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EARLINESS AND YIELD IN SWEET POTATO

I. GENERAL GROWTH ANALYSIS AND VARIETAL DETERMINATION OF YIELD

By L. Degras

INTRODUCTION

That investigations into growth analysis can create fresh impetus to root crops improvement in the Caribbean has found recent support with research workers (SPENCE, HAYNES 1966; GOODING, HOAD, 1966; HAYNES, SPENCE, WALTER, 1969; DEGRAS, 1967) in the area.

The investigations reported herein are aimed at supporting this physiological basis to which the morphological criteria utilized in plant breeding must relate. Moreover, such a physiological approach seems essential to the progress of root crops improvement. It has been observed for example in the case of Sweet Potato, that an estimate of the yielding capacity of genotypes, based on morphological criteria, may be often inconclusive.

DEGRAS (1967) attempted to develop an integrated approach for assessing yield capacity in Sweet Potato dependent on growth analyses and morphological appraisals. Earliness and morphological structures appeared to be the framework for the greatest production of dry matter. However, the validity of this hypothesis should not be determined only by the occasional successes but rather by an extended application and by a deeper knowledge of the relationship between growth physiology and morphology. The present study shows principally, the results of general growth analysis and yield determination of two very close varieties of Sweet Potato.

MATERIALS AND METHODS

Varieties: DUCLOS XI, selected from natural varieties in Guadeloupe, and IRAT 4/65, collected by the local Agency of the Institut de Recherehes Agronomiques Tropicales in Martinique, were the clones utilized. They are red skin, white flesh varieties. Their aerial parts seem morphologically identical, at least within the first month of growth. Previous observations classified IRAT 4/65 as later than DULCLOS XI in tuber bulking.

Experimental design: For each variety a nursery was established and renewed in order that cuttings could be always one and a half months old at planting time. In each case *five types of cuttings were taken:*

1. From the first developed vine:
   At the top (S1).
   At the base (B1).
2. From the second d--eloped vine:
   At the top (S2).
   At the base (B2).

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3. From the third developed vine:
   At the middle (M); this third being normally too short for two cuttings.

These were planted in a field layout that ensured one plant from each cutting type and for each sample during the 22 weekly observations made for each culture. Care was taken to avoid added competitive effect from sampling in the field. Care was given also to homogeneity in sampling.

Each sample was observed for fresh weight and dry weight of the whole plant, leaves and of stems plus petiole; number of leaves, leaf surface; and vegetative events like flowering, yellowing and drying.

Two plantings were considered. The first from the 27th April to the 28th September, 1967; the second from 7th August, 1967 to the 8th February, 1968. Several small departures from the exact weekly sampling occurred account of which was taken.

Data interpretation techniques: Graphic representation, arithmetic and semi-logarithmic scale, variance analysis, regression and correlation were employed. Through all these techniques the search for growth phases was a key objective.

The utilization of semi-logarithmic representation refers to the fundamental principle of the exponential form of growth (V.H. BLACKMAN in G. E. BLACKMAN, 1965). A clear-cut demonstration of the value of this approach in the study of dry matter accumulation process is found in the work of MOULE (1960).

RESULTS AND DISCUSSIONS

I. The Growth Curves—Total Fresh Weight:

Figure 1 shows the evolution of fresh weight against age of the crops for the two varieties and plantings. Generally, three phases were seen; a fourth might be added.

1. Exponential growth at the highest rate.
   Effect of time of planting was visible; the early one having the highest rate.

   Varieties effect; at least for the growth rate, these seemed to be identical; a possible interaction could exist with time of planting.

2. Exponential growth at a lower rate.

   Effect of the time of planting followed the same pattern as before.

   Varieties effect existed markedly for the second planting; IRAT 4/65 having a higher origin of the regression line than DUCLOS XI

3. Stopping of growth. No curve could be safely described. There was no doubt about DUCLOS XI for the second planting as to what might be discarded if the next step was not considered separately.

4. Possibly, a decrease in weight would be observed for the second planting.

Contribution of Lamina (I) Stem & Petiole (II) and Tuber (III) in total fresh weight evolution Sweet Potato

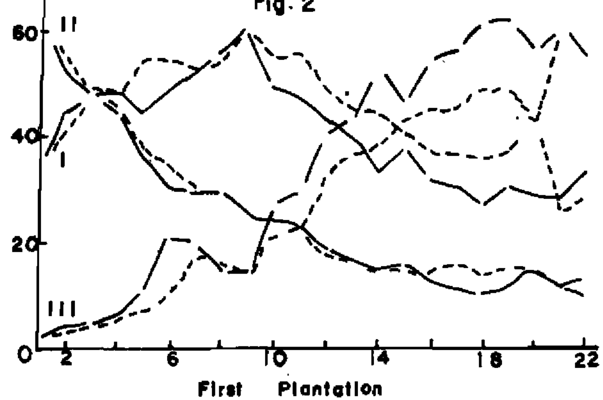


Fig. 2

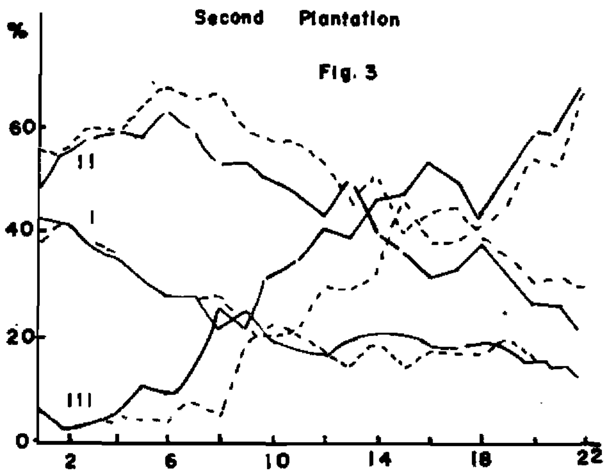


Fig. 3

Distribution of Total Dry Matter in Laminae (I) Stem & Petiole & Tuber (III)

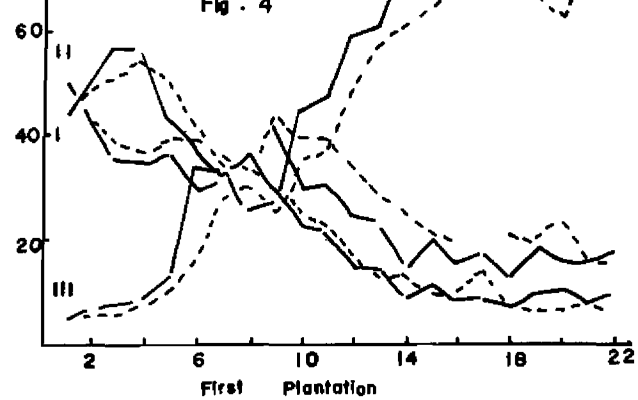


Fig. 4

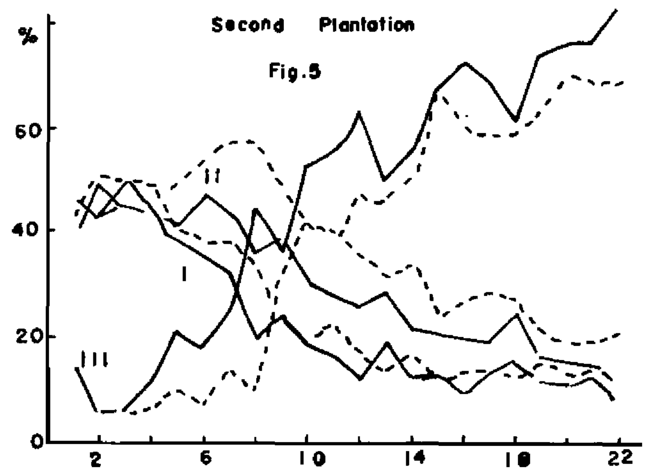
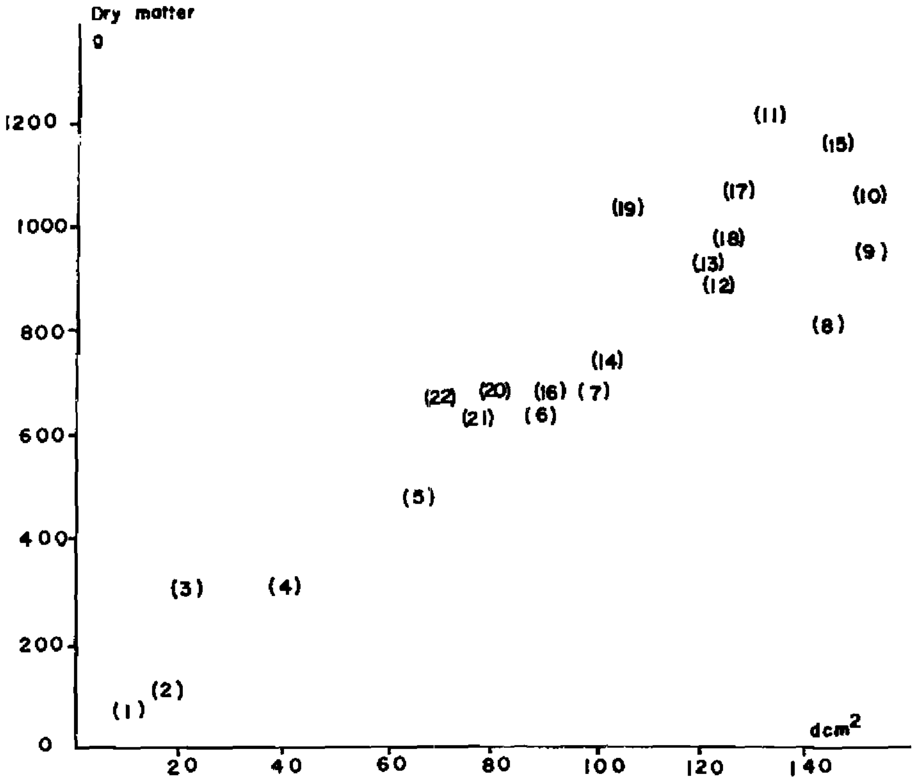


Fig. 5

FIG. 6-
Leaf area, laminae total dry matter accumulation & ageing in Sweet Potato

No. in brackets : sampling order



The first phase seemed to fluctuate, ending between 30 days and 60 days after planting. The second might be more accurately seen around 9–100 days. The apparent decrease of the second planting began after the 150th day. The main vegetative events for each time of planting are shown in Table 1. The final scores for the different items studied are summarized in Table 2.

II. Relative proportion of organs and dry matter distribution:

Figures 2 to 5 deal with the relative evolution of root or/and tuber, stem and petoile, lamina, in per cent of fresh and dry weight. A marked shift of tuber participation in total weight may be observed when considering dry matter.

Dry matter accumulation is greater in tubers of DULCOS XI. It is conversely greater in the other organs of IRAT 4/65. These differences appear at the very departure of growth for tuber and stem. They are inconspicuous between lamina dry matter evolutions of the two varieties in the first planting. In the second planting the differences for lamina dry matter accumulation are erratic from the 95th day. The comparative evolutions of lamina dry matter accumulation must be viewed in the light of the varietal x planting interaction exhibited during the two first exponential growth phases of total fresh weight. There we find another justification for the key value of dry matter investigation in determining varietal differences. Support for this is also shown by the leading role of lamina activity in Sweet Potato growth.

III. Dry matter accumulation in Sweet Potato:

(*a*) *Dry matter accumulation in lamina*

The percentage of dry matter in lamina fresh weight is about 20 in lamina of the first planting and 18 in lamina of the second planting. This confirms the positive intervention of this site of accumulation in the level of total fresh weight, which is higher in the first planting. No varietal differences have been observed. The curves of evolution with ageing of leaf show three pikes near 22 per cent at the third sampling of each planting (i.e. an age of 27 days and 45 days for first and second one respectively). This was also observed around the tenth or eleventh sampling of both plantings (78–82nd and 102–109th day), and at the 17th sampling of first planting (125th day), and 19th sampling of second planting (165th day), a fall is noticed in both plantings at the 8th sampling (62nd and 89th day). On account of the vegetative events quoted, the pikes could be associated with the onset of tuberisation and the full blooming or first drying of lamina. Then the fall would be associated with the prefloral state.

An analysis of variance of the dry matter total weight distributed in lamina (*see* Table 11), shows no significant varietal differences. But differences exist in planting values and may be reported as follows:

Superiority of first planting.

No varietal interaction.

In the first planting the significant steps with ageing are:

Onset of accumulation at 27th day.

Steady gain between 35th and 75th day.

Decrease after the 139th day.

Whereas in the second planting significant periods are:

Onset of accumulation at the 45th day.

Irregular gain with little differences from the 67th to the 151st day.

Absolute maximum on the 158th day.

Apart from the first steps of both plantings there is a marked discrepancy between the evolution of dry matter percentage and dry matter total accumulation in lamina with ageing of the crop. It could be ascribed to relative proportion of leaves of various ages.

(*b*) *Dry matter and evolution morphology of laminae systems*

The internal evolution of the laminae systems with ageing can be represented through correlations between the dry matter total content and the surface, and also through the correlations between this surface and the number of leaves.

Lamina surface (*see* Table II) submitted to variance analysis shows:

No varietal differences.

Superiority of first plantation.

No variety x planting interaction.

In the first planting:

Onset of increase on the 27th day.

Steady increase from 35th to 82nd day.

Decrease after 82nd day,

whereas in the second planting:

Marked increase was achieved between 81st and 89th day.

Relative maximum on the 89th, 123rd, 137th days.

Relative decrease toward the 102nd day.

Absolute maximum on the 158th day.

The general relationship inferred from some comparisons between these significant steps and those of dry matter total weight are clarified by figure 6. Values are means obtained from combining the data from two plantings on account of order of sampling (this transformation is discussed further). Four phases can be seen:

1. Before the ninth mean sampling: positive correlation linked to ageing.
2. From ninth to eleventh mean sampling: short inverse correlation linked with ageing.
3. From eleventh to seventeenth mean sampling: positive correlation without clear relationship to ageing.
4. From the seventeenth to the last mean sampling: positive correlation between the two characteristics to lamina, the values of which are negatively correlated with ageing.

Number of leaves (*see* Table II). This is not significantly different between varieties. Between plants the most striking difference is in evolution. This is obvious from figure 7. There is positive correlation up to the eleventh sampling. No correlation exists after.

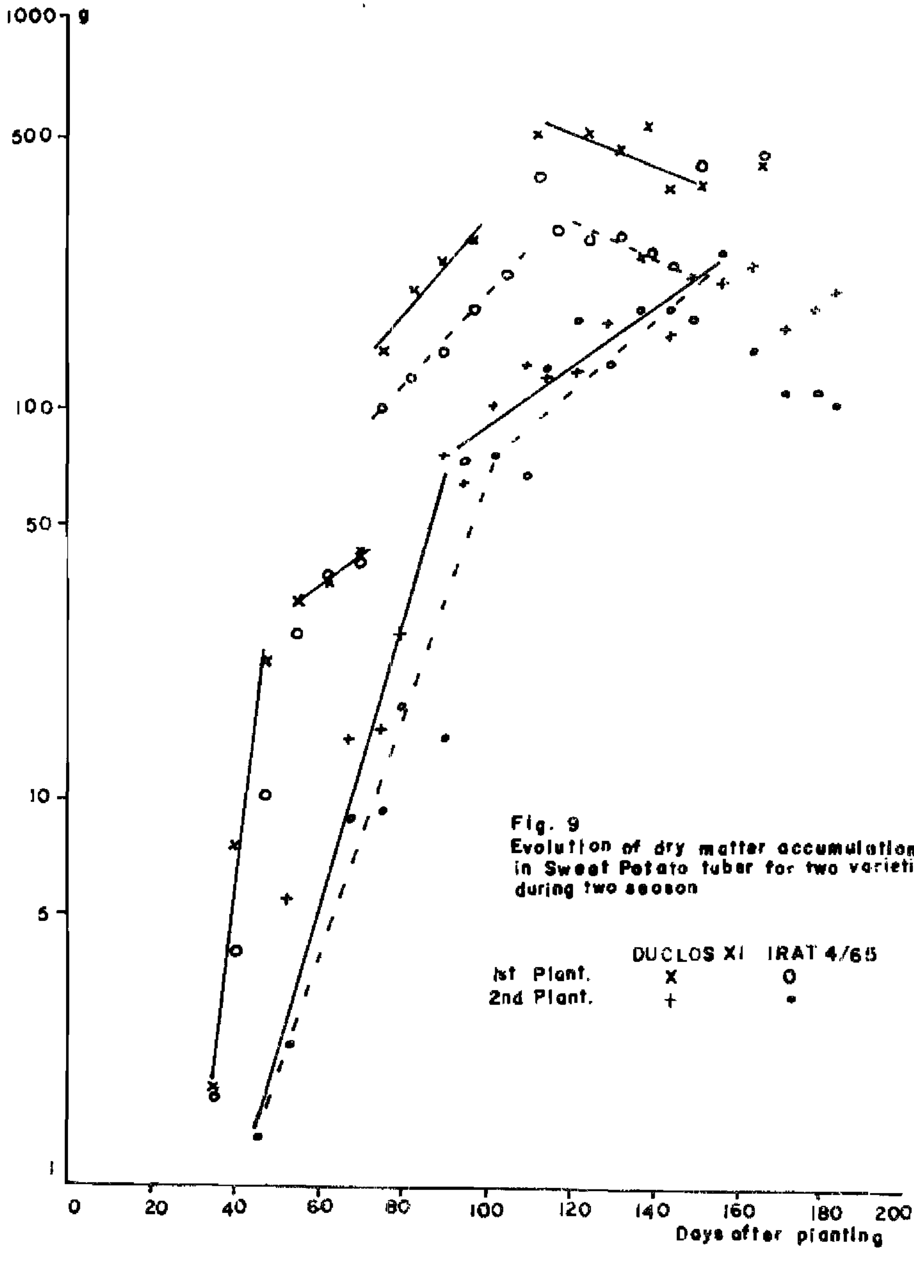


Fig. 9
Evolution of dry matter accumulation in Sweet Potato tuber for two varieties during two season

	DUCLOS XI	IRAT 4/65
Ist Plant.	X	O
2nd Plant.	+	•

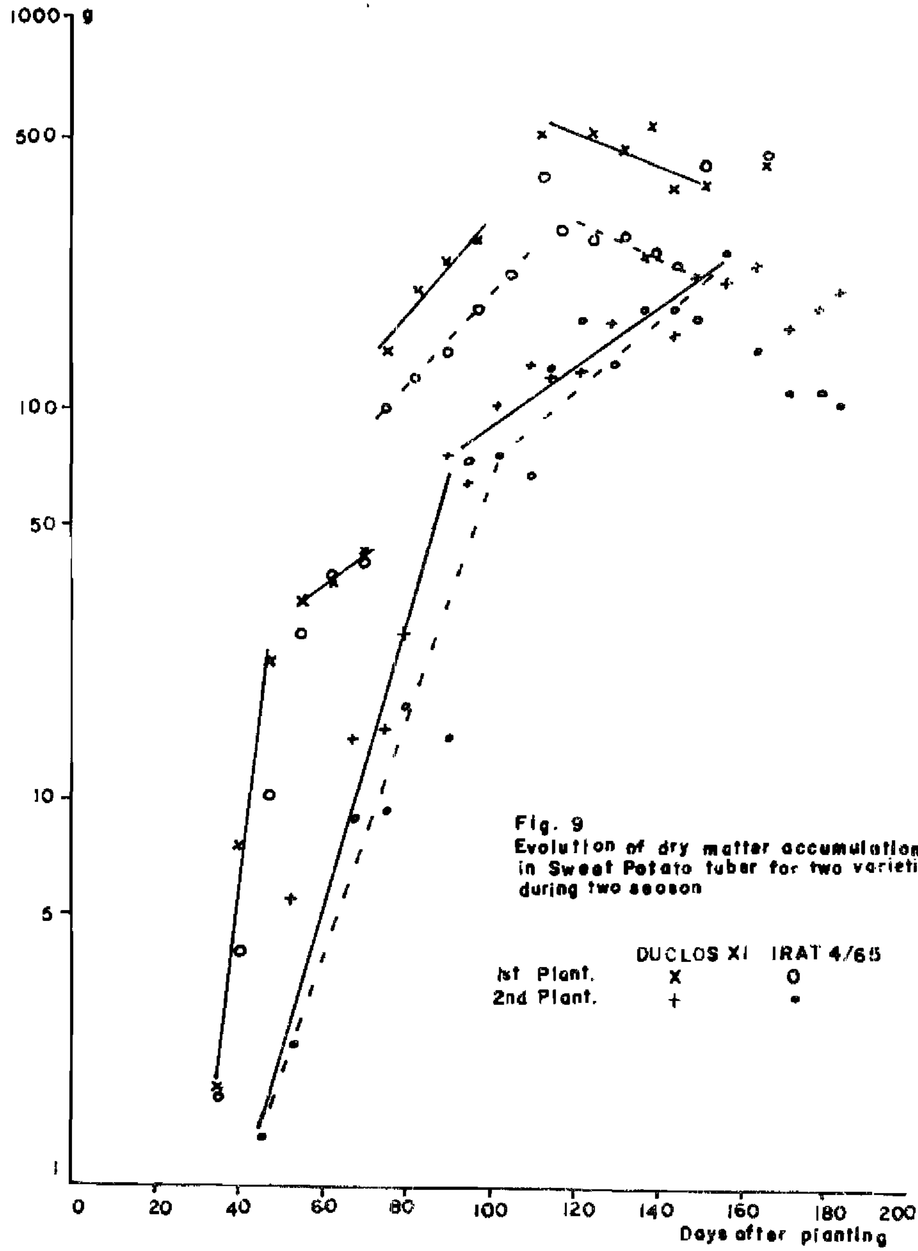


Fig. 9
Evolution of dry matter accumulation in Sweet Potato tuber for two varieties during two season

These facts relate to particular relationships between lamina surface and number of leaves. They are visible in Table III where correlation and regression coefficients support the following points:

Highly significantly correlations between number of leaves and lamina surface; no differences among the coefficients.

Significant variation of regression coefficients among periods of growth and between the plantings.

Superiority of the coefficient of 14–82nd day of first planting over the others.

Inferiority of the coefficient of 32–74th day of second planting to the coefficient of the 32–109th day of the same planting.

It is difficult to say whether in the first planting evolution is more normal than in the second. In both it happens that changes in relationships, involving modified lamina individual size, are rapidly effective and may explain the discrepancies between dry matter total accumulation in lamina and evolution of its mean dry matter percentage.

(c) *Leaf and stem-petiole system*

The morphology of the lamina itself does not account for varietal differences here, if it reacts siguificantly with planting time. But the lamina is an integral part of the canopy, and the stem-petiole system determine the supporting network of lamina system.

A conventional "shading index" was employed (DEGRAS, 1967) in Yam investigations from lamina surface divided by fresh stem and petiole weight. The figure 8 shows the result when applied to the Sweet Potato plantings.

We find that the final form of the canopy of the first planting appears early and generally so in the canopy structure of second plantation (*see* regression coefficients above). However the varietal difference is there, and fairly constant.

What is implied iu this situation proceeds from the variance analysis of dry matter accumulation in the stem-petiole system: it is that the usual superiority of first planting over the second one remains. But a definite superiority of DULCOS XI exists in the second planting.

The role of the stem-petiole system as a preferential site of accumulation seems here associated with a decrease in the "shading index" which may correspond to smaller new leaves and/or fall of old leaves, as well as to growth of the stem-petiole system.

(d) *Dry matter accumulation in tuber*

The growth curve (figure 9) of dry matter accumulation is clear. Mainly, three exponential phases exist and perhaps another short one is present in the first planting.

1. High rate increase phase from onset of tuberisation:

   35–48th day—DUCLOS XI in first planting.

   35–55th day—IRAT 4/65 in first planting.

   52–90th day—DUCLOS XI in second planting.

   52–95th day—IRAT 4/65 in second planting.

This phase is a little shorter with DUCLOS XI in which rate of growth is higher.

2. Medium rate increase phase:

(*a*) In the first planting a break in the regression line is possible. This does not alter the rate of growth but leads to a new ordinate with a marked superiority of DUCLOS XI.

(*b*) As at the beginning of tho first planting phase, no varietal difference is noted during the second planting.

2. Stopping or decrease rate phase.

Its beginning and general form are not clear-cut in every case. This may be due to lack of homogeneity of the remaining plants.

With regard to these aspects, however, superior to first planting is observed over the second. Two mechanisms are involved:

(*a*) Different growth rates: in the first phase.

(*b*) Difference in ordinate origins of the phase (or during the phase): two other phases.

The analysis of variance confirms all these trends. It supports:

Superiority of DULCOS.

Superiority of first plantation, and no plantation × variety interaction.

Significant evolution up to the 112th day in the first planting.

Significant decrease from the 158th day in the second planting.

As the tuber represents the finality of the crop, the stage of *Maturity* badly defined from the growth curve, must be determined from another criterion. Water/dry matter balance give the best one. Figures 10 and 11 lead to three kinds of conclusion in this respect. They are: Regularity of the curves offering three phases: rapid increase, middle rate decrease, very low rate increase. Maturity stage may be defined as third phase. In the first planting it begins on the 104th day, and in the second planting on the 116th day, for both varieties.

The varieties, as well as the plantings, allow for perfect superimposition of the curves, which implies:

Similarity of level balance of water/dry matter content at every state.

Bioliogical equivalence of first and second plantation sampling on account of sampling order.

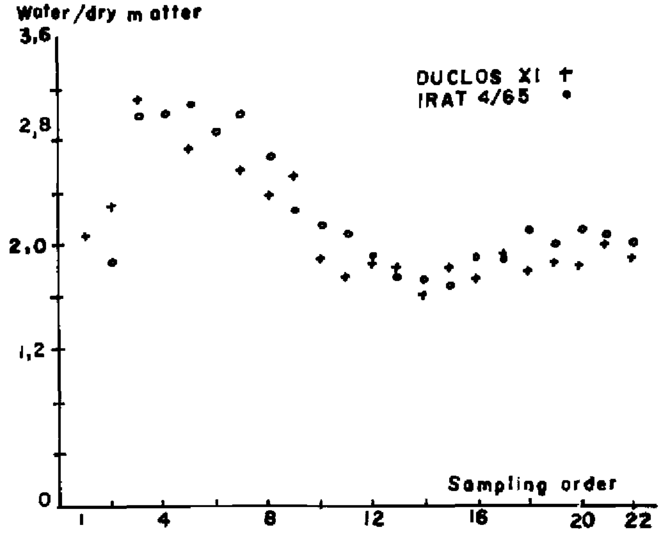
(*e*) *Leaf area and tuber relationship*

The following values of correlation and regression coefficient calculated over means of equivalent samplings for both plantings are interesting:

Periods	*Coefficient*	*b coefficient*
1–9th week	+0,960 (H.S.)	+0,354
9–14th week	—0,919 (H.S.)	—2,330
15–22nd week	+0,615 (N.S.)	+0,937

It appears that there is not an unidirectional relationship between leaf area and tuber growth. The leaves may determine tuber growth during their increase as well as during their regression. The correspondence of the last period (15–22)

Fig. 10 - Evolution of water/dry matter balance in tuber of two varieties of Sweet Potatoe



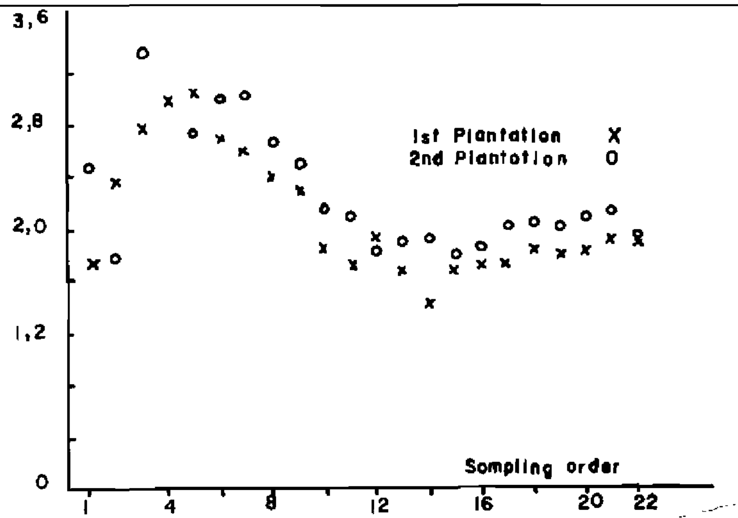
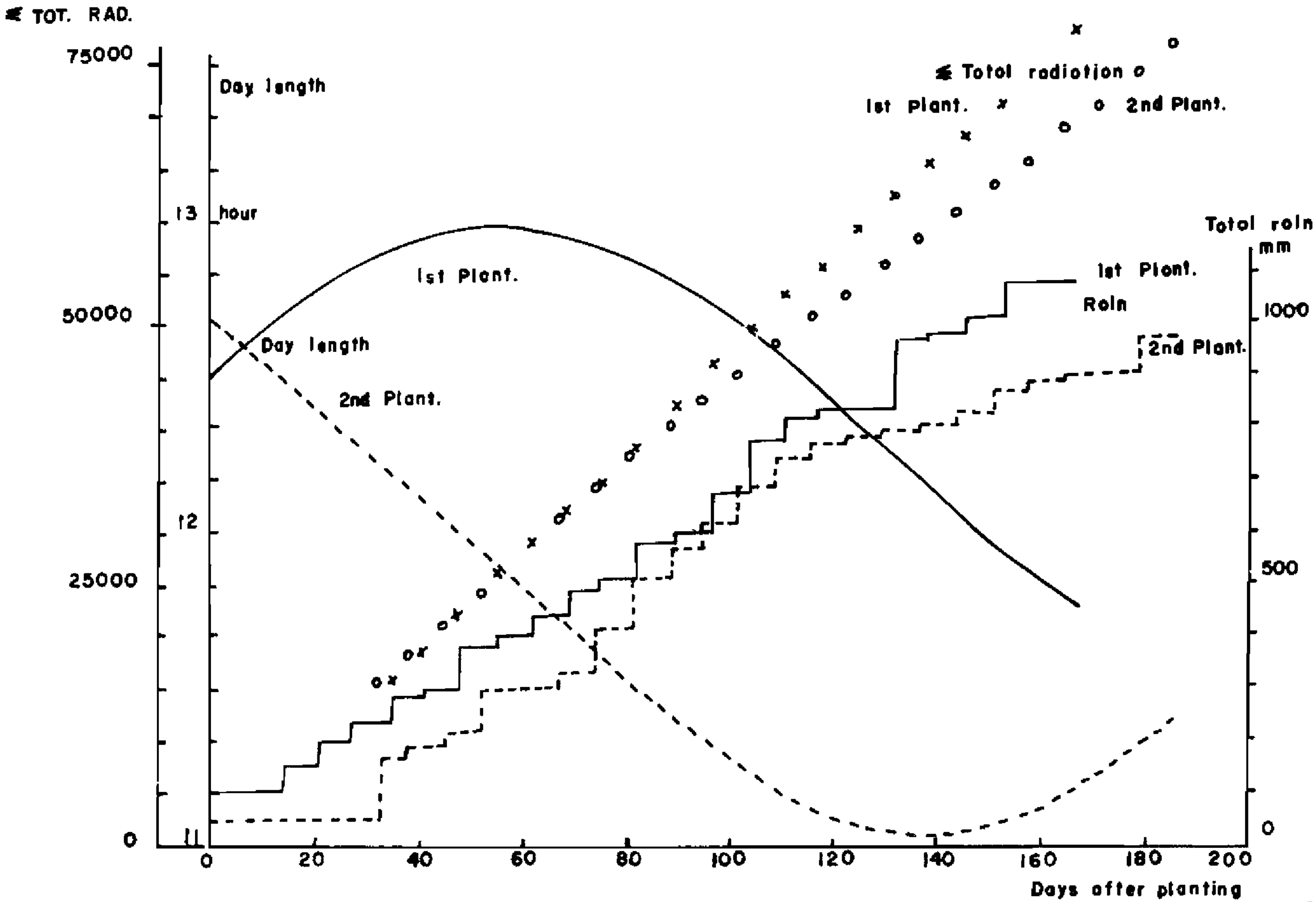


Fig. 11 —Evolution of water/dry matter balance in tuber of Sweet Potato for two plantations



EVOLUTON OF TOTAL RADIATION, DAY LENGTH AND AMOUNT OF RAIN DURING TWO SWEET POTATO PLANTATIONS
(From data of Station de Bioclimatologie, C.R.A.A.G., Duclos, Petit-Bourg, Guadeloupe, 1967-1968)

with the maturity stage seen above is noticeable. Also is the correspondence between the curve of water/dry matter balance in tuber with the curve of percentage of lamina in dry weight of plant. However, more is to be learnt before binding all those possible interactions.

IV. Climatic incidents in growth of Sweet Potato

It follows from above that seasonal effects are far more important in growth level than varietal one, for the material considered.

Figuro 12 sums up the main climatic data: total radiation, rain, day length the effects of which are briefly outlined.

(*a*) *Total radiation:* This element can aid to define some growth phases. But, in this case, it does not account for the differences between plantings (figures 13 and 14).

(*b*) *Rain:* Here, a better approach for seasonal differences is seen, at least for the beginning of crop cycle (Figures 15 and 16). For tuber, as well as for leaf area, the crop responses are closer at the beginning, when estimated in function of total rain, than with total radiation. Nevertheless, very soon, the different seasonal behaviours prevail.

(*c*) *Day length:* It is generally accepted that Sweet Potato is a short day plant. Indeed no flowering occurs in the first crop, while both varieties set flower in the second one. The floral stage corresponds, in this planting, to the end of the high rate increase phase of dry matter in the tuber. The marked breaking of the regression line of the middle rate increase phase in the first plantation suggests that lack of successful internal process of flowering can play some part in the shift of ordinate origin which leads to better yield.

V. Yield and varietal growth differences in Sweet Potato

Several aspects of growth and morphological differences conditioning varietal yield ability have been gathered during this study. They may be summarised below:

The most simple aspect reside in variation of level of origin of a growth phase. We found it first for the second phase of the growth curve of fresh total plant weight. There, IRAT 4/65 is superior to DUCLOS XI. Again we found it for the second phase in growth curve of dry matter accumulation in tuber. There, DUCLOS XI is superior IRAT 4/65.

Different processes are involved in each case and they relate to other ways of varietal determination of yield. In the first case it is obvious that duration of the growth phase preceding a lower rate phase entails higher performance. The second case has been related to lack of normal occurrence of the floral stage. This may be understood from the seemingly poorer seed-setting ability of this clone as observed in the second crop. Its physiology supposes a better organisation toward vegetative reproductive system. Each condition that promotes flowering inhibition would be advantageous.

Consistent duration of growth phase is to be found in the steady yield of DUCLOS XI, when in IRAT 4/65 seed-setting occurs and a corresponding decrease of tuber dry matter is noticed. These above varietal process are often linked with ecological pressure. Their occurrence is not evident in both plantings for the same phase.

Rate of growth leads to a constant situation in respect of greater participation of stem-petiole system and less participation of tuber in dry matter distribution for IRAT 4/65. This, conversely, corresponds to the higher initial rate of tuber bulking in DUCLOS XI. This involves also the general superiority of its shading index.

ACKNOWLEDGMENT

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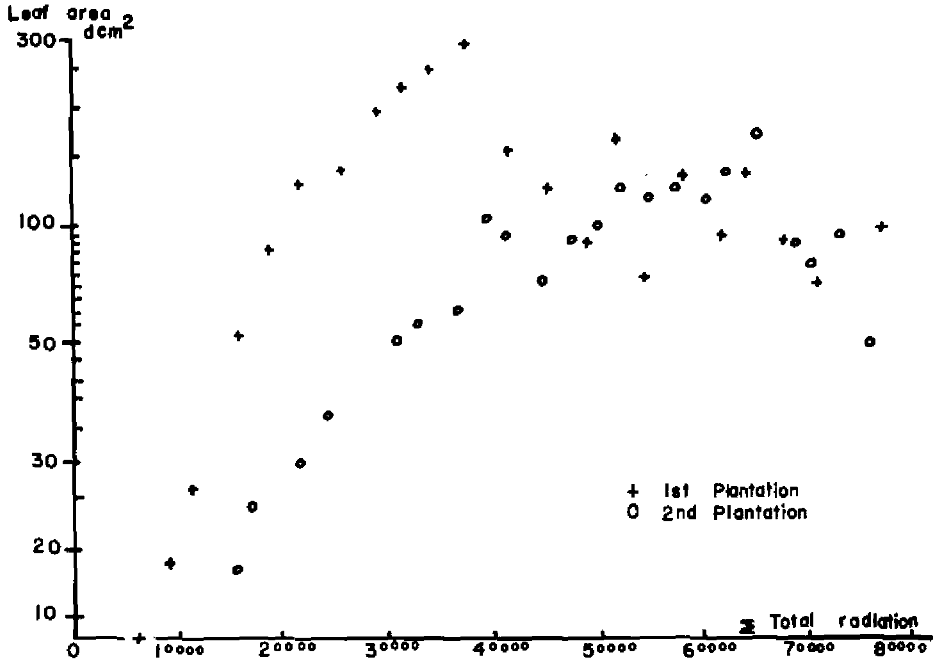
TABLE 1

Vegetative Event in Sweet Potato Plantings

	First Plantings		Second plantings	
	Dato	Age in days	Date	Age in days
Plantation...	4.27.68	0	8.7.68	0
First sampling	5.11.68	14 (1)	8.8.68	32 (1)
Tuberisation (onset)	6.1.68	35 (4)	9.28.68	52 (4)
Flowering (onset)	none	—	11.9.68	95 (9)
First drying of leaf	7.19.68	82 (11)	11.23.68	109 (11)
Seed formation	none	—	12.7.68	123 (13)
Last sampling	10.12.68	168 (22)	2.8.68	186 (22)

(Number in brackets referred to rank of sampling)

Fig. 13 - Total radiation & seasonal leaf area in Sweet Potato



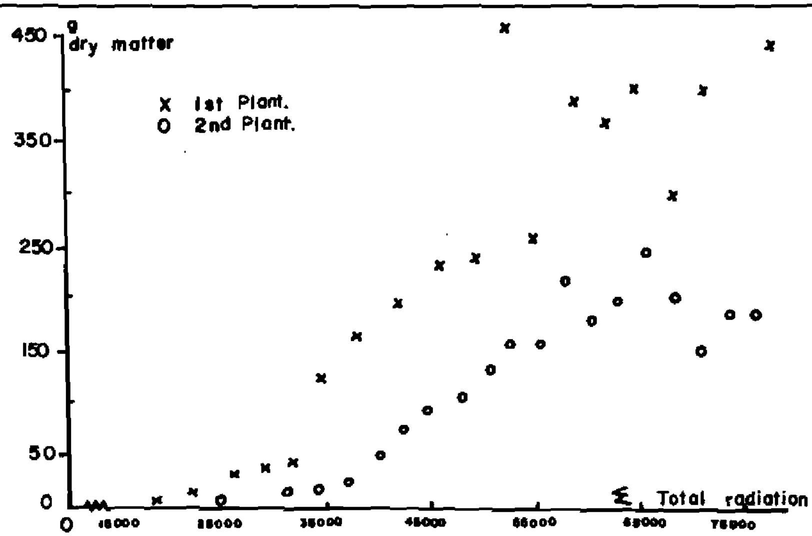


Fig. 14 - Total radiation & seasonal dry matter accumulation in Sweet Potato.

Fig. 15 - Amount of rain & seasonal leaf area in Sweet Potato

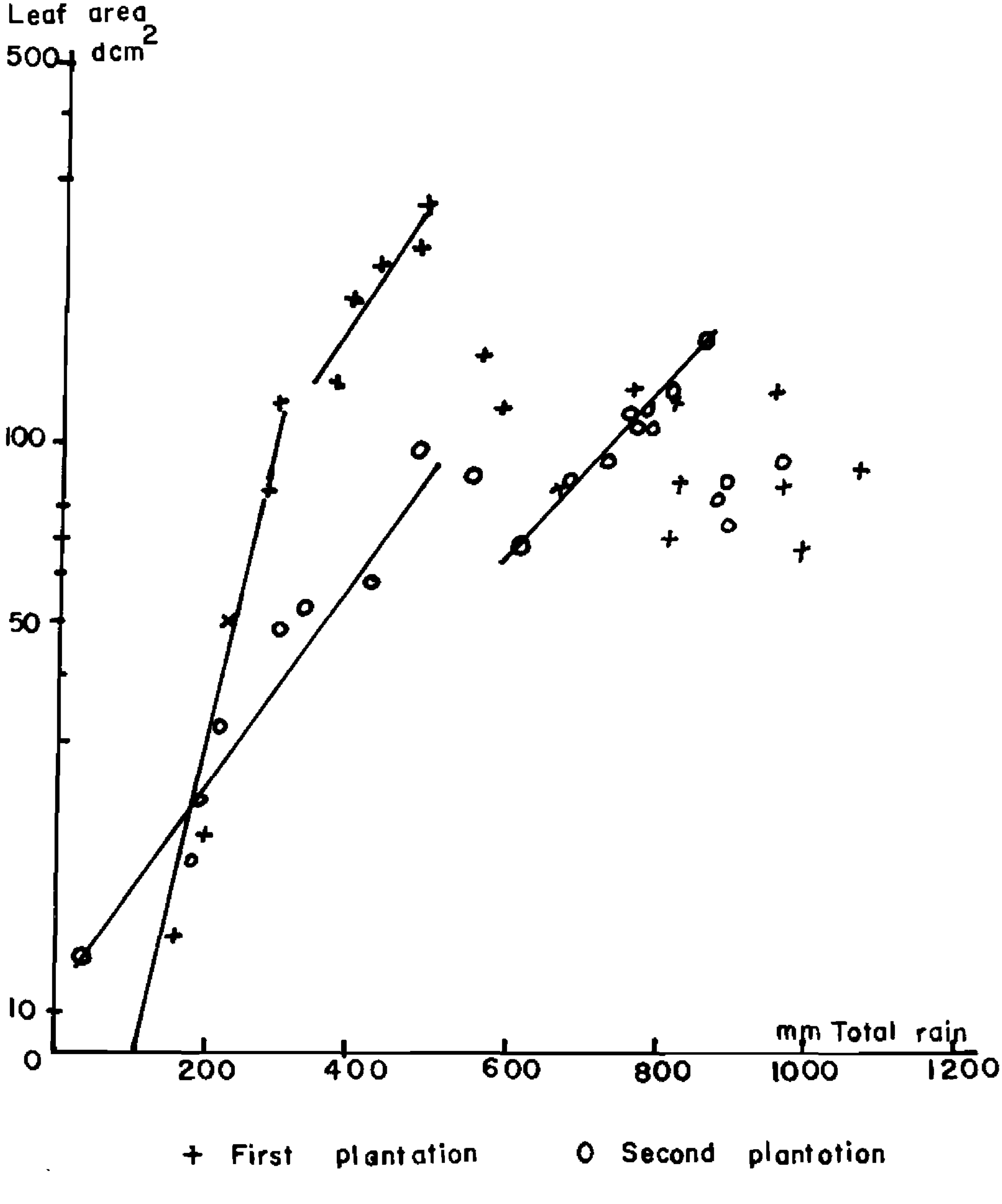


Table II

Maximum or/and mean values of Sweet Potato observations

Observations		Varieties XI 1	Varieties XI 2	Varieties 4/65 1	Varieties 4/65 2	Plantation 1	Plantation 2	Mean
LAMINA								
DRY MATTER ACCUMULATED (G/PLANT)	Maximum	92.3	51.9	78.3	52.5	83.2	51.3	67.3
	at (days)	112	158	82	95	83	158	120
	Mean	43.8	29.2	42.0	32.8	42.9	31.0	36.9
	Final	61.1	15.8	40.9	18.7	51.0	17.3	34.1
IN % TOTAL PLANT	Maximum	57.0	49.0	50.0	51.0	53.5	50.0	51.7
	at (days)	27	45	27	38	27	41	34
	Final	10	6	7	6	8.5	6	7.2
IN % FRESH WEIGHT	Maximum	23	21	22	19	22.5	20.0	21.2
	(at days)	125	165	75	123	100	144	122
	Final	20	16	19	19	19.5	17.5	18.5
NUMBER	Maximum	343	302	301	275	322	312	317
	at (days)	112	158	139	158	120	158	139
SURFACE (DM2/PLANT)	Maximum	29.4	16.8	268	161	281	164	223
	at (days)	82	158	82	158	82	158	120
	Mean	121	79	111	80	116	79	98
STEM + PETIOLE								
DRY MATTER ACCUMULATED (G/PLANT)	Maximum	156	82.1	141	112	149	95.7	122
	at (days)	112	158	112	95	112	158	135
	Mean	67.0	45.0	71.7	58.7	69.3	51.8	60.6
	Final	108	25.2	95.9	30.9	102	28.0	64.9
IN % TOTAL PLANT	Maximum	52	49	51	51	51.5	50.0	50.7
	at (days)	14	38	14	32	14	35	29
	Final	18	10	18	16	18	13	16.5
IN % FRESH WEIGHT	Maximum		16	17	15	16	15.5	15.7
	at (days)	132	186	153	151	142	168	158
	Final	14	16	16	15	15	15.5	15.2
TUBER								
DRY MATTER ACCUMULATED (G/PLANT)	Maximum	526	245	442	257	448	234	341
	at (days)	139	137	168	158	112	158	135
	Mean	208	112	157	89.1	182	100	141
	Final	424	205	442	103	433	154	294
IN % TOTAL PLANT	Maximum	79	83	76	69	77.5	76	76.7
	at (days)	132	186	168	172	150	179	164
	Final	71	83	76	68	72	75.5	73.7
IN % FRESH WEIGHT	Maximum	40	35	37	38	38.5	36.5	37.5
	at (days)	82	130	97	38	89	84	86
	Final	35	34	33	32	34	33	33.5

TABLE III

Number of leaves (x) and leaf area (y) for periods of growth in Sweet Potato

	Corrolation Coofficient	Regression Coefficient
FIRST PLANTATION		
14—82nd day	0.966	1.076(A)
90—168th day	0.811	0.546(C)
SECOND PLANTATION		
32—74th day	0.990	0.312(D)
32—109th day	0.926	0.633(B)
116—186th day	0.890	0.573(C)
	All are highly signifiactive	Letter group significative —diff.

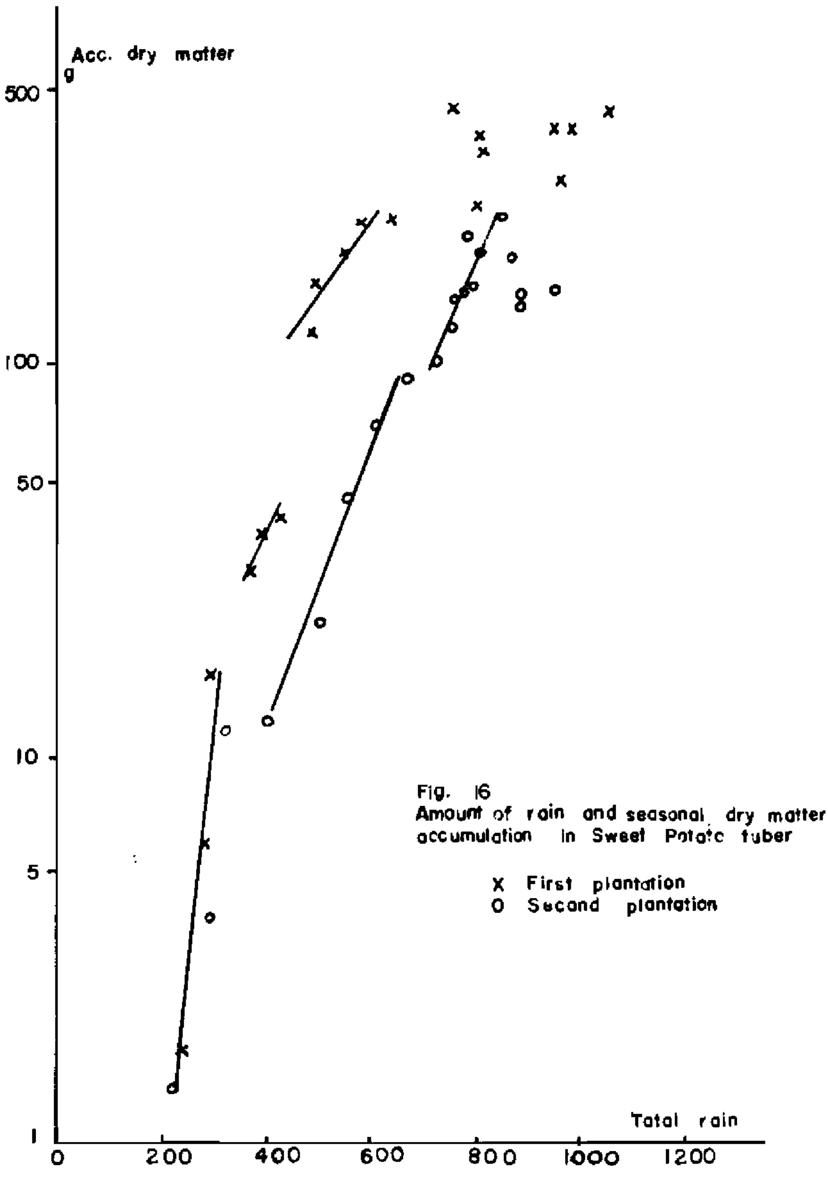


Fig. 16
Amount of rain and seasonal dry matter accumulation in Sweet Potato tuber