrogen application in high leaf area types. Moreover, Haynes (1969) classified St. Augustine cultivars into N-responsive, N-depressing and N-indifferent types on the basis of yield responses to 80 lb. N/acre.

Water Relations

Like all vegetatively propagated crops, sweet potato vine cuttings require an adequate supply of water for establishment and rapid early growth. However, the process of tuber initiation which occupies the period 2 - 8 weeks after planting (Lowe and Wilson 1974) is adversely affected and early tuber growth is suppressed by waterlogged conditions. Accordingly, tuber yields are often reduced in wet season cultivation (May-June) by the occurence of waterlogging during early growth, and irrigation is necessary for crop establishment and further growth, if high yields are to be obtained in dry season cultivation. Irrigated dry season crops are known to give higher yields than wet season crops. (Walter 1966) and Lowe (1971) demonstrated a 37% increase in yield in an irrigated dry season crop compared with a wet season crop.

Spacing

Given adequate soil and land preparation, fertilizer application and water relations, a most important agronomic constraint to the achievement of maximal yields is use of the optimal plant spacing for the variety cultivated. Such optimal spacing would optimize the use of radiant energy, fertilizers and "tuber space" in the soil. Thus, there is a wide range of vegetative habits to be found among sweet potato cultivars ranging from types with high leaf areas and long, trailing much-branched stems, to short stemmed low leaf area types with a "gathering" habit. Clearly, closer spacings will increase yields in the latter types. On the basis of spacing/fertilizer trials by Haynes (1968), the spacing recommended for cv. 049 in Trinidad is 31cm (12") intervals along rows 69cm (27") apart (i.e. a plant density of 50,000 plants per hectare or 20,000 plants per acre). This plant density can no doubt be increased with lower leaf area cultivars.

Crop Protection

Weed Control

The weed constraints to the achievement of highest sweet potato yields is adequately demonstrated in experiments by Seeyave (1969). Applications of paraquat (0.6 kg/ha or 0.5 lbs/acre) to keep a sweet potato crop weed-free for the first three weeks of growth resulted in yields which were 93% of weed-free controls. Unweeded plots gave yields that were only 20% of those of weed-free controls. The percentage increase in tuber yield obtained by maintaining weed-free conditions during the first three weeks of the sweet potato crop was therefore 365%.

Pest Control

The major pests of sweet potato in the Caribbean are the Pyralid moth *Megastes grandalis* (Guen) in Trinidad and *Euscepes* in the rest of the Caribbean. Effective methods for the control of both of these pests have been established by Parasram (1968). Thus, for *Euscepes* control, a combination of the soil insecticide chlordane and foliage insecticide Lebacid increased yield some 45% over untreated controls in a St. Vincent trial. The practice adopted for *Megastes* control in Trinidad includes dipping stem cuttings in 0.5% dieldrin before planting followed by alternate two-weekly sprays of either dieldrin and Sevin or Lannate and Malathion. Such treatment has been shown to result in up to 100% increases in tuber yields over untreated controls. In seasons with severe *Megastes* infestation no marketable tubers are obtained from plots in which *Megastes* is uncontrolled.

Recently, Braithwaite (1974) demonstrated that nematodes are also serious pests of sweet potato in Trinidad. Among six species found in association with sweet potato roots the Reniform nematode *Rotylenchus reniformis* was the most abundant. Application of DD soil fumigant (a mixture of dichloropropene and dichloropropane) at a rate of 72 litres/ha resulted in a 92.6% increase in yield over untreated controls.

Evaluation of yield increase due to removal of agronomic constraints

Data (Table 5) shows some experimentally established yield increases due to removal of agronomic constraints. Increases due to use of appropriate varieties and suitably cultivated planting material, soil type as well as pest and weed control are notably high. Although the interaction of agronomic practices for the production of optimal yields are clearly not expressed by a simple additive equation, there is an interesting but perhaps fortuitous coincidence of the approximately 1900% increase in yield between the 1 m.ton/ha sometimes obtained in Caribbean sweet potato cultivation (Rankine 1972) and the 20 m.tons/ha reported for Japanese sweet potato yield.

It is often stated that small under-capitalized Caribbean farmers cannot be persuaded to invest the additional capital involved in proper crop management. It is interesting to note, however, that constraints such as choice of variety and soil type could probably be removed at little cost, and indeed both fertilizers and insecticides are regularly, though often improperly, used.

Data (Haynes & Thomas, 1967) also show that a considerable proportion of the total cost of a sweet potato crop:-

Collection of cuttings	5.7%
Planting	22.8%
Vine turning	9.1%
Harvesting, collection and preparation of soil	24.3%
TOTAL	61.9%

is usually supplied as the manual labour input by the small farmer. It is difficult to believe that such a high percentage of the total cost of production will not benefit from capitalisation in the form of loans to the farmer for the remaining cultural practices necessary to remove critical agronomic constraints to sweet potato yield improvement.

TABLE 5 : Evaluation of Yield Increases Due to Removal of Agronomic Constraints

1 - for yams
2 - estimated

Agronomic Constraint	% Yield Increases	Reference
Variety/Planting Material	585	
Variety	585	Baynes (1972) (St. Vincent)
Cutting	54	Godfrey-Sam-Aggney (1974) (Sierra Leone)
No. Subterranean Nodes	200	Lowe and Wilson (1974) Trinidad
SUBTOTAL	839	
Management of Soil/Crop/Environment		
Soil Type	520	Baynes (1974) (St. Lucia)
Land Preparation	10[1]	Ferguson & Gumbs (1974) Trinidad
Fertilizer Application	100	Cross (1974) (Trinidad)
Water Relations	37	Lowe (1971) (Trinidad)
Spacing	50[2]	Haynes (1968) (Trinidad)
SUBTOTAL	717	
Crop Protection		
Pest Control		
Euscepes Control	45	Parasram (1968) (St. Vincent)
Megastes Control	100	Parasram (1968) (Trinidad)
Nematode Control	93	Braithwaite (1974) (Trinidad)
Weed Control	365	Seeyave (1968) (Trinidad)
SUBTOTAL	603	
GRANDTOTAL	1,859	

Physiological Constraints

Some causes, effects and implications

a) Competition and Yield Variability

Physiological constraints to crop production as here defined are related to the inter-plant competition which results from the growth and development of plants in a crop community compared with that achieved by the individual plant. Such competition may limit the availability of the following growth requirements to each plant in the community:

(1) Inorganic raw materials for growth and development from

(i) the aerial environment (e.g. carbon dioxide), and

(ii) the soil environment (e.g. water, essential mineral nutrients, oxygen).

(2) Radiant energy

(3) Aerial space for foliage development as well as soil space for root and tuber development.

In turn, limitation of the above-mentioned requirements leads to plant competition, which results in plant-to-plant variation in tuber yield. This variability expresses the random capacity of individual plants in the community to compete for growth requirements. The highest yielding cultivar, therefore, will be the one which could effect the most efficient conversion of limited growth requirements per unit area into final tuber yield, thus minimizing competition and concomitant variation in tuber yield.

Data (Table 6) show that in experiments with six cultivars, the high yielding cultivars 049 and A28/7 had much lower yield variabilities over three crops than the low yielding cultivars AI6/15 and 03/62.

TABLE 6 : Total and marketable yields and yield variabilities in six sweet potato cultivars (average of three crops).

Cultivar	Total Yield		Marketable Yield	
	(gm/plant)	(C.V.%)	(gm/plant)	(C.V.%)
049	508	36	444	44
A28/7	598	46	417	68
C9/9	493	47	282	97
I62	449	58	259	98
AI6/15	422	40	139	134
03/62	271	91	156	159

C.V. % - Coefficient of Variation

After Lowe and Wilson (1974)

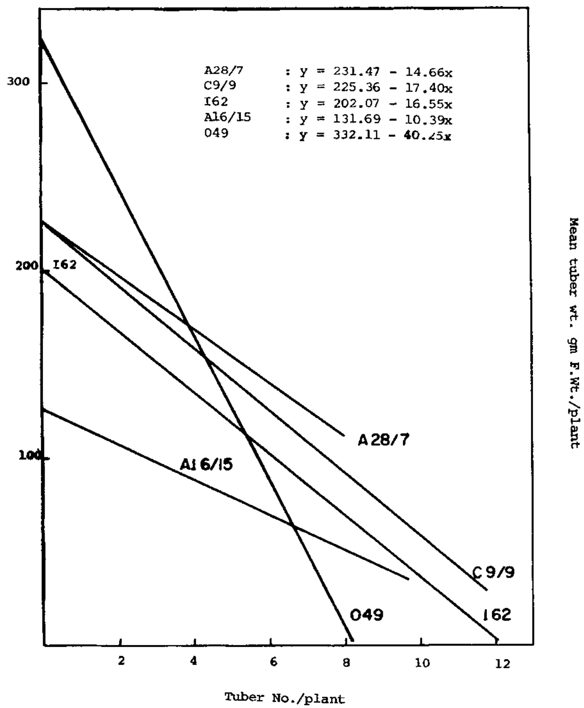

FIG. 1. Regressions of mean tuber wt. on tuber number in five sweet potato cultivars.

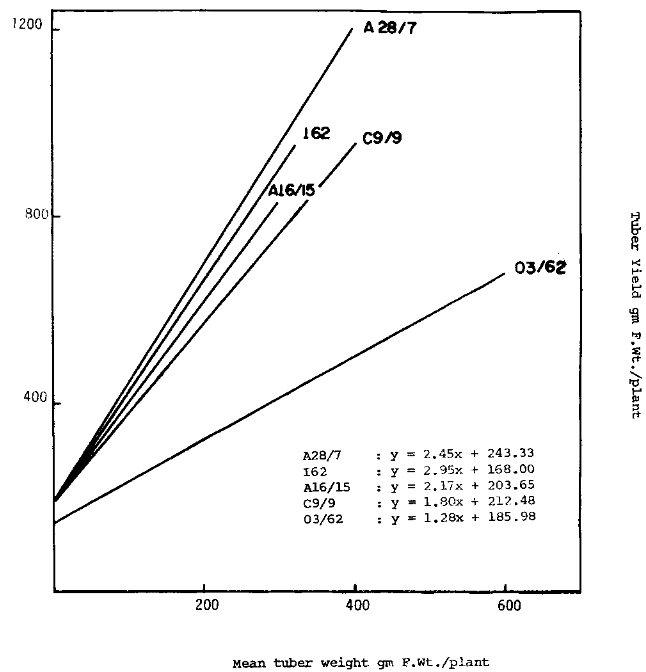

FIG. 2. Regressions of tuber yield on mean tuber weight in five sweet potato cultivars.

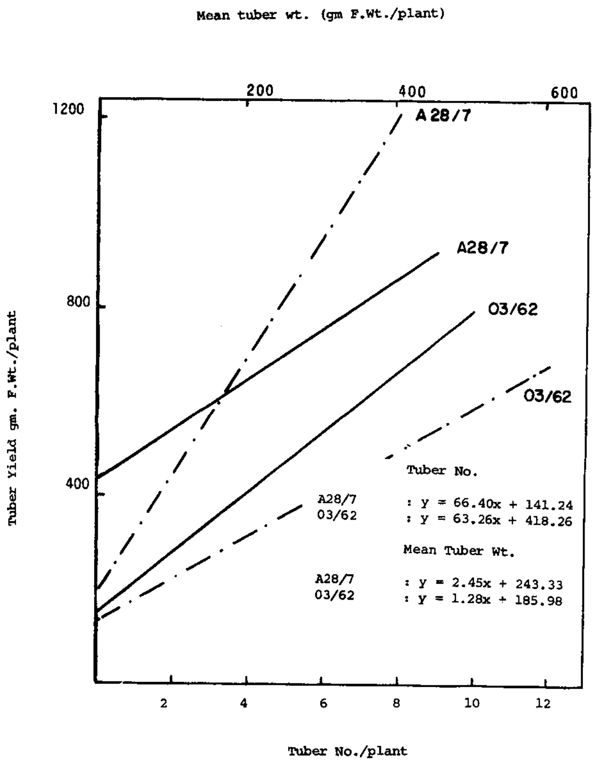

FIG. 3. Regressions of tuber yield on tuber no. and mean tuber wt. in two sweet potato cultivars.

b) **Yield Component Compensation**

Since the terminal components of yield in sweet potato are the mean weight and numbers of tubers per plant, then physiological constraints can be expected to influence yield through effects on these components. But yield components develop sequentially : tuber initiation, which determines tuber number, occurs <u>before</u> tuber growth which determines final tuber size and weight (Wilson and Lowe, 1973). However, such sequential development leads both to the interdependence and integration of yield components in the determination of final yield. Accordingly the sequential, interdependent and integrated development of yield components result in the phenomenon of yield component compensation, whereby increase in the value of one component (e.g. tuber number) leads to a decrease in the other (e.g. mean tuber weight).

Such yield component compensation has been demonstrated at different degrees of intensity in the same six sweet potato cultivars (Lowe and Wilson, 1974), as is shown by negative regression coefficients between mean tuber weights and tuber number (Fig. 1). Yield component compensation was highest in the high yielding cultivar 049, where increase in tuber number by one reduced mean tuber weight by 40 g. (approx.). However, cv A28/7 with the highest total yield showed the lowest yield component compensation.

Yield component compensation illustrates the developmental plasticity inherent in developing plant organs which affords alternative developmental pathways for the attainment of final yield, thus maintaining more stable and less variable plant yields in the crop community. It is not surprising therefore that although highest total yield was recorded in cv. A28/7, marketable yield of cv. 049 was superior, suggesting that strongest yield component compensation leads to least variability and highest marketable yields.

Despite the existence of yield component compensation among plants of the same variety in the crop community, there is evidence that the ratios of mean tuber weights to tuber numbers of the six cultivars, were cultivar characteristics. Thus, a significant negative regression of mean tuber weight on tuber number was demonstrated for the mean values of these components for five of the six cultivars over three crops (Fig. 2).

Data (Fig. 2) also suggested that cultivars with higher ratios of mean tuber weight or tuber number e.g. 049, A28/7 were higher yielders, and that yield component compensation also operated at the genetic level as has been found by Edwards and Cooper (1961) for leaf size and leaf number in <u>*Lolium*</u>.

c) **Relationship between yield components and yield**

Sweet potato yield potential could only be increased by increasing either or both the terminal components of yield, tuber number and mean tuber weights, in such a way as to optimize the relationship between these components consistent with highest total yields (Grafius 1956). However, the strategy for yield increase depends on the relationship between either component and yield. Thus, data (Figs. 3, 4) show that the six sweet potato cultivars studied could be classified according to the relationship between either component and yield, expressed by positive regression coefficients into:

A. Tuber number/tuber weight types (i.e. A28/7, 03/62) in which both components were significantly correlated with yield.

B. Tuber weight types (i.e. C9/9 I62, AI6/I5) in which tuber weight was significantly correlated with yield.

C. A random type (i.e. 049) in which neither component was significantly correlated with yield.

These results are interpreted to mean that there may be genetic lines within the sweet potato species where yield may be increased by (a) increases in both tuber number and tuber weight or in (b) tuber weight alone.
In addition, there may be a third line (e.g. cv 049) in which yield component compensation at the genetic level is so strong as to preclude yield improvement.

The relationship between yield components and yield also explains the expression of plant competition in yield variability referred to earlier. Thus, data (Table 7) shows that the existence of significant positive regressions of total yield on tuber number in cvs A28/7 and 03/62 accounted for 16-26% of the yield variabilities of these cultivars. Alternatively, where there were significant positive regressions of yield on mean tuber weight in C9/9, I62, A28/7, 03/62 and AI6/15, 16-48% of yield variabilities were ascribable to these regressions. Moreover, regressions of yield on mean tuber weight and tuber number accounted for more than 60% of yield variability in cv A28/7, whereas the low yield variability of 049 may be due to the absence of significant regressions of total yield on either component, in this cultivar. Therefore, variability which is an expression of plant competition, can be either intensified or ameliorated by the relationship of yield components to total yield.

TABLE 7. Percentage of total variability due to regression of yield on yield components.

	% Total yield variability						
	C9/9	I62	A28/7	03/62	AI6/15	049	Crop Mean
Mean Tuber Weight							
Dry season crop	22	44	22	21	n.s	n.s	18
Wet season crop	48	33	33	32	31	n.s	30
Cultivar Mean	35	39	28	27	16	n.s	24
Tuber Number							
Dry season crop	n.s	n.s	23	32	n.s	n.s	n.s
Wet season crop	n.s	n.s	29	n.s	n.s	n.s	n.s
Cultivar Mean	n.s	n.s	26	16	n.s	n.s	n.s

Metabolic consequences of physiological constraints

Physiological constraints resulting from limitations in external growth requirements in the plant community result in metabolic deficits which restrict the growth and development of individual plants in the crop community. These deficits include (i) soluble carbohydrates, (ii) amino acids, and (iii) plant growth substances. But a clear distinction must be made between the effects of these deficits on growth, development and final yield. Thus, soluble carbohydrates and amino acids are the organic substrates for growth, development and storage and hence their reduced availability would restrict the yield potential of the individual plant. However, limited availability of plant growth substances would curtail the capacity for realization of the tuber yield potential defined by the availability of organic substrates. Such restricted capacity for yield potential realization often results in alternative forms of growth e.g. premature sprouting of "Pencil roots" and young tubers in developing sweet potato crops subjected to waterlogged soil conditions.

There is evidence to show that metabolic limitations resulting from physiological yield constraints in sweet potato differ in different cultivars. In some cultivars the limitation is in organic substrates (e.g. soluble carbohydrates resulting from photosynthesis), whilst in others the limitation is in the hormonal requirements for tuberisation. It is the task of the breeder to produce a superior cultivar in which both types of limitations are removed by means of judiciously chosen hybridizations.

Genetic Constraints

The major genetic constraint to yield improvement in sweet potato is the restricted possibilities for hybridization among varieties in the species effected by cross incompatibility. The establishment of pure lines by selfing is also restricted by the phenomenon of self-incompatibility. Establishment of inter- and intra-compatible groups of cultivars is therefore the first step in the removal of this constraint. However, the great variation in vegetative characteristics in the sweet potato species suggests that several characteristics associated with high yield may be obtained within a single compatible group of cultivars.

Comparative productivity of some tropical crops.

De Vries, Ferweda and Flach (1967) analysed average world production data for a number of tropical food crops (Table 8) and emphasized the following points:

1. Although root crops produced more bulk than grain crops, because of their higher water content, the average energetic food value of root crops (121 Cal/100 g) amounted to only 34% that of grain crops (354 Cal/100 g).
2. However, when differences in the percentage edible yield as well as the relative period of vegetation are taken into consideration, then the average crop efficiency of root crops (38.5×10^3 Cal/ha/day) is only slightly lower than that for tropical grain crops (44.5×10^3 Cal/ha/day).
3. The crop efficiency of sweet potato - 48×10^3 Cal/ha/day - was second only to maize at 56×10^3 Cal/ha/day.

Further comparisons of crop efficiency calculated from highest experimental yields (Table 9) showed that the average crop efficiency of cassava and sweet potato (215×10^3 Cal/ha/day) was some 43% higher than that for tropical grains at 150×10^3 Cal/ha/day. Also, sweet potato crop efficiency (180×10^3 Cal/ha/day) was only 10% less than maize (200×10^3 Cal/ha/day) but cassava efficiency (250×10^3 Cal/ha/day) was some 40% higher than that for sweet potato.

Despite the high crop efficiency of cassava, however, sweet potato offers advantages of (a) a shorter crop, leading to more efficient land utilization, (b) better distribution of tubers in the soil thus allowing for mechanical harvesting and the concomitant reduction of production costs, and (c) longer retention of high protein foliage which can be utilized both for human consumption and animal feeds.

TABLE 8. Average world production of a number of tropical food crops.

Crop	Tons/ha	Cal./100g	Edible portion	Cal./ha $\times 10^6$	Period of growth	Cal./(ha.day) $\times 10^3$
	(1)	(2)	(3)	(4)	(5)	(6)
Rice	2.0	352	70	5.0	150	33
Wheat	1.2	344	100	4.1	120	34
Maize	2.1	363	100	7.6	135	56
Cassava	9.1	153	83	11.6	330	35
Sweet potato	6.5	114	88	6.5	135	48
Yam	8.0	104	85	7.1	280	25
Colocasia	5.8	113	85	5.5	120	46

After de Vries et al (1967)

TABLE 9. Maximum yields in selected experiment stations in the tropics

Crop	tons per ha per harvest	tons per ha per year	Cal./(ha.day) $\times 10^3$	Rate of breeding
	(1)	(2)	(3)	(4)
Rice	16.4	26.0	176	***
Wheat	3.9	11.7	110	*
Maize	5.5	20.0	200	**
Cassava	77.0	71.1	250	**
Sweet potato	41.0	65.2	180	*
Banana	39.0	39.0	80	-

(From De Vries et al 1967)

CONCLUSIONS

It is concluded that sweet potato yields can be increased in the Caribbean by removing agronomic constraints to yield improvement. Further, current understanding of the physiological and genetic constraints to yield improvement could lead to the future development of superior sweet potato cultivars with increased yield potential, which would make this crop a highly competitive source of cheap carbohydrate.

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