NOTES ON SWEET POTATO RESEARCH IN WEST NEW GUINEA (WEST IRIAN)

— *by* —

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In most of the Papuan communities of West New Guinea (West Irian), like on many other islands in the Pacific, the food intake is largely dependent on a single staple food, namely sago, taro or sweet potato.

The sweet potato is the crop of the high valleys in the central part of the territory, where almost half of the population lives. These people, whose existence was not known until twenty or thirty years ago and who since their first contact with explorers and governmental administrators hardly have been influenced by modern civilization, apply a remarkably accomplished agricultural system. The particular areas are very densely populated and suitable land is scarce. Consequently, shifting cultivation is a luxury the highland Papuans from time immemorial have not been able to afford. They developed instead agricultural methods permitting almost permanent soil utilization. It is their practice to grow sweet potato in checker-board gardens, which generally consist of more or less square beds, often the size of as little as 2 or 3 m^2 , and wide and deep drainage ditches surrounding the beds. After each harvest and before planting the next crop the ditches are deepened considerably. All mud, plant waste and other dirt thus excavated is spread over the beds, thereby covering and conserving the organic material left over from the previous crop. Apparently as a result of this routine, the soil is kept in a sufficiently fertile condition to produce time after time satisfactory yields.

In every respect the physical well-being of the highland Papuans depends on the sweet potato, which accounts for nearly one hundred percent of their diet. In addition they consume negligible quantities of sugarcane, some wild herbs and pork, the latter only when on the occasion of the sporadically occurring ritual festivities pigs are slaughtered.

Of course, this unbalanced diet — although, as readily is admitted, the people concerned have survived on it for many generations — was a matter of great concern to physicians and nutritionists. They detected various deficiencies, the most serious of these being a general prevalence of protein malnutrition.

Steps to counterbalance the protein deficiency were considered necessary. But how should this problem be tackled? It would certainly not be a practical and lasting solution to import protein-rich food from elsewhere for distribution among the numerous highland communities, which generally neither know money nor are in a position to earn it and due to the absence of roads and navigable waterways are completely isolated from the coastal areas. Therefore, any realistic attempt to improve the diet would have to be based on measures within reach of the people concerned, viz., raising more farm animals and fish, growing crops containing much protein and increasing the protein content of the traditional food crop.

The first and second approach are both beyond the scope of this paper. Suffice it to say here that the agricultural officers responsible for carrying these measures into effect encountered almost insurmountable difficulties, mainly because of the mountain dwellers' fervent dislike for everything which is new to them, including new food stuffs.

The present paper deals with research predominantly aimed at improving the nutritional value of the sweet potato, which was carried out by the Agricultural Research Station, Manokwari, in co-operation with the Department of Tropical Crops of the State of Agricultural University, Wageningen, The Royal Tropical Institute, Amsterdam and The Central Institute for Food Research, Utrecht. Investigations began in 1959 and lasted until 1963, when the work had to be broken off in consequence of the transfer of West New Guinea (West Irian) by the Netherlands to Indonesia. Part of the findings have been published in scientific journals. A great deal of the results, however was still hidden in internal reports and notes. It seemed useful to recapitulate the whole of the work in one paper to be presented to the First International Symposium on Tropical Root Crops.

CHEMICAL COMPOSITION OF SWEET POTATO TUBERS

Introductory Remarks

In the literature on the subject widely diverging percentages for the various constituents of sweet potato tubers occur. To a certain degree this lack of uniformity may be due to genotypical differences between the clones concerned, but it is very likely that also other factors play a role, such as methods of sampling, treatment of the samples, age of the crop and environmental conditions during the growing period.

Consequently, most of the analysis performed as part of the present study were not only to provide data on the chemical composition of tubers of different clones, but at the same time had to turn out information on the import of these other factors.

Not until 1962, a branch of the Agricultural Research Station was established in the highland. As a result during the greater part of the research period most of the field work had to be carried out at the main station, in the beginning at Hollandia and later at Manokwari (both lowland). This did not present serious difficulties, since the sweet potato grows very well at low altitudes. Moreover, a large collection of clones from the coastal area as well as the high valleys and from abroad was already available at the main station.

A more detailed presentation of part of the work discussed below is given in Oomen et al (1961) and Ruinard (1960).

Sampling and treatment of the samples

All chemical analysis had to be performed in The Netherlands, mainly at the Royal Tropical Institute and partly at the Central Institute for Food Research.

Preliminary laboratory work had shown that for chemical analysis Samples of 1kg fresh weight each were adequate. It was also found that such Samples provided they consisted of big and small tubers selected at random from the whole lot, were large enough to be sufficiently representative for the ample quantities of tubers obtained from sizable plots.

Table I. Chemical composition of the tubers of thirteen high-yielding clones

Contents (in percentages of fresh weight)	Budodugi	Kadakaga red	Kadakaga white	Egeida	Mogoudugu
water	69.4	71.2	69.9	77.2	73.2
fibre	0.98	1.19	1.23	0.82	1.02
starch	21.4	19.2	20.9	13.7	16.3
sugar	2.9	3.0	3.1	4.3	5.2
crude protein	0.89	0.63	0.78	0.82	0.70
real protein	0.86	0.60	0.66	0.64	0.59
ash - total	0.92	0.91	0.81	0.86	0.83
K	0.39	0.41	0.35	0.38	0.39
P	0.052	0.044	0.045	0.044	0.037
Mg	0.025	0.019	0.019	0.016	0.018
Ca	0.039	0.030	0.031	0.029	0.021
Na	0.0012	0.0009	0.0009	0.0014	0.0016
Real/crude protein	0.97	0.95	0.85	0.78	0.84
Flesh colour	(.......... white ....)			(.... light yellow ....)	
Origin of the clones	(.............. Wissel Lakes area (highland) ....)				
Site where grown	(......................... do. ....)				
Age when harvested	(...................... 7 months ....)				

Genjem 1	Genjem 2	Putri Selatan	Louisiana 5	Early Port	21—51	21—82	21—172
70.3	73.4	72.3	74.5	75.0	69.5	75.2	76.9
1.37	0.98	1.08	1.22	1.08	1.16	1.09	1.04
17.8	15.9	14.8	12.2	13.2	18.9	13.6	12.1
5.3	3.5	4.2	6.5	4.6	4.6	4.5	4.8
1.43	2.45	2.22	2.12	2.35	2.20	2.18	1.73
1.07	1.68	1.69	1.45	1.50	1.62	1.51	1.11
0.80	0.86	0.89	1.06	0.82	0.79	0.86	0.73
0.40	0.34	0.37	0.40	0.30	0.31	0.34	0.29
0.064	0.082	0.059	0.094	0.074	0.090	0.083	0.068
0.028	0.048	0.040	0.056	0.054	0.050	0.043	0.049
0.026	0.036	0.036	0.061	0.046	0.039	0.031	0.028
0.0015	0.0013	0.0014	0.0013	0.0015	0.0015	0.0012	0.0012
0.75	0.69	0.76	0.68	0.64	0.74	0.69	0.64
(white purple)	(............ yellow ....)			(.................. orange ....)			
(... Hollandia ...) (lowland)		Indonesia	(.................. U.S.A. ....)				
(..................... Hollandia (lowland) ....)							
(..................... 5½ months ....)							

To economize on airfreight costs and to prevent deterioration during transport, immediately or at most a few days after being harvested (except in the storage experiment) all tubers were cut to slices not thicker than 5mm and subsequently dried at temperatures ranging from 35° to 45°C. The dry and crisp slices, containing not more than 10% moisture, were then packed in polythene bags and immediately shipped by air to the above-mentioned Institutes.

Constituents of various clones

To begin with the chemical composition of tubers from eight clones grown in the collection of the main station (lowland) and five clones grown in an experimental garden in the Wissel Lakes area (highland) was ascertained. All thirteen clones are relatively high-yielding. The first eight were grown at the same site and planted and harvested at the same date. This also applies to the second group of five clones. The results are presented in Table I. The percentage starch was found by direct determination. Sugars were determined as glucose. Crude protein was found by means of the Kjeldahl method, real protein by precipitating first all protein compounds with $CuSO_4$ and NaOH followed by Kjeldahling the precipitate (both nitrogen contents thus determined were multiplied by 6.25 to obtain the percentages crude and real protein).

Table I confirms that the chemical composition of different clones may vary widely. Particularly striking were the differences in protein content. On the whole the clones grown in the lowland contained considerably more crude and real protein than those from the highland. However, in the former group the ratio real/crude protein was smaller than in the latter. There were also noticeable differences in the contents of starch and sugar, indicating that certain clones are much sweeter than others. The differences in the mineral compounds were generally less conspicuous.

Effect of ecological factors

Four clones native in the high valleys were grown at the same time in the Wissel Lakes area (highland) and at Manokwari (lowland). To rule out even the slightest chance of accidentally using impure planting material, all cuttings used for the two plantings had been raised in multiplication plots, one for each clone at each site, both planted with cuttings obtained in the highland from a single plant of the particular clone. At both sites the crop was harvested when seven months old. Table II gives a resume of the results.

Two striking differences between the two sites stand out. The first concerns the protein content. The tubers grown in the Wissel Lakes area contained considerably more crude protein and also their real/crude protein ratio was noticeably higher, the net result being a real protein content approximately twice as high as in the tubers produced at Manokwari. Secondly, the lowland tubers contained roughly fifteen to twenty times as much sodium compared with the highland tubers.

Effect of storage

Immediately after harvesting a field trial with the clones Okinawa 1 and Louisiana 5 at Hollandia, from both clones three samples were taken. One

Table II. Effect of ecological factors; composition of the tubers of four clones grown in the Wissel Lakes area (at + 1700 m) and at Manokwari (+50 m)

Contents (in percentages of fresh weight)	Tettoweja		Nabedau		Mogoudugu		Buguanotta	
	Highland	Lowland	Highland	Lowland	Highland	Lowland	Highland	Lowland
water	64.7	67.8	69.0	69.1	69.9	71.3	73.8	69.9
fibre	0.92	1.06	0.93	0.99	0.96	0.89	0.86	1.23
starch	24.6	21.2	19.0	20.2	18.9	19.6	15.6	21.4
sugar	4.7	5.3	5.3	4.3	5.0	4.2	5.6	3.4
crude protein	1.06	0.53	1.36	0.96	0.78	0.52	0.90	0.66
real protein	0.95	0.47	1.15	0.71	0.66	0.32	0.81	0.39
ash - total	0.86	1.03	0.95	1.17	0.89	0.92	0.60	1.11
K	0.31	0.28	0.29	0.28	0.32	0.30	0.18	0.26
P	0.072	0.074	0.065	0.062	0.053	0.075	0.052	0.054
Mg	0.015	0.018	0.018	0.015	0.010	0.016	0.020	0.018
Ca	0.058	0.078	0.056	0.108	0.039	0.077	0.051	0.106
Na	0.0021	0.0335	0.0019	0.0337	0.0021	0.0370	0.0016	0.0352
Real/crude protein	0.90	0.89	0.85	0.74	0.85	0.62	0.90	0.59
Flesh colour	(.................. white ....)				(....light yellow....)		(..... orange .....)	
Origin of the clones	(............................Wissel Lakes area (highland)....................................)							
Age when harvested	(..7 months.............. ....)							

sample of each clone as dried at once and directly sent to the Netherlands for analysis. The second sample was stored for half a month and third for onc month, at a shady and wind-swept place, prior to being dried and shipped.

Storage for half a month caused many buds to swell and sprout. After having been stored for a month part of the shoots had even developed green leaves. As appears from Table III particularly during the first half month strong desiccation occurred, resulting in wrinkling and softening of the tubers. It is likely that the stored tubers in addition to moisture also lost dry matter. The composition of the dry matter, however, did not undergo great changes.

Effect of age when harvested

From plots planted with the clones Okinawa 2 and Unit 1 Porto Rico (Hollandia) samples were taken four, five and six months after planting, whereas plots planted with the clones Mogou and Buguanotta (Wissel Lakes area) were sampled when the crop was six, seven, eight and one-half and nine and one-half months old.

Table IV shows that as to the chemical composition it did not make any significant difference whether the tubers were harvested early or late. The contents of the various constituents remained practically unchanged.

Carotene

From a nutritional point of view carotene is an important component of sweet potato tubers. However, since carotene present in stored vegetable material tends to disintegrate rapidly, particularly when exposed to relatively high temperatures, the above-mentioned dried samples were not suited for estimating the carotene content in fresh tubers. Instead, newly harvested tubers from a number of clones grown in the experimental garden at Manokwari were immediately sent by air to The Netherlands and analysed at once.

It is evident from Table V that the carotene content varied widely from clone to clone. In accordance with the results of simliar investigations elsewhere, it was found that the tubers contained more carotene as the colour of the flesh was darker.

Discussion

The analysis described so far have revealed that the tubers of different clones grown at the same time in the same environment may differ considerably in their chemical composition, particularly as regards the contents of carbohydrates, protein and carotene. They have also shown that differences in environment may cause noticeable changes in the nutritional value of tubers of the same clone.

Some of the clones in the lowland collection were found to contain twice or three times as much real protein as polular highland clones grown in the Wissel Lakes area (Table I). On the other hand, however, highland clones growing in the lowland appeared to produce only half as much real protein per kg fresh tubers as in their original environment (Table II). This may indicate that in the highland conditions for protein formation are better than in the lowland. If this conclusion is correct, then it is not unlikely that the best clones from the

Table III. Effect of storage; composition of tubers of two clones grown at Hollandia (lowland) and harvested when 5½ months old (after drying directly shipped)

Contents (in percentages of dry matter)	Okinawa 1			Louisiana 5		
	Drying immediately after harvest	Drying ½ month after harvest	Drying 1 month after harvest	Drying immediately after harvest	Drying ½ month after harvest	Drying 1 month after harvest
fibre	4.4	3.4	3.7	3.9	3.9	3.8
starch	61.3	67.6	66.8	54.7	56.9	55.2
sugar	11.2	12.1	11.2	19.6	17.5	17.0
crude protein	4.2	4.0	3.8	5.3	5.2	5.8
real protein	3.9	3.6	3.2	4.6	4.6	5.0
ash	3.1	2.8	3.1	3.4	3.4	3.7
Real/crude protein	0.93	0.90	0.84	0.87	0.88	0.86
Dry matter as a percentage of the weight of the tubers (before drying began)	28.6	38.0	38.8	30.4	36.3	36.5
Flesh colour	(........... white ....)			(............ yellow ....)		
Origin of the clones	(.... Papua and New Guinea ....)			(............ U.S.A. ....)		

Table IV. Effect of age when harvested: composition of tubers of four clones; two of them were

		Okinawa 2		Unit 1 Porto Rico		
	4	5	6	4	5	6
Contents (in percentages	months	months	months	months	months	months
of fresh weight):	76.4	76.6	75.9	74.3	74.7	75 0
water	0.97	0.87	0.89	1.26	1.09	1 03
fibre	13.8	13.6	14.0	11.5	12.3	12 8
starch	3.3	3.9	4.3	5.4	5.8	5.6
sugar	1.77	1.59	1.35	2.08	1.75	1.82
crude protein	1.30	1.05	0.96	1.59	1.32	1.30
real protein	0.76	0.72	0.70	0.86	0.94	0.88
ash - total	0.35	0.29	0.29	0.36	0.39	0.33
K	0.043	0.065	0.057	0.057	0.071	0.068
P	0.036	0.036	0.035	0.042	0.037	0.036
Mg	0.024	0.024	0.024	0.047	0.044	0.034
Ca	0.0009	0.0014	0.0012	0.0008	0.0015	0.0010
Na	0.73	0.66	0.71	0.76	0.75	0.71
Real/crude protein		white				
Flesh colour						
Origin of the clones	(. . . . . white . . . .)			(. . . . . . . orange . . .)		
Site where grown	(. . . . Papua and New Guinea . . . . .)			(. . . . . U S A. . . . . .)		
	(. . . . . Hollandia (lowland) . . . .)					

harvested 4, 5 and 6 months after planting (lowland) and two 6, 7, 8½ and 9½ months after planting (highland)

Mogou				Buguanotta			
6 months	7 months	8½ months	9½ months	6 months	7 months	8½ months	9½ months
71.6	74.8	74.4	73.9	75.9	77.4	76.8	76.7
1.11	1.06	0.84	0.89	1.04	1.06	0.79	1.00
16.6	15.4	15.0	16.0	13.0	12.7	13.8	13.4
3.6	4.2	5.1	4.2	6.3	5.2	5.4	4.8
0.94	0.76	0.79	0.86	0.77	0.59	0.65	0.72
0.82	0.71	0.67	0.73	0.63	0.52	0.53	0.56
1.07	0.96	1.00	0.95	0.64	0.60	0.57	0.64
0.50	0.43	0.45	0.43	0.29	0.25	0.24	0.22
0.060	0.058	0.057	0.032	0.048	0.039	0.036	0.036
0.046	0.018	0.016	0.018	0.035	0.012	0.016	0.016
0.046	0.022	0.020	0.025	0.020	0.016	0.024	0.032
0.23	0.22	0.0010	0.0010	?	0.0011	0.0009	0.0009
0.87	0.93	0.85	0.85	0.82	0.88	0.82	0.78
(........ white ....)				(........ orange ....)			
(........ Wissel Lakes area (highland) ....)							
(........ do. ....)							

Table V. Carotene contents of fresh tubers of various clones grown in the experimental garden at Manokwari

Clone	Flesh colour	Carotene content in mg per 100g dry matter
Okinawa1	white	0.65
Genjem 2	yellow	0.78
Louisiana 5	yellow	0.93
Louisiana 3	yellow	1.31
Louisiana 2	yellow	1.69
Louisiana 4	yellow	1.86
Putri Selatan	yellow	4.00
Porto Rico	pink	7.85
Copperskin Goldrush	orange	14.65
Louisiana 6	dark pink	17.83
Early Port	orange	29.04
Unit 1 Porto Rico	orange	33.12

lowland collection when grown in the highland would make an even better figure with respect to the highland clones in their own environment than finds expression in Table I. However, that may be, the results obtained strongly supported the assumption that it would be possible to improve the protein nutrition of the highland communities by making available to them sweet potato clones containing much more protein in their tubers than the traditional ones.

Total ash contents and composition of the ash were fairly constant for the different clones and sites. However, in this respect there was one very auspicious exception, viz., that tubers produced at Manokwari contained fifteen to twenty times as much sodium as tubers from the Wissel Lakes area and Hollandia (Tables I, II and IV). This was clearly an environmental effect that may be the result of soil differences.

Root crops like sweet potato have not a clear-cut stage of maturity. In the lowland people start collecting tubers when the crop is only three to four months old and often harvesting is not completed until seven or eight months after planting. In the highland, where growth is not rapid, harvest usually begins and ends one or two months later. As far as their nutritional value is concerned, there are indications that it does not make much difference whether the tubers, within certain limits, are harvested early or late (Table IV).

It is not uncommon that tubers are stored for a short time before being consumed. Table III shows that under normal storage conditions during the first weeks the tubers may lose a great deal of moisture. The chemical composition of the dry matter, however, was hardly affected.

NUTRITIONAL VALUE OF THE LEAVES

In addition to tubers the highland people also consume leaves of young shoots. These young and tender leaves are frequently roasted and eaten together with the tubers. The question arose whether this amounts to a nutritious contribution to the diet.

Samples of tubers and approximately 30 cm long top shoots were harvested in Okinawa 2 and Genjem 2 plots at Manokwari when these plantings were three, four and five months old and immediately sent by air to The Netherlands for analysis. The results are summarized in Table VI (taken from Ruinard, 1961).

It is evident that the dry matter of the leaves contained on the average five to six times as much real protein as the dry matter of the tubers. As to carotene the ratio was even much more in favour of the leaves. Also the contents of minerals tended to be higher in the leaves than in the tubers.

It is true that these analyses were concerned with plants grown in the lowland, but there is no reason to expect that highland material would prove to be very different in this respect. Consequently it may with due reserve be concluded that young leaves are valuable source of important nutrients, particularly of protein and carotene, so that there is every reason to stimulate in the protein-deficient highland communities the consumption of such leaves.

IMPROVEMENT OF THE HIGHLAND CROP

As appears from the analyses described in Chapter 2, some of the lowland clones contained considerably higher protein percentages than the common highland types. Obviously, introduction of these clones into the highland valleys and, provided the yields are satisfactory, their large scale distribution among the local communities would seem to contribute much to elimination of the protein malnutrition. However, this direct approach was out of the question, owing to the occurrence in the lowland plantings of an unknown but apparently serious disease, that according to investigations carried out in The Netherlands is caused by a virus or complex of viruses. Badly affected plants show dwarfish growth and do not produce any tubers. Import of this disease into the highland could be disastrous. Selfing or mutual crossing of highland clones, in the hope that among the progeny individuals rich in protein would be found, did not offer good prospects either because of the low protein contents of the parental plants.

Consequently the only way of obtaining better clones for the highland was to bring in from elsewhere seed of protein-rich clones and to select in the plant populations raised from this seed individuals with high protein contents and other desirable characteristics. The seed could either be imported from breeding stations abroad or it could be produced in the lowland collection. As to the latter source, however, it would have to be demonstrated first that the virus disease present in these plantings is not conveyed by seed. Starting from those considerations a programme was designed, of which unfortunately only a small, introductory part was realized when the work had to be broken off in the first months of 1963. Van Rheenen (1963, 1964, 1965) reported on these investigations. The following paragraphs are a resume of his publications.

Flower formation of most clones in the lowland collection was scanty and thus insufficient for large-scale breeding work, so that preliminary attempts were made to stimulate flowering by artificial means. With three clones the effect of training the tendrils along vertical racks was studied. All three appeared to

Table VI. Chemical composition of tubers and leaves

Contents (in percentages of dry matter)	Genjem 2					
	3 months old		4 months old		5 months old	
	tubers	leaves	tubers'	leaves	tuber	leaves
fibre	3.1	?	3.8	?	?	?
starch	65.9	4.2	71.0	7.2	70.9	8.0
sugar	7.3	1.1	10.4	1.5	12.1	4.0
crude protein	5.1	30.8	5.4	30.4	6.8	32.1
real protein	4.7	25.8	4.6	?	4.9	27.3
ash - total	3.5	?	3.4	9.5	2.5	10.1
K	1.29	3.37	1.17	2.78	0.95	1.88
P	0.15	0.62	0.20	?	0.22	0.39
Mg	0.09	0.30	0.04	?	0.04	0.39
Ca	0.34	1.00	0.28	?	0.19	?
Na	0.041	0.061	0.067	0.056	0.105	0.094
Real/crude protein	0.92	0.84	0.85	?	0.72	0.85
Carotene content, in mg per 100g dry matter	1.5	72.1	3.0	74.1	1.9	55.7
Dry matter as a percentage of the fresh weight of tubers and leaves	30.4	14.1	?	13.9	31.6	13.3
Flesh colour	(........................... yellow ....)					
Origin of the clones	(..................... Hollandia (lowland) ....)					
Site where grown	(..					

(— leaf blades) of two clones, 3, 4 and 5 months after planting

Okinawa 2					
3 months old		4 months old		5 months old	
tubers	leaves	tubers	leaves	tubers	leaves
3.4	?	3.1	?	2.5	?
68.7	10.1	77.3	4.4	75.4	?
6.1	0.2	10.0	1.4	10.8	3.2
6.0	31.7	6.2	32.3	6.2	34.0
4.8	30.6	4.1	23.5	3.9	26.3
3.8	?	3.1	?	2.4	?
1 60	3.03	1 22	3 51	0.82	?
0 11	0.46	0.21	?	0.22	?
0.07	0.23	0.04	?	0.03	?
0.30	0.75	0.23	?	0.19	?
0.028	0.057	0.050	0.049	0.130	?
0.80	0.97	0.66	0.73	0.63	0.77
0 7	62 0	0 5	101.1	0.4	68 0
26.2	15.5	29.4	?	31.6	13.8

(... .. .. white ....)

(...... ... . Papua and New Guinea .. ..)

... Manokwari (lowland) ....)

Table VII. Rotation experiment: tuber and groundnut yields in four successive plantings that were planted and harvested on the dates indicated

No. of planting	Treatments A	B	C	D	E
	continuously sweet potatoes without application of fertilisers	continuously sweet potatoes from 2nd planting 60 kg P_2O_5 per ha	sweet potatoes alternating with weed fallow	sweet potatoes alternating with Crotalaria	sweet potatoes alternating with groundnuts
1st	sweet potatoes 1/10/60 - 22/2/61 7,650 kg/ha	sweet potatoes 1/10/60 - 22/2/61 6,840 kg/ha	sweet potatoes 1/10/60 - 22/2/61 8,280 kg/ha	sweet potatoes 1/10/60 - 22/2/61 7,670 kg/ha	sweet potatoes 1/10/60 - 22/2/61 7,650 kg/ha
2nd	sweet potatoes 2/5/61 - 21/9/61 4,930 kg/ha	sweet potatoes 2/5/61 - 21/9/61 5,440 kg/ha	weed fallow	Crotalaria	groundnuts 3/5/61 - 30/8/61 1,120 kg/ha
3rd	sweet potatoes 23/11/61 -24/4/62 1,280 kg/ha	sweet potatoes 23/11/61 - 24/4/62 1,440 kg/ha	sweet potatoes 23/11/61 - 24/4/62 1,080 kg/ha	sweet potatoes 23/11/61 - 24/4/62 1,050 kg/ha	sweet potatoes 23/11/61 - 24/4/62 1,610 kg/ha
4th	sweet potatoes 30/5/62 - 17/10/62 3,680 kg/ha	sweet potatoes 30/5/62 - 17/10/62 3,060 kg/ha	weed fallow	Crotalaria	groundnuts 30/5/62 - 25/9/62 1,430 kg/ha

produce more flowers. Also grafting on other *Ipomoea* species followed by training the plants along vertical racks, tried with two clones, was sometimes beneficial. Mutilating the plants by removing a wedge of tissue half-way across the main stem just above the root collar and training also in this case the tendrils along vertical racks, was for one of the two clones tested favourable but did not make any difference for the other. In order to give an idea of the quantitative results, it may be mentioned that the clone Louisiana 3 developed during its flowering period when growing in the ordinary way per plant on the average 1 flower in 100 days, when trained along racks 1 flower in 20 days, when grafted on *Ipomoea congesta* R. Br. (the best one of the stocks tried) 1 flower in 8 days and when incised also 1 flower in 8 days. Two more methods were tested, viz., fertilizing the plants heavily and reducing the daylight period to 8½ hours, both with one clone. The former was virtually ineffective; the latter reduced flowering to zero.

Natural fruit setting in the lowland collection was often sporadic but sometimes moderate (up to 25% of all flowers under observation). Fruit setting after artificial cross-pollination was usually good (up to 50% of the flowers pollinated); in a few instances, however, the percentage success was zero, this apparently being due to cross-incompatibility between the parental clones concerned. Artificial self-pollination proved unsuccessful in most of the clones tested.

Under natural conditions sweet potato seed often germinate very slowly whereas the germination percentage is low. Various experiments were conducted to improve this. Scarification near the top or the hilum yielded satisfactory results, but better still was immersion of the seeds in concentrated sulphuric acid for ten or twenty minutes followed by rinsing them thoroughly in clean water. In one case the latter treatment raised the percentage germination after one week as compared to the check from 10 to 70% and in another from 20 to 90%. Immersion of the seeds for 2 minutes in boiling water killed the embryos. Placing the seed in a little water of 100°C and allowing it to cool down to room temperature was not successful either, though this treatment did not kill the seed.

The breeding and selecting programme proper was only in its exploratory phase when the work had to be broken off. Yet some methods and findings seem worth mentioning. In the lowland collection parents were chosen on the basis of their yield, tuber shape and size, protein percentage and degree of resistance to the above-mentioned virus disease, the fungus Elsinoe batatas Jenkins and Viegas and the weevil *Cylas formicarius* F. The young seedlings resulting from controlled crossings were during the first critical weeks raised in pots and then transferred to the field, where by repeatedly pruning them the development of new shoots was stimulated. As soon as they had formed enough foliage 10 cuttings were taken from each seedling and planted in one row amidst two rows of the test clone. This planting constituted the first selection round. During the growth period and when harvesting some five months after planting, the performance of the new clones was compared to that of the adjacent test clone rows, whereby particular attention was paid to the characteristics mentioned before (except the protein percentage, because the equipment needed for simple and rapid protein determinations was not yet available). The worst 75% of the new clones were then discarded and the tubers of the best 25% were planted to provide cuttings for the second selection planting. The procedure during the second round was similar to that in the first, the only difference being that the

Table VIII. Rotation experiment: chemical composition of tubers and leaves

Contents (in percentages of dry matter			1st		2nd	
	A	B	C	D	E	A
tubers - starch	61.5	59.5	61.1	61.3	62.4	63.4
sugar	12.6	13.4	12.6	10.8	12.5	11.1
crude protein	7.9	7.6	7.0	7.0	6.2	7.4
real protein	5.8	6.2	5.8	5.8	5.0	5.9
ash - total	3.2	3.5	3.7	3.3	4.0	4.0
K	1.24	1.24	1.16	1.22	1.40	1.34
P	0.22	0.24	0.22	0.20	0.28	0.16
Mg	0.10	0.10	0.10	0.10	0.09	0.19
Ca	0.16	0.22	0.26	0.20	0.22	0.29
Na	0.130	0.125	0.115	0.105	0.085	0.067
leaves - starch	?	?	?	?	?	6.2
sugar	?	?	?	?	?	1.6
crude protein	31.7	32.8	32.1	33.0	31.1	32.8
real protein	27.4	26.8	23.8	27.2	25.9	27.4
ash - total	?	?	?	?	?	?
K	3.34	3.26	3.49	2.86	3.08	3.17
P	0.52	0.48	0.52	0.46	0.46	0.35
Mg	0.39	0.43	0.43	0.42	0.40	0.47
Ca	0.74	0.83	0.77	0.75	0.80	0.94
Na	0.018	0.019	0.014	0.013	0.017	0.006
Real/crude protein:						
tubers	0.73	0.82	0.83	0.82	0.80	0.80
leaves	0.87	0.82	0.74	0.82	0.83	0.84
Dry matter as a percentage of fresh weight:						
tubers	27.8	30.6	29.9	29.1	27.7	28.0
leaves	16.2	16.0	17.4	15.0	19.6	15.7

(— leaf blades) of close Genjem 2

Plantings and treatments

		3rd				4th	
B	A	B	C	D	E	A	B
63.4	64.0	65.2	65.1	64.7	64.3	64.8	63.5
11.6	13.9	12.1	13.2	13.2	13.6	9.6	11.6
7.9	5.7	5.6	5.5	6.2	5.4	5.9	5.5
6.2	4.7	4.2	4.2	4.7	4.0	4.4	3.7
4.0	4.3	4.0	4.2	4.1	3.9	5.1	5.4
1.23	1.16	1.04	1.16	1.19	1.05	0.82	0.93
0.18	0.15	0.14	0.12	0.09	0.14	0.14	0.18
0.19	0.14	0.15	0.12	0.14	0.11	0.39	0.42
0.33	0.29	0.28	0.24	0.18	0.24	0.37	0.33
0.079	0.048	0.045	0.050	0.041	0.051	0.053	0.059
6.8	6.9	6.6	8.0	7.7	8.5	7.0	6.7
1.5	1.9	1.2	1.4	1.2	1.4	1.3	1.1
32.3	30.8	31.4	31.6	30.0	29.5	26.8	27.8
26.8	25.7	27.5	26.0	24.6	24.6	23.9	23.2
?	?	?	?	?	?	?	?
3.09	3.45	3.37	3.28	3.19	3.14	3.88	4.22
0.38	0.38	0.42	0.40	0.38	0.39	0.30	0.34
0.42	0.40	0.40	0.40	0.36	0.40	0.77	0.73
0.96	0.78	0.94	0.77	0.79	0.80	1.18	1.08
0.007	0.005	0.004	0.004	0.004	0.004	0.016	0.012
0.78	0.82	0.75	0.75	0.76	0.74	0.75	0.67
0.83	0.84	0.87	0.82	0.82	0.83	0.89	0.84
28.2	30.6	30.2	29.8	30.7	30.9	?	?
14.9	?	?	?	?	?	14.4	14.9

rows were much longer. Again 75% of the clones were discarded. The remaining 25% were transferred to the third selection planting, where each new clone occupied a square plot the size of 20 m^2 and was surrounded by identical plots planted with the test clone. Again the same selection procedure was pursued. It was intended to discard once more 75% of the clones and to test the remaining 25% (that is 1½% of the initial number of seedlings) in full variety trials. However, on termination of the work this stage had not yet been reached. Of course it was too early to draw conclusions. Nevertheless, it should be remarked here that in the generative progenies thus tested several prospectively good clones occurred and that with respect to yields and properties of the tubers (size, shape, colour of the flesh and colour of the skin) there was evidence of an appreciable resemblance between each offspring in its entirety and the parents. At the highland station, established in 1962, a similar selection programme was started, using seed received from the U.S.A. and Japan. Unfortunately, this had to be broken off already a few months after its beginning.

MORE ABOUT THE EFFECTS OF ECOLOGICAL FACTORS

Earlier in this paper attention was drawn to the observation that the chemical composition of the tubers of four highland clones when grown in the lowland was different from that of the tubers of the same clones when in their original environment.

The farmers cannot alter climate and weather. Within certain limits, however, he is capable of changing the chemical and physical properties of his soil. It is important to know whether such changes influence yield and nutritional qualities of the sweet potato crop grown in this soil. For that reason in 1960, a rotation trial of many years' duration was initiated at the Manokwari station (lowland). The experiment was laid out as a latin square with five treatments being:—

A — continuously sweet potatoes, without fertilizer application;

B — continuously sweet potatoes, with fertilizer application as needed ;

C — sweet potatoes alternating with weed fallow;

D — sweet potatoes alternating with *Crotalaria usaramoenis* Bak.;

E — sweet potatoes alternating with groundnuts.

The soil used for the trial was a sandy loam, rich in calcium, magnesium potassium and sodium, and poor in phosphorus and organic matter. It was therefore decided to apply to treatment 'B' from the second planting onwards 60 kg P_2O_5 per ha per planting and not to remove vegetable material (except the tubers and groundnuts) from any of the treatments throughout the duration of the experiment. When harvesting, samples consisting of tubers and 30 cm long top shoots were taken in each treatment and immediately sent by air to The Netherlands for analysis. The clone used was Genjem 2. The outcome of four plantings—after the fourth the trial had to be terminated—is presented in Tables VII and VIII. In amplification of the data it is mentioned that the rather long intervals between any two consecutive plantings were due to the weather in those periods; lack or rain prevented the planting of sweet potato cuttings. The exceptionally low tuber yields of the third planting were the results of an explosive fungus infestation (presumably a *Sclerotium* sp.) that in all plots killed the greater part of the foliage during the third and fourth month after planting.

Noticeable differences in yield and chemical composition of leaves and tubers due to treatment differences did not yet crop up in these four planting. It is not unlikely, however, that continuation of the experiment would eventually have shown quite a different picture.

SUMMARY

In the highland valleys of West New Guinea (West Irian) where an estimated three or four hundred thousand people live under very primitive conditions, the sweet potato is by far the most important crop. It accounts for almost one hundred percent of the human food intake in the area. As a result of this unbalanced diet various deficiencies occur, a general prevalence of protein malnutrition being the most serious of these. Introduction of sweet potato clones with a higher protein content than the traditional types seemed to be the best possible method to counterbalance the protein deficiency. In 1959, the Agricultural Research Station, Manokwari, in co-operation with several institutes in The Netherlands, started a research programme aimed at this goal. The work was still in its introductory phase when it abruptly came to an end in the first months of 1963. In the present paper a description is given of the investigation methods applied and the results obtained during these four years.

To begin with data about the chemical composition of the tubers of a number of popular lowland and highland clones are presented. The figures show that on the whole the former were richer in protein than the latter. In another experiment tubers of highland clones grown in their natural environment appeared to contain twice as much protein as tubers of the same clones when grown in the lowland. This may indicate that in the highland conditions for protein formation are better than in the lowland. Furthermore, in combination with the data obtained from the first experiment, it supports the assumption that it is possible to provide the highland communities with new clones which produce considerably more protein than the traditional types.

Storage of the tubers and the age on which they were harvested had, within certain limits, apparently no or only a minor effect on the composition of their dry matter. It was further confirmed that the carotene percentage of tubers of different clones varied widely and that it tended to be higher as the colour of the flesh was darker.

Analysis of young leaves and tubers of the same plants revealed that the dry matter of the former contained five to six times as much protein as that of the latter, thus proving that these young leaves, which the highland people use as a vegetable, constitute a very nutritious food.

As part of a comprehensive breeding programme methods to stimulate the flowering of various clones and to improve the germination of sweet potato seed were studied. Also a beginning as made with selection work in new clones developed from seed.

Finally the preliminary and still inconclusive results of a rotation trial, that was planned to extend over many years, are presented.

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