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9. ABSTRACT

Examines the current agronomic and economic status of sweet potat production in Taiwan. The study, conducted by the Asian Vegetable Research and Development Center, addresses in particular the dramatic decline in sweet potato planting occuring between 1971 and 1975. The report presents reasons for the decline, and provides a list of the study's special objectives and working hypotheses. The research methodology, which primarily consisted of questionnaire surveys and intervi of random samplings of Taiwanese farmers, is also delineated. The stu results provide information on the effects of season, irrigation availability, soil type, and fertilizer on crop yield; economic data comprising production costs and the influence of production inputs; and a summary of farmer attitudes toward the profitability of sweet potato production. Numerous tables and several maps are included.

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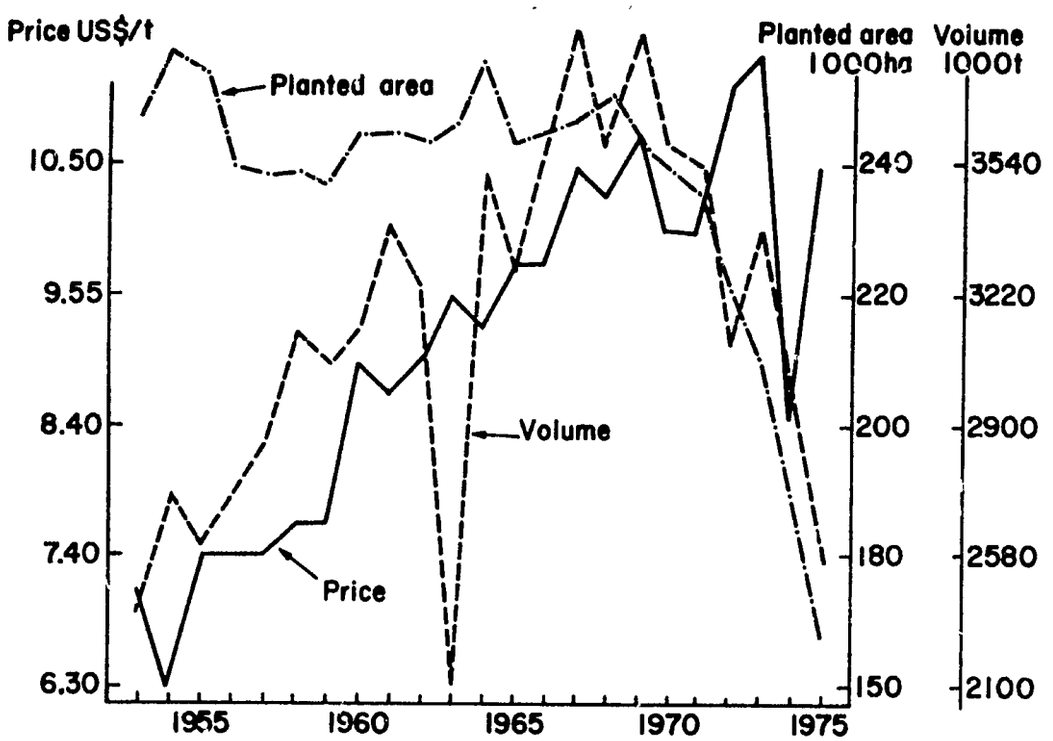

Fig. 1. Price, planted area and volume of sweet potato in Taiwan 1953-1975.

Farmers' Viewpoint of

Sweet Potato Production in Taiwan

Based on 1976 survey and economic analysis of 319 sample farms in six agricultural districts.

P.H. Calkins, S.Y. Huang, J.F. Hong*

INTRODUCTION

Between 1971 and 1975 the area planted to sweet potatoes in Taiwan declined dramatically. Yields per hectare showed a steady increase, averaging 214 kg gain per year but the hectarage declined so rapidly that the total production curve also showed a steep decline (Fig. 1). The major reasons for the decline in total production are thought to be:

1. Taiwan consumers tend to regard sweet potatoes as a low status food. As their incomes have risen, they have switched to other foods.

2. The guaranteed price for rice reduces the risk in growing it compared to sweet potatoes.

3. Farmers used to grow much of the sweet potato crop to feed small bunches of hogs. Today, hog-raising is being concentrated in large confinement operations. Managers of these specialized farms prefer to use processed feed which is easier to store and handle.

4. The increase in irrigated land allows cultivation of rice and sugar cane on land once suited only to sweet potato.

5. A shortage of farm labor tends to make farmers choose a crop like sugar cane, which can be harvested mechanically by a factory.

The present study seeks to evaluate changes in yield and planted area from the farmers' point of view to shed more light on trends in sweet potato production in Taiwan. Sweet potato in Taiwan is grown in four seasons: first, second, fall, and fall relay (planted in rice). We chose the following six districts because they best represented the island-wide trends in planted area for each season. In each district, a sample of farmers was interviewed between June and September, 1976.

District	Crop name**	Duration in the field	Percent change in planted area, 1971-5
Taitung	First	Feb. - July	- 11
Pingtung	Second	June - Oct	- 1
Miaoli	Second	Aug. - Jan.	- 1
Kaohsiung	Fall	Oct. - Apr.	- 6
Tainan	Fall	Oct. - Apr.	- 18
Changhua	Fall Relay	Oct. - Feb.	- 9

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* Associate agricultural economist, research assistant, and research aide, respectively AVRDC.

** These terms are the ones in current use in Taiwan.

Objectives

The four objectives of the study were to:

1. Measure the influence of weather, water availability, soil type, fertilizer, and cropping pattern on sweet potato yield in six representative districts in four seasons.

2. Determine the cost and returns structure, production functions, on-farm post-harvest costs, and sales patterns of sweet potato in these districts.

3. Identify the breeding, crop management, entomological, and economic problems of sweet potato production in Taiwan as perceived by farmers under their own conditions.

4. Help to explain the dramatic decline in hectares planted to sweet potato in Taiwan since 1971.

Hypotheses

After meeting these objectives it will be possible to test 15 hypotheses regarding the profitability of sweet potato production in Taiwan:

(Agronomic)

1. Temperature and day length affect sweet potato yield such that yields are highest in the fall and lowest in the first season.

2. Yields in areas with irrigation systems are better than in rainfed areas.

3. Sandy loam and loamy soils are most favorable for sweet potato production, while heavy clay soil is least favorable.

4. Among inorganic fertilizers, potassium increases yield most and phosphorus least.

5. The yield of monocultivated sweet potato is higher than that under intercropped conditions.

(Economic)

6. Both overall investment and net profit by season are positively correlated with levels of agronomic yield potential.

7. Sweet potato is a low capital, labor-intensive crop, especially in seasons with low yield potential.

8. Area planted to sweet potato is increasing in those seasons in which it is most profitable and decreasing in those seasons in which it is least profitable.

9. Low-input technology can provide improved economic returns to farmers with capital constraints but abundant labor.

10. The expansion of on-farm processing can improve levels of return from sweet potato production.

11. Hog production (as reflected in an area's use of concentrated feed) and the presence of starch factories are the major stimuli to sweet potato marketing.

12. Farmers who must produce sweet potatoes because of lack of alternatives raise more hogs.

13. Farmers who have abandoned sweet potato production are more conscious of profit than current producers.

14. Current producers face more natural constraints than former producers.

15. Lack of irrigation is a major motivation for growing sweet potato.

METHODS

Questionnaires

Three types of questionnaires were used. One type was given to 129 current producers of sweet potatoes. This was a production-cost (PC) questionnaire. Another 122 growers were given a production factor (PF) questionnaire designed to determine producer attitudes. The third type, designed to seek reasons for abandoning sweet potatoes, was answered by 68 former growers (labeled NP for non-producers).

Sampling method (See Table 1)

A purposive selection for district, municipality, and village was made. First, we selected districts according to their long term change in area planted to sweet potato. From each district, 3 to 5 municipalities with the most planted area were chosen. Then, by using simple random sampling, we selected 3 of 5 villages recommended by each township Farmer Association for high sweet potato acreage (Fig. 2). Two of the 3 selected were considered primary sample villages and the third a reserve.

The sample of farmers for interviewing in each village was selected as follows.

1. By consulting the village chief or extension leader, each village was arbitrarily divided into 3 sections according to its major roads. A section was defined as the area within the boundary of the sample roads.

2. Within each section a specific sample size for PC, PF, and NP was prearranged by dividing the total quota by three.

3. Samples were selected on a "cluster" basis. A cluster was a group of 5 farm households adjacent to and including an initially selected central household.

4. If the prearranged sample size for the section was not completed within the first cluster, sampling was taken to a second cluster. The maximum number of clusters per section was set at three.

5. After trying 3 clusters in one section, if the needed samples could still not be found, we moved to the reserve village. But in the reserve village, the maximum number of sections to be visited was two.

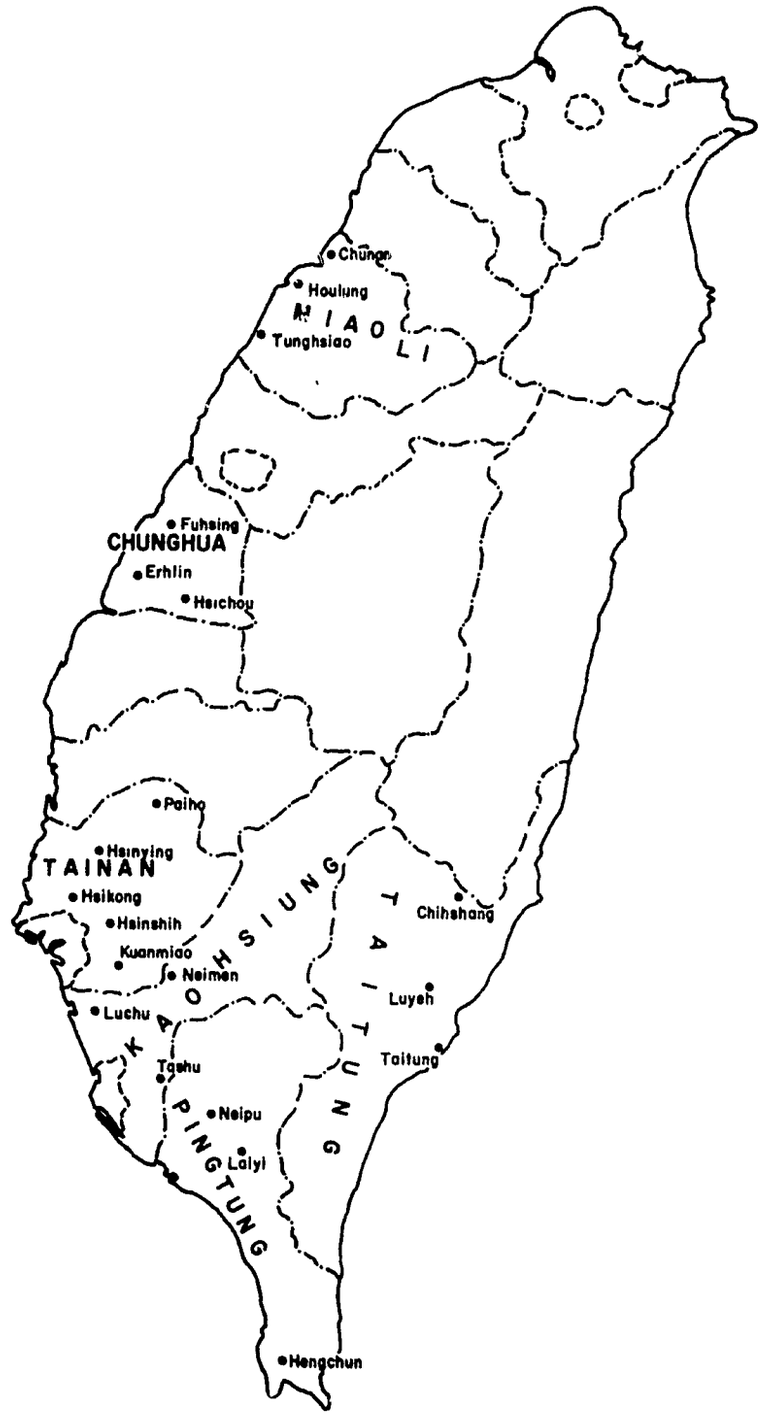

Fig. 2. Location of sample municipalities for AVRDC sweet potato survey, 1976.

Table 1. Distribution of farmers in the survey sample.

Crop	Prefecture	Township	Production cost	Production factors	Non-producers
First	Taitung	Taitung	7	8	3
		Luyeh	7	7	3
		Chihshang	8	7	2
Second	Miaoli	Tunghsiao	7	3	1
		Houlung	7	4	0
		Chunan	6	3	3
	Pingtung	Hengchun	8	6	4
		Laiyi	5	7	1
		Neipu	4	5	3
Fall	Kaohsiung	Neimen	7	8	1
		Tashu	7	8	5
		Luchu	6	8	5
	Tainan	Hsikong	6	8	4
		Kuanmiao	6	7	5
		Hsiaying	6	7	3
		Paiho	6	7	5
		Hsinshih	6	7	3
Fall relay	Changhua	Hsichou	6	4	6
		Erlin	7	4	5
		Fuhsing	7	4	6
Total			129	122	68

RESULTS AND DISCUSSION

Yield rank by season

To completely evaluate hypothesis 1, data for all seasons in all districts would be necessary. As sweet potato is not a significant crop in all seasons and districts, however, we selected the most representative districts for each season. Given the available data, the prediction in hypothesis 1 that fall crop would have the highest yields appeared valid. The prediction that first crop would yield lowest, however, did not. In a preliminary study of environmental factors and yield records in the areas, it was discovered that the fall crop ranked highest in yield, the first crop second, relay crop third, and second crop fourth. Relay crop yields, the interviewees explained, are reduced by shading and second crop yields are reduced by wind and/or inadequate water, enabling the first crop to rank second in yield. The yields of the first and fall crops are directly related to the total solar energy received during the cropping periods. The average yields in the 1975-76 crop year are given in Figure 3. More environmental details are given in Appendix 1.

The first crop is mostly planted in February and March. In Taitung district, day length and temperature are inadequate in the early spring for seedling growth. In the middle-late growth period, rising temperature and day length result in yield loss through too much respiration and low starch deposition.

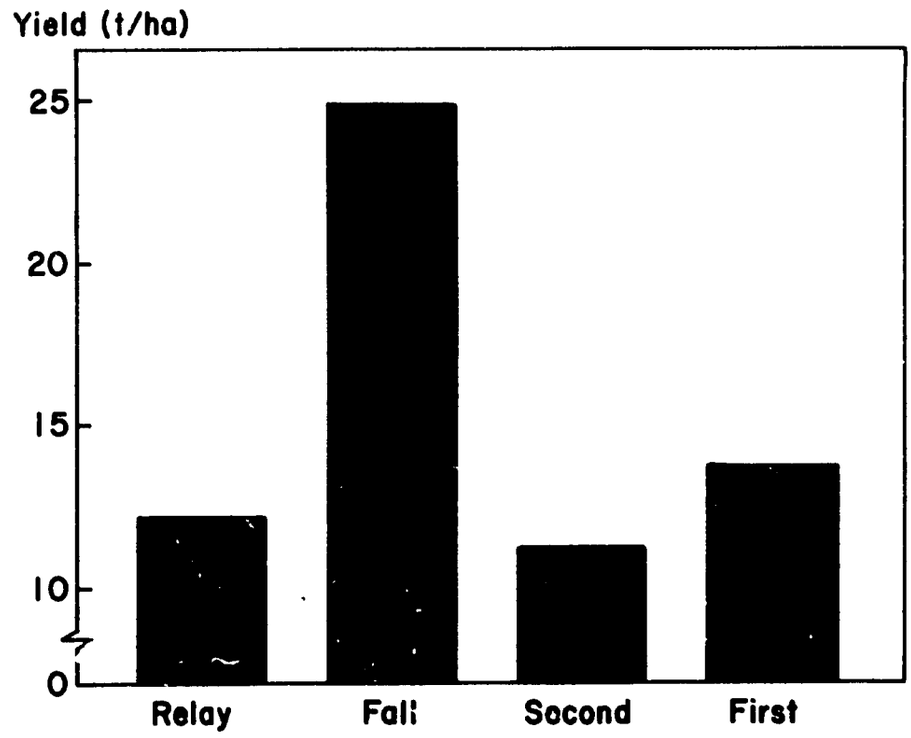

Fig. 3. A comparison of average sweet potato yield by season.

Source: Survey data 1976.

The second crop is mostly planted in July and August. Day length and temperature at that time are good, but there are serious wind and water problems in Miaoli and Pingtung districts. Plants on the rainfed land receive inadequate water, the farmers reported. Strong sea winds, blowing landward in the late growth period, also cause great losses in yield.

The fall crop is usually planted in October, which falls at the end of the rainy season in Tainan and Kaohsiung districts. Fall conditions supply the seedlings appropriate day length and temperature. After October, the dry season with lower temperature and shorter day length inhibits plant growth. Yield is affected positively by starch deposition in this latter stage and by the long growth duration (6 to 7 months).

The relay crop is planted in rice fields 20 to 30 days before the the second rice harvest. Although it has a similar planting season to that of the fall crop, the yield is lower due to low temperature and inadequate light for the seedlings, which are shaded by the leaves of the mature rice plants.

Effect of irrigation availability

Table 2 shows the prediction in hypothesis 2 proved true: Lands with a water source are far more productive than those without a water source.

Sixty-seven percent of the farmers surveyed planted sweet potatoes on fields that had a water source. Eighty-four percent of fall crop farmers, 48% of second crop farmers, 42% of first crop farmers, and 100% of relay crop farmers planted on land with a water source.

The shading problem described above reduced yields of the relay crop despite its water supply advantage and first crop ranked second in yield in spite of poorer water supply, possibly because of plentiful rainfall at planting time. Overall, however, the irrigated areas yielded well above the fields that had to depend on rain alone.

Table 2. Average yield of sweet potato on land with and without irrigation by season Taiwan Province, 1975-6.

Season	Yield (kg/ha)		Ratio
	with irrigation	without irrigation	with/without
Fall crop	26,465	16,000	1.65
Second crop	13,100	9,400	1.39
First crop	15,250	12,962	1.18
Relay	11,950	-	-
Average	16,691	12,787	1.43

Source: Survey data 1976.

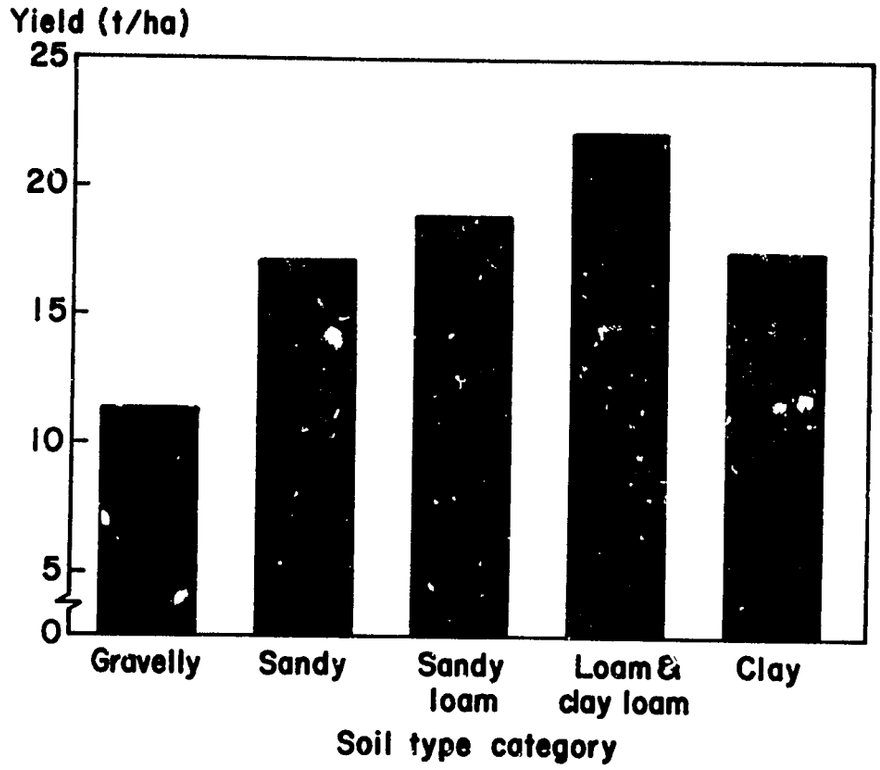

Fig. 4. A comparison of average sweet potato yields on 6 soil types.
Source: Survey data 1976.

Influence of soil type on yield

We classified the soils into 6 types: Sandy, sandy loam, loam, clay loam, clay, and gravel. The distribution of producers by soil type was 31%, 36%, 15%, 2%, 11%, and 6%, respectively. Figure 4 shows the yield sequence by soil type.

Loam and clay loam were the most productive, a result which amends hypothesis 3 that sandy loam and loam would rank first and heavy clay last. Loam has good qualities for air circulation, water retention and fertility maintenance and provides an excellent environment for root growth. Clay loam is inferior to loam in soil quality but it provides excellent yields, influenced by other traits such as water retention and cation exchange capacity, which are important to the fall crop. (All clay loam sample farmers planted fall crop sweet potatoes.)

Sandy loam has similar qualities to loam, but its yields averaged somewhat lower.

Clay soil has a tight texture that obstructs root growth. Its poor drainage is also unfavorable. Thus, we hypothesized that clay would be the least favorable soil for sweet potato. However, clay soils were a little more productive than sandy soils, possibly because the clay holds moisture longer, a critical factor on non-irrigated land.

According to our survey, the good qualities of sandy soil in air and water relations were overshadowed by serious water shortages and it had an overall productivity similar to clay.

The very loose texture of gravelly soil causes large water and fertility losses, which greatly affect yield. Its level of productivity was the lowest of the 6 soil types. Table 3 gives more detailed analysis of the influence of soil types on yield by season.

Season influences yield much more than soil type. It is clear that for the relay crop, sandy soil is by far the best, probably because of the aeration and room for root growth mentioned, under the wet paddy conditions. Because the second rice crop requires much water, a hardpan tends to form below the surface in all but the sandy soils. This obstructs root growth.

Sandy soil did not yield significantly lower than the others in the second and first crops. But, as general stress of the environment in these seasons makes the picture less clearcut; loam and even gravelly soils produced as well as the soils that were expected to contribute the most yield in these seasons.

For the fall crop, clay loams and loams did better in promoting yield than sandy and sandy loam soils. This may have been because the sandy and sandy loam soils, while good in terms of aeration and root growth, are not able to retain water as well as the loam and clay loam when the soil dries out through November and December.

The optimal condition might still be a sandy loam with facilities for irrigation. However, because many fields on which sweet potato are grown in the fall do not have irrigation facilities, loam and clay loam soils tended to average as well as the sandy and sandy loam soils.

Thus, in Table 3 we see that the optimal soil type varies by season and a range of conditions must be met before maximum yields of sweet potato may be achieved. Hypothesis 3, that sandy loam and loam soils are most suited for sweet potato in Taiwan thus needs further study before drawing final conclusions.

Table 3. The combined influences of soil type and season on sweet potato yield.

	Gravel	Sandy	Sandy loam	Loam & clay loam	clay
	mt/ha				
First	14.0	14.0	15.5	14.0	10.0
Second	8.4	12.5	10.6	12.5	-
Relay	-	18.5	7.9	13.5	13.8
Fall	-	24.3	27.2	28.9	19.5

Source: Survey data, 1976.

Fertilizer

The amount of fertilizer farmers used differed by season. For example, fertilizer rates on relay sweet potato were much higher than those used on the fall crop. Table 4 compares rates of N and K application on relay and fall crops with levels recommended by the Chiayi Agricultural Experiment Branch Station. N quantity per ha used by farmers on the relay crop was 3.6 times the recommended amount; fall crop producers used 1.8 times the recommendation. They also used 1.6 times the K recommendation for relay crop and 1.3 times the K recommendation for fall crop.

The evidence implies that there is generally excessive use of fertilizer on the Changhua relay crop. Possible explanations are (1) farmers are trying to compensate for the lack of "resting" time for the land by adding fertilizer and (2) because sweet potato is planted as a relay crop in rice, farmers know it will grow poorly and they add fertilizer to minimize yield loss.

Table 4. Fertilizer application rates in relay sweet potato, fall crop and the experiment station's recommendation.

Item	N(kg/ha)	K(kg/ha)
Recommended[a]	66	110
Relay	239	173
Fall	122	145

[a]Application rates recommended by Chiayi Agricultural Experiment Station.
Source: PDAF, Agricultural Review Vol. 2 : Soil and Fertilizers; Survey results, 1976.

Cropping pattern

Figure 5 shows that the yield of monocultivated sweet potato in each season is higher than that of intercropped potatoes, as predicted (hypothesis 5). The difference between the two groups in the fall season is 4,065 kg/ha, and in the first crop, 7,363 kg/ha. There is no significant difference in yield between the mono-cultivated (11,350 kg/ha) and the intercropped (11,000 kg/ha) in the second crop. It is likely that the difference in yield between the mono-cultivated and the intercropped sweet potato is caused by both inadequate light reaching the low-lying intercropped plants and competition in nutrient absorption.

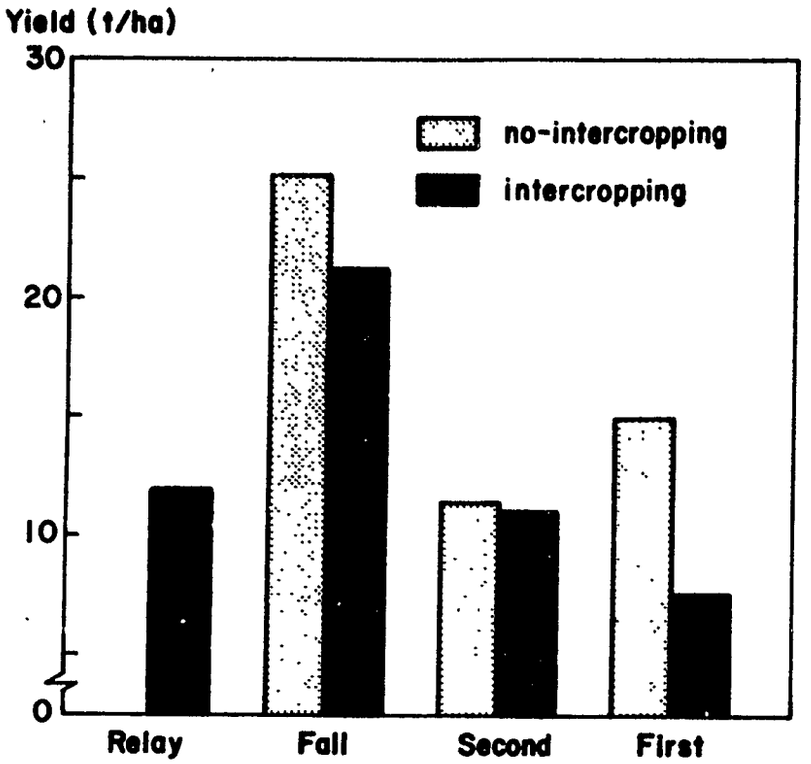

Fig. 5. Average yield of sweet potato by no-intercropping and intercropping.

Production cost and returns

Table 5 lists the average production budgets of between 17 and 30 farmers for each of the six season-district categories.

In terms of yield it is clear that the two fall season samples, taken in Tainan and Kaohsiung, have the highest values. These are followed by the first crop in Taitung, the second crop in Miaoli, the relay crop in Changhua, and the second crop in Pingtung.

The total values of these crops follow the same pattern, except that the price of the second crop is high enough in Pingtung to rank it before the second crop in Miaoli. Farm returns follow the latter pattern, evidence that variations in cost of cash inputs are not large enough to affect relative profitability as much as price. The only exception is the Pingtung second crop where farmers were able to make another step forward in the rankings by using relatively low cash investments. Net revenue, which takes further account of imputed costs of resources owned by the farmer, such as home labor, also follows this pattern.

We see clearly the dominant correlation under on-farm conditions between yield and net profit, regardless of season. This is because (1) product price differences by district are not enough to offset the general

Table 5. Production budgets for sweet potato by district 1975-6.

Budget element	District					
	Changhua	Tainan	Kaohsiung	Miaoli	Pingtung	Taitung
	(N=20)	(N=30)	(N=20)	(N=20)	(N=17)	(N=22)
Season	Relay	Fall crop	Fall crop	2nd crop	2nd crop	1st crop
Yield (kg/ha)	13,284	28,163	21,794	14,101	12,262	14,275
Price (US$/100 kg)	2.9	3.7	4.5	3.4	4.7	4.2
Revenue (US$)	385	1,038	975	482	600	601
Expenses (US$)						
A. Cash (US$/ha)						
Human labor	54	91	82	33	55	54
Animal power	14	28	64	14	18	34
Machine power	12	50	67	0	43	15
Chicken manure	0	0	5	1	0	0
N	60	34	42	16	18	32
P	22	12	18	6	5	14
K	21	21	21	8	8	15
Seedling	48	131	83	30	24	32
Pesticide	8	5	2	< 1	3	3
Fuel	< 1	16	4	0	42	3
Water fee	29	47	0	16	1	11
Land tax	40	42	38	24	8	14
Subtotal	305	480	427	148	226	227
B. Non-cash (US$/ha)						
Family labor	206	141	172	217	115	157
Animal power	70	49	40	128	121	110
Machine power	0	17	22	0	3	3
Compost	166	86	50	24	46	30
Interest on land	139	87	128	71	23	25
Interest on capital	8	14	13	3	5	6
Subtotal	590	394	424	442	313	331
Total	594	874	852	590	539	558
Farm return (US$ /ha)	80	558	548	335	374	374
Net profit (US$ /ha)	-510	164	123	-108	61	43

Source: Survey results, 1976. US$ - NT$38.

trend and (2) there is a high correlation between the overall level of investment in crop management practices and agronomic yield. Therefore we may accept hypothesis 6, that yield potential by season is positively correlated with levels of both overall investment and net profit.

But more significant than a sequential ranking of yields and costs is that the six districts fall into two distinct groups: those planted in the fall and those planted in the first and second seasons. There is a total of about US$870 per hectare invested in each of the relay and fall crops. Because the fall crop has the greatest agronomic potential, as we have seen, such investment is rational. The investment of inputs in the relay crop, on the other hand, seems too high in view of the returns.

The main source of over-investment in Changhua is in fertilizer of all types (Table 6). The intensive use of fertilizer in Changhua is closely related to the local land use pattern. Changhua is noted in Taiwan for the variety and seasonal adaptability of its crops. Lands with extremely high cropping intensity are accordingly supplied more nutrients in an attempt to maintain land fertility. The high investment in fertilizer cannot be justified for the relay sweet potato crop. If the farmers are acting rationally the fertilizer added must benefit other crops grown on the same land during the year.

Expenditures on the first and second crops average a little over US$562 per hectare or about US$311 less than on the fall and relay crops (see Table 5). The expenditures for labor, animal power, and machine power total between US$355 and $392 in five districts, and reach $447 in Kaohsiung. Thus, the source of variation in investment is not to be found in these inputs. Investment levels on fertilizer do, however, fall into the two distinct groups noted above, with an average of US$186 in the fall and relay crops and US$74 in the first and second crops.

Why does this pattern emerge? If the farmers spent more on fertilizer and other inputs in Miaoli, Pingtung, and Taitung would they be able to elevate yields to the Tainan and Kaohsiung levels? Probably not. The case of Changhua shows us that high investment in fertilizer does not necessarily give high returns. Similarly, wind, rain, solar radiation and temperature, as noted in the first and second crops, influence yield, illustrating the ceiling that may be imposed by natural conditions. The risk faced by the farmer from these natural hazards is much higher for the first and second crops than for the fall crop.

To help offset these hazards farmers plant about 6,000 seedlings per ha* and use more animal power and less machine power than farmers who plant in the fall. Most of the animal power is home owned and capital outlay is very low.

First and second crop farmers use similar levels of labor to those used by fall crop farmers, but their returns per hour of labor are less, which suggests that the former group have reached the point of diminishing returns in use of this input.

In all seasons planting, weeding, and harvesting tend to be the most labor-consuming among sweet potato farming practices (Table 7). Only in

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*See Appendix II for further analysis of seedling density.

Table 6. Measures of sweet potato productive efficiency and income in six districts of Taiwan.

Measure	District					
	Changhua	Tainan	Kaohsiung	Miaoli	Pingtung	Taitung
	(N=20)	(N=30)	(N=20)	(N=20)	(N=17)	(N=22)
Crop season	fall relay	fall	fall	second	second	first
Average field size (ha)	0.43	0.48	0.44	0.85	0.53	0.46
Value of output/ha (US$)	384	1,038	975	482	600	601
Human labor/ha (hrs)	647	564	552	543	407	485
Animal power/ha (hrs)	72	58	81	94	146	136
Machine power/ha (hrs)	4	16	28	0	14	6
Compost/ha (kgs)	12,774	8,546	5,045	1,577	5,818	5,797
N/ha (kgs)	132	84	87	36	39	74
P/ha (kgs)	57	38	46	15	13	41
K/ha (kgs)	93	106	105	41	40	75
AVP*/Human-labor hour	< 1	2	2	1	1	1
AVP/Animal-power hour	5	18	12	5	4	4
AVP/Machine-power hour	96	65	35	∞	43	4
AVP/kg of compost	< 1	< 1	< 1	< 1	< 1	< 1
AVP/kg of N	3	12	11	13	15	8
AVP/kg of P	7	27	21	32	46	15
AVP/kg of K	4	10	9	12	15	8

*AVP = average value product, defined as the total value of the crop divided by the use level of a given input.
Source: Survey results, 1976.

Table 7. Labor hours per hectare for sweet potato production, 1975-76.

Operation	District (and crop season)											
	Changhua (fall relay)		Tainan (fall)		Kaohsiung (fall)		Miaoli (second)		Pingtung (second)		Taitung (second)	
	(N=20)		(N=30)		(N=20)		(N=20)		(N=17)		(N=22)	
	hrs	%	hrs	%	hrs	%	hrs	%	hrs	%	hrs	%
Land preparation	3	0	0	0	0	0	0	0	8	2	0	0
Bed formation	14	2	5	1	3	1	25	5	0	0	0	0
Basal fertilizer	126	19	42	7	34	6	20	4	20	5	12	2
Planting	152	23	112	20	128	23	50	9	82	20	81	17
Intertillage & weeding	95	15	135	29	89	16	128	24	42	10	84	17
Top dressing	29	4	0	0	5	1	7	1	25	6	21	4
Vine turning	38	6	41	7	31	6	42	8	17	4	56	12
Irrigation	2	0	17	3	19	3	3	1	17	4	19	4
Pest control	7	1	8	1	3	1	1	0	7	2	4	1
Harvest	181	28	204	36	240	43	267	49	189	46	208	43
Total	647	100	564	100	552	100	543	100	407	100	485	100

Source: Survey results, 1976.

Changhua does compost fertilization take a more significant place than weeding, due to the relatively greater amounts of compost used by the producers of relay sweet potato. The ratio between labor cost and overall cost for sweet potato production in all districts is 1 to 3. Forty-one percent of the labor cost is for harvesting.

We conclude that first and second season farmers use low levels of cash inputs in an effort to make full use of their on-farm resources such as labor and animal power in seasons where they cannot grow rice or other crops. They invest in low levels of overall inputs because of the greater risk and low ceiling on expected yield in the first and second seasons. Moreover, even though they get higher returns to fertilizer, they invest in less because there is no guarantee that from one year to the next they will be able to recoup their costs. Thus, hypothesis 7, that sweet potato is a low capital, labor-intensive crop especially in seasons with low yield potential, is borne out.

Hypothesis 8, that area planted to sweet potato is increasing in those seasons in which it is most profitable, was disproven. One would expect that farmers would grow more and more area in sweet potatoes in the fall season and less and less in the other seasons over time. However, the change in planted area in the period 1971-1975 shows an opposite trend. This does not indicate that farmers are irrational. Rather, it means those who plant in the fall season have many alternative crops while those who plant in the first and second seasons have few or no alternatives. Hectarage of second crop sweet potato in Miaoli and Pingtung decreased by only 1% over the five years noted.

The cost/return pattern revealed in the survey poses a dilemma for researchers. Should they try to elevate yields under optimum conditions (fall) still further? This would tend to increase the peak season production and lower prices to farmers. This might or might not benefit consumers and starch manufacturers because low prices eventually cause farmers to switch to other crops. An alternative is to concentrate on developing low cost input technology for the first and second season crops. The country's increase in production might be negligible but the farmers who lacked alternatives to growing sweet potato would be more likely to benefit.

If Taiwan had a large poor population which needed the highest tonnage of food per hectare possible, a case for a high-input approach in fall seasons could be made. But, such a situation does not exist now and is not likely to develop in the future.

A further question facing research institutes is whether sweet potato, renowed as a source of carbohydrates, is in fact as high a producer of dry matter as the more preferred grain crops. It is also important to consider whether admittedly higher yields per hectare in fact yield higher returns to the farmer. Table 8 lists for the important seasons of rice and sweet potato in Taiwan, their duration in days, dry matter accumulation

Table 8. Rice and sweet potato[a]: A comparison of the dry matter accumulation and profit per hectare per day.

Season/crop		Location	Duration (days)	Dry matter[b] accumulation/kg/ha/day	Farm return US$/ha/day[c]
1st	rice	Taiwan avg.	120	23.0	158.3
1st	sweet potato	Taitung	154	23.2	2.4
2nd	rice	Taiwan avg.	110	19.9	91.5
2nd	rice	Miaoli	110	17.0	77.4
2nd	sweet potato	Miaoli	158	22.3	2.1
2nd	rice	Pingtung	110	17.6	21.2
2nd	sweet potato	Pingtung	137	23.2	2.7
Relay	sweet potato	Changhua	135	24.6	0.6
Fall	sweet potato	Tainan	202	34.9	2.8
Fall	sweet potato	Kaohsiung	174	31.3	3.1

[a]The statistics for rice are for the better than average 1975 season (Taiwan Agricultural Yearbook), those for sweet potato are from the present survey, 1975-76. [b]The dry matter in sweet potato is assumed to equal 25% of harvested weight; and the entire sweet potato is assumed edible. The dry matter in paddy is assumed to equal 93% of harvested weight; and the conversion ratio of paddy to rice is assumed to be 60%. [c]Does not include an imputed charge for family labor.

per day, and farm return per day. In the first season, rice has just as much dry matter accumulation per day and vastly higher net return. Therefore, a logical alternative to investing in sweet potato research for the first season is to invest in expanding irrigation facilities for rice production.

In the second season, sweet potato does average 31% more dry matter accumulation per day. Its profitability is, however, distinctly below the Taiwan average for rice. If Taiwan were a non-market economy where there was a steady demand for sweet potato, then production of this crop in the summer wet season would be a viable policy for bridging the gap between food and population. But as this is not the case there is little justification to promote the crop in this season.

No rice production is reported in the fall season in Taiwan. The data on sweet potato, however, show that despite its long fall growth duration, the crop accumulated dry matter at a higher rate per day than in any other season for rice or sweet potato. In fact there appears to be an increase in yield per day as total crop duration increases. (Fig. 6). But profit is again an issue. Because of the steady decline in demand mentioned, net and farm return per day are extremely low, and there is little reason to promote sweet potato, even in its most productive season, on the basis of human food supply. Thus, sweet potato research in Taiwan can be justified only in the interest of improving the lot of low income farmers in the first and second seasons through low-input technology. We may accept hypothesis 9, that low input technology can provide improved economic return to farmers with capital constraints but abundant labor.

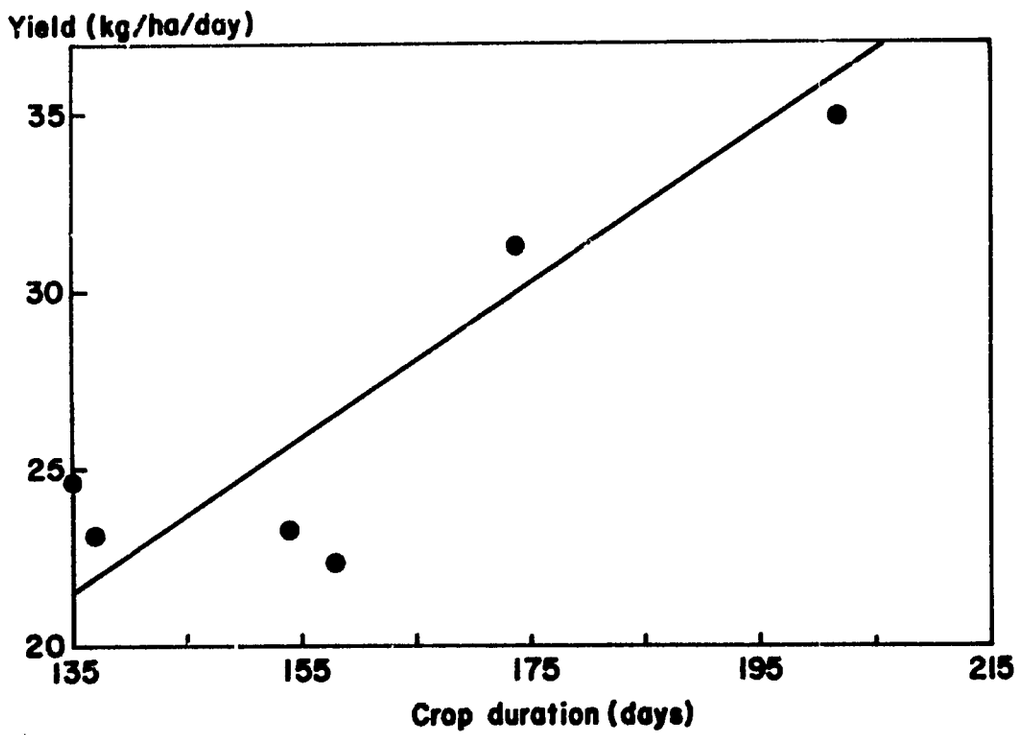

Fig. 5. The relationship between crop duration and yield per day of sweet potato.

The influence of production inputs

The influence of various input mixes for the farms was explored by computer, using the mathematical technique, multivariate regression analysis (for further description, see Appendix III). Major conclusions from the regression results given in Tables 9 and 10 are:

1. Season and district differences (rainfall, elevation, & altitude) influenced yield more than soil type.

2. The contribution that inorganic fertilizer made to increases in yield did not differ significantly according to soil type. However, analysis on a seasonal basis showed signigicant (.01) influence of fertilizer on yield in two districts. In the second season crop in Maioli, potassium fertilizer increased yields an average of 411 kg per $1 invested. In the Kaohsiung district fall season crop, the addition of $1 worth of phorphorus increased yield by 1042 kg while $1 invested in potassium reduced yield almost that much. Thus, production function analysis of the survey data leads to rejection of hypothesis 4, that potassium is most effective and phosphorus least effective in increasing sweet potato yields.

3. Compost was found to have little influence on sweet potato yields in any of the regions.

4. Other investments such as those in insecticides and seedlings have a significant influence on sweet potato yield only on sandy and loamy soils.

Post-harvest handling

In general, sweet potatoes are processed on the farm before entering commercial channels. Processing is the largest on-farm post-harvest handling cost, according to the survey (Table 11). The wide range in costs of $26 to $112 U.S. is primarily due to the variation in amounts processed in the 6 districts.

A much larger volume of sweet potato was processed in Tainan, Kaohsiung and Pingtung districts. The variation is caused by variation in yields and amounts sold off the farm as well as hectarage devoted to sweet potato.

Sales practices

Farmers plant sweet potato primarily for its value as feed. The percentage of total production sold to various outlets, presented in Table 12, reflects the different levels of production allocated to on-farm and off-farm use in each district. Tainan and Taitung districts sell the most sweet potatoes. The former is noted for its high yields, large planted area and, hence, volume of production. It is also known for its high use of concentrate feeds for hogs. As a result, there are large surpluses of sweet potatoes to sell to starch factories* despite the relatively large hog raising enterprise in this district. Because hog producers prefer to use concentrated feed, they market almost half of their sweet potato crop

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*See Appendix IV for the production cost structures of three such factories.

Table 9. Linear production functions to determine per hectare yield of sweet potato in 6 districts, 1975 - 76.

District	Variable									R^2
	yield	intercept	labor	nitrogen	phosphorus	potassium	compost	other capital	power	
	kg/ha		Value of regression coefficient							
Changhua	12,443	5,368	12.20	77.52	155.42	-216.60	- 9.88	-139.08	60.48	0.32
t for $H_0:\beta=0$		(0.51)	(0.80)	(0.62)	(0.67)	(-1.30)	(-0.33)	(-1.27)	(0.59)	
Tainan	27,650	19,109	-0.81	-33.82	-198.74	107.16	-15.58	63.84	41.62	0.16
t for $H_0:\beta=0$		(1.82)	(-0.06)	(-0.40)	(-0.62)	(0.53)	(-0.57)	(1.48)	(0.50)	
Kaohsiung	24,263	25,407	-18.39	9.50	1,042.34	-922.64	-8.74	35.72	62.58	0.50
t for $H_0:\beta=0$		(2.15)[a]	(-1.20)	(0.06)	(2.31)[a]	(-2.76)[a]	(-0.26)	(0.44)	(1.16)	
Miaoli	13,679	10,577	-1.86	43.32	11.78	410.78	0.76	8.36	-0.69	0.54
t for $H_0:\beta=0$		(4.48)[a]	(-0.43)	(0.36)	(0.05)	(2.45)[a]	(0.04)	(0.63)	(-0.04)	
Pingtung	10,729	10,838	-6.96	31.92	207.86	85.12	38.38	10.64	-13.58	0.54
t for $H_0:\beta=0$		(2.73)[a]	(-0.77)	(0.20)	(0.96)	(0.63)	(1.03)	(0.49)	(-0.70)	
Taitung	14,714	25,344	-19.48	-46.74	-207.86	-61.94	-61.18	50.16	28.48	0.16
t for $H_0:\beta=0$		(1.89)	(-1.00)	(-0.33)	(-0.86)	(-0.26)	(-1.44)	(0.36)	(0.50)	

Source: Survey data 1976. [a]Reject the null hypotheses at the 1% level of significance. Negative regression values show a negative effect of the given input on sweet potato yield, positive values show a positive effect. Labor is given in hours and all other inputs in US$.

Table 10. Linear production functions to determine per hectare yield of sweet potato on five soil types, Taiwan province 1975-76

Soil type	Variable									R^2
	yield	intercrept	labor	nitrogen	phosphorus	potassium	compost	other capital	power	
	kg/ha	Value of regression coefficient								
Sand	17,853	11,868	2.01	1.52	92.72	28.88	17.48	83.60	-29.84	0.47
t for H_0:β=0		(2.21)[a]	(0.32)	(0.16)	(0.63)	(0.35)	(0.95)	(3.72)[a]	(-1.23)	
Sandy loam	19,381	18,115	5.47	28.12	109.06	-74.86	-15.20	25.08	-43.51	0.11
t for H_0:β=0		(3.22)[a]	(0.62)	(0.34)	(0.41)	(-0.33)	(-0.72)	(0.97)	(-1.38)	
Loam	18,246	-3,326	-4.46	119.70	-44.08	76.38	-30.40	158.84	81.83	0.25
t for H_0:β=0		(-0.17)	(-0.27)	(0.68)	(-0.16)	(0.32)	(-0.16)	(1.74)	(1.19)	
Clay	17,621	4,472	10.06	42.18	25.84	-318.44	-3.80	53.96	88.91	0.39
t for H_0:β=0		(0.32)	(0.47)	(0.26)	(0.05)	(-0.95)	(-0.13)	(0.53)	(0.90)	
Gravel	12,617	16,314	-11.48		7.22			154.54	-29.44	0.42
		(1.38)	(-0.52)		(0.22)			(0.97)	(-0.46)	

Source: Survey data 1976. [a]Refect the null hypotheses at the 1% level of significance.

Table 11. The structure of on-farm post harvest handling costs of sweet potato[a] 1975-76.

Item	District					
	Changhua	Tainan	Kaohsiung	Miaoli	Pingtung	Taitung
	%					
Root transportation						
Labor cost	8	0.4	0	7	2	25
Animal cost	28	8.5	3	14	1	35
Machine cost	0	11	22	3	24	3
Subtotal	36	19.9	25	24	27	63
Processing						
Labor cost	64	74	72	75	73	36
Animal cost	0	0	0	0	0	0
Machine cost	0	6	2			
Subtotal	64	74	74	75	73	36
Chip transportation						
Labor cost	0	0.1	1	0	0	1
Animal cost	0	0	0	0	0	0
Machine cost	0	0	0	1	0	0
Subtotal	0	0.1	1	1	0	1
Total : %	100	100	100	100	100	100
: US$	26	87	112	67	105	44

[a]Based on one hectare of output. Source: Survey data 1976.

in Taitung district, too. Therefore, we may accept hypothesis 11, that the switch to concentrated feed and the presence of starch factories are the major stimuli to sweet potato marketing.

Changhua and Pingtung are the least commercialized districts. Quantities produced just meet demands for on-farm use. Changhua hog producers use sweet potato chips and vines as 55% of their feed mixture and Pingtung producers 79%.

It is beyond the present survey to determine total amounts sold to such final buyers as starch factories, feed factories, and hog producers. This is because we do not know the quantities sold to these outlets by local shippers. Even so, it is certain that the farmer's biggest market outlet for sweet potatoes is the starch factory.

Although Tainan and Taitung farmers market the same percentage of the sweet potato as they produce, further trends will depend upon the differing commercial situations in these two districts. In Taitung, prospects for sweet potato will follow the fortunes of the hog raising enterprise. Since there are few competing crops on the slopelands of Taitung districts, hog raising could be promoted to fully use the sweet potatoes produced. In Tainan, on the other hand, prospects depend on the further development of starch factories.

Table 12. Sales patterns of sweet potato in six districts of Taiwan, 1975-76.

District	Total production	Total % sold	Sold to									
			starch factory		feed factory		local shipper		hog producer		neighbor & gifts	
			%	price[a]	%	price[a]	%	price[a]	%	price[a]	%	price[a]
Changhua (N=32)	143,683	4	0		0		3	2.2	0		1	2.2
Tainan (N=66)	753,503	53	43	3.5	0		5	4.4[b]	3	3.8[b]	2	3.8[b]
Kaohsiung (N=44)	377,913	24	6	4.4	0		18	4.7	0		0	
Miaoli (N=30)	323,960	36	0		2	2.84	32	3.7	0		2	3.5
Pingtung (N=35)	153,138	3	0		0		1	4.4	1	6.6	1	4.7
Taitung (N=44)	244,106	54	0		0		26	3.8	16	4.5	12	4.4

[a]All prices are in $US/100kg. [b]Chip prices $12.71 local shipper; $13.16 hog producer; and $13.16 neighbor & gifts in Tainan.
Source: Survey data 1976.

Attitudes and characteristics of producers and former-producers

Appendices I and II list the answers to key questions and the indices to key production criteria for two samples: 122 producers of sweet potato, pooled from 6 district/season combinations, and 68 former producers of sweet potato who have now abandoned the crop.

Major conclusions based on their answers are:

1. The farm size of current sweet potato producers is 1½ times that of former-producers. Yet the cropping intensity index per unit area on the land of current producers is higher than that of former-producers. This suggests a very high use of labor in producing households.

2. The family size of producers is 1.2 members larger, and there are almost 1/3 more members in the agricultural work force of producing households. They work 33 percent more hours per week in the summer and 34 percent more hours per week in the winter, and are assisted by 16 and 8 percent more occasional help in these two seasons, respectively. This suggests that the entire farm operation of sweet potato producing households is more labor intensive than that of households of former producers. These results agree with Table 2, which showed the importance of labor in the profitable production of sweet potato, and reconfirm hypothesis 7, that sweet potato is a low capital, labor-intensive crop.

3. Sweet potato producers tend to grow less rice and more field crops than those who quit, suggesting that the availability of irrigation water is a key factor in decisions to switch from sweet potato and dry land crops.

4. Low yields of sweet potato are not a significant determinant of abandonment, as shown by the fact that producers are getting only 17 tons per hectare while former-producers got 20 tons per hectare. Only 29 percent of former producers said they stopped planting sweet potato because of low yield, while 46 percent said that they abandoned cultivation in favor of competing crops which may have had lower costs of production.

5. Current sweet potato producers raise 72% more hogs than former-producers and use a much higher percentage of sweet potato chips in their feed mixture. Thus, hog-raising is directly related to the cultivation of sweet potato. The direction of causality is clear from the fact that only 30% of former-producers raise hogs to utilize farm products, while 53% of producers cite this reason. Therefore, we may accept hypothesis 12, that farmers who must produce sweet potato raise more hogs. Hogs are raised more for income and less for farmyard manure in current sweet potato producing households than former-producing households.

6. The management background of producers is not significantly different from that of former-producers. Producers have about one year less of education, are one year older, and have only slightly lower general levels of education in the family than former-producers.

7. The motivation for growing sweet potato between producing and former-producing households is quite different, however. Current producers originally grew sweet potato for their own consumption and for animal feed in much higher percentages than former-producers. In subsequent years, the reason former-producers continued to grow sweet potato for a time was to fit the cropping pattern rather than produce income. Thus, when competing crops entered the picture, former-producers were quick to stop the production of sweet potatoes. Low price and low yield were next in importance in the reasons for dropping sweet potatoes. The replacing crops were considered more profitable. Therefore, we may accept hypothesis 13, that farmers who have abandoned sweet potato production are more conscious of profit than current producers.

8. The main differences in production problems noted by the current and former producers were in their listings of natural constraints and rat damage. Only 19 percent of the former-producers name natural constraints as reasons for abandoning the crop, while a full 39 percent of the current producers list natural constraints and 5 percent rat damage as major problems. This indicates that former-producers have better land and more alternative crops. Those still producing sweet potatoes have few alternatives that will fully utilize their relatively less irrigated land and more abundant labor resource. That former producers already had better land is shown by the fact that they enjoyed higher yields before abandoning sweet potatoes and that 71% of the land abandoned for other crops has had no improvement. Fifty-four percent of current producers claim they have no alternative. Thus, hypothesis 14, that current producers face more natural constraints than former-producers, is supported by the study.

9. The main crops which have replaced sweet potato are sugarcane, rice, corn, tomato, and peanut, in that order. In the competing crops cited by current producers corn replaces rice as the major crop. This is further evidence that irrigation is a major constraint to converting land now planted to sweet potatoes. Hypothesis 15, that lack of irrigation is a major motivation for growing sweet potato, is supported by the evidence.

10. Sweet potato is intercropped by about 37% of both current producers and former producers. More of the former-producers, however, said their purpose in intercropping was to increase income. Those who did not intercrop gave reasons such as: acted to avoid yield loss; the difficulties of high labor use; inappropriate soil utilization; and low returns. Current producing housholds have fewer reasons for not intercropping.

11. Fifty-four percent of the producers rotate their sweet potato production plots. The main reasons they give for rotating are to improve soil conditions and because there is a larger system of rotation on the farm. The main reasons given for planting in the same plot were: limited number of parcels and want to plant sweet potato only on the rainfed land.

12. Thirty-eight percent of the farmers are willing to add more fertilizer (although we have seen that this may not necessarily contribute to higher income), while 20 and 31 percent, respectively, are willing to

increase their use of insecticides and irrigation. These generally low figures reinforce the conclusion that research institutes should be looking at a low input type of technology for those farmers who still have to grow sweet potato in an economy which is demanding less and less of this commodity.

13. The major problems of growers in 1976 were natural constaints, insects, low yield, and low price, in that order. The last is a function of the downward shift in the demand for sweet potato in Taiwan and is beyond the scope of plant breeding and other physical research at research institutes. Natural constraints are also difficult for scientists to overcome, although work in crop management, irrigation, and breeding for tolerance to moisture stress can help to minimize their adverse effects. The main constraints scientists can address for sweet potato, however, are low yield, a genetic character, and insect problems, which may be solved by both genetic and chemical means.

14. Only 48% of all the farmers interviewed listed insect problems in the 1975-76 growing season. The main pests they cited were weevil, *protoparce convolvoli*, sweet potato leaf folder, and aphid.* The degree of weevil damage this year was fairly severe to very severe on 16% of the farms reporting, with 90% of the weevil damage occuring during the growth period. Sixty-two percent of farmers did not spray and 80% of those who did only sprayed one to two times. If breeders and entomologists can develop varieties resistant to pests and/or a set of recommendations for chemical control whereby the return to the farmer will pay costs of spraying, sweet potato profitability will be enhanced. This is especially true because 75% of weevil damaged roots must be thrown away.

15. The conditions under which current producers would plant more sweet potato are (a) an increase in sweet potato price (which is unlikely in view of the downward shift in demand over time), (b) an increase in farm land area, (c) an increase in hog price, and (d) an increase in sweet potato yield. Research institutes can work most profitably at trying to achieve the last condition. Indeed, 29 percent of former-producers cited low yield as the reason they got out of sweet potato production. Seventeen percent of current producers would increase their production area if improved, high-yielding varieties were developed, while 9% of former producers would replant if new varieties were made available. That current producers are very sensitive to yield is clear from the fact that 45% of current producers have changed varieties in an attempt to achieve higher yields.

16. Farmers seem unaware of the possibilities of reducing production costs as an alternative to increasing yields in making sweet potato production more profitable.

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*In fact, this was not aphid but the coccoon of a beneficial coccid parasite of the sweet potato leaf folder.

CONCLUSIONS

(Agronomic)

1. The fall crop has the highest yield and second crop has the lowest.

2. Lands with a water source are more productive than those without a water source.

3. Loam and sandy loam soils are the most suitable for sweet potato production.

4. More economical use of fertilizer is needed.

5. The yield of mono-cultivated sweet potato is greater than that of intercropped sweet potato.

(Economic)

6. Both overall investment and net profit by season are positively correlated with agronomic yield potential.

7. Sweet potato is a low capital, labor-intensive crop, especially in seasons with low yield potential.

8. Low input technology can provide improved economic returns to sweet potato farmers who have capital constraints but abundant labor.

9. Because of other more desirable alternatives, area planted to sweet potato in the best areas for their production is decreasing most rapidly.

10. Because of declining demand for sweet potatoes in Taiwan, on-farm processing offers only limited prospects for improving farmer income.

11. The switch of hog producers to use of concentrated feed and the presence of starch factories are major stimuli to marketing of sweet potatoes. The crop was once used mainly on the farm.

12. Research to develop feeding formulae for hogs based on sweet potatoes might enhance the price for the product.

13. Farmers who continue to grow sweet potato have more family labor available.

14. Farmers who must produce sweet potato at this time raise more hogs.

15. Current producers have more land and face more natural constraints than former-producers.

16. Profitable alternatives are few without irrigation.

There are two alternative pathways to increasing sweet potato yield: (1) concentrate on maximizing fall yield and incomes, with possible bene-

fits to urban and industrial consumers but still no guarantee of high rates of adoption because of competing crops, (2) develop better, low-input technologies for low income farmers in the first and second seasons.

Present farmers' conditions suggest that the latter technology is more suited to Taiwan. Such technology could use crop management to control the production environment and could gain from higher use of seedlings, inorganic fertilizer, and farmer-owned animal power. Emphasis on higher and more stable levels of return could take precedence over low levels of input *per se*. Scientists at research stations should quantify production costs of the new technologies they develop to compare them with present costs under farmers' conditions.

APPENDIX I

Influences of environment on yields[a]

Day Length and Temperature:

An increase in day length and temperature affects the growth of sweet potato leaves positively. In the early root growth period, a day length of 12 hours and 40 minutes to 13 hours, and a temperature of 24°C are the best. After this period, similar day length (12-13 hours) is ideal for enlargement of the roots; while a slightly lower temperature (22-23°C) is optimal. The mean temperature during cropping periods and other environmental data are given in Table 1 Appendix I.

The Water Factor:

Sweet potato plants need more water in the early growth period than in the late period. The addition of water accelerates stem and leaf growth. Insufficient water constrains vegetative growth which eventually limits root growth, since smaller amounts of carbohydrates are translocated.

Soil Factors:

Sandy loam and loam are reported to be the best soils for sweet potato because they have suitable qualities in terms of water relations, air circulation, and light absorption. Heavy soil or land with high levels of underground water is unfavorable to sweet potato production.

Fertilizer:

The rates per hectare of fertilizers needed by sweet potato are N:P:K= 66:51:110 (Chiayi Agricultural Experiment Branch Station). The element K is needed most and has the highest efficiency among these 3 elements, while the P element affects yield least. Of course, this assumption depends upon the native available P level or level built up through continuous cropping. If soil tests reveal available P at 30-90 ppm this may not be true. If the O.M. of soils is above 1.5%, less N may be needed. The amount of N needed varies inversely with organic matter. Excessive amounts of N may stimulate vegetative growth at the expense of roots.

Solar Radiation

Yield potential is proportional to the solar radiation received during the cropping period. In this study the yields of the first (Taitung) and

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[a]References: Taiwan, Provincial Department of Agriculture and Forestry, Agriculture Review Vols. 2 and 6, (Taichung, 1960 and 1964) (In Chinese).
Harvest Farm Magazine, Volume 26 No. 13 (Taipei, July, 1976) (In Chinese).
Kuo K'uei-shih, Soil Science (P'ingtung, 1974). (In Chinese).
T'ang Wen-t'ung, Agronomy (Taipei, 1973) (In Chinese).

Appendix I. Mean environmental conditions.

Season	Location	Approx. cropping period	1976 climatic condition					
			mean temperature		rainfall	day with		total solar radiation
			max.	min.		strong wind	sunshine	
			------- °C ------		-- mm --		-- % --	Kcal/cm²
First	Taitung	Feb. - Jun.	27.3	18.2	572	7.8	37.0	41.0
Second	Pingtung[a]	Jun. - Oct.	31.0	24.6	1429	13.2	53.4	49.6
Second	Miaoli[b]	Aug. - Jan.	27.5	19.9	474	18.3	53.6	48.6
Fall	Kaohsiung	Oct. - Mar.	25.8	18.0	143	9.4	56.3	52.7
Fall	Tainan	Oct. - Apr.	26.8	16.1	226	4.1	60.1	67.7
Fall relay	Changhua[c]	Oct. - Feb.	24.8	14.6	159	0.8	59.0	41.3

[a]Kaohsiung data. [b]Hsinchu data. [c]Calculated per day; other environmental data are rounded to the nearest.

Sources: 1. Summary of meteorological data Taiwan Vol. III. 1961-1970. Feb. 1974 Central Weather Bureau, Taiwan R.O.C.
2. Weast, R.C. (ED) 1976. Handbook of Chemistry and Physics 56th Edition CRC Press.

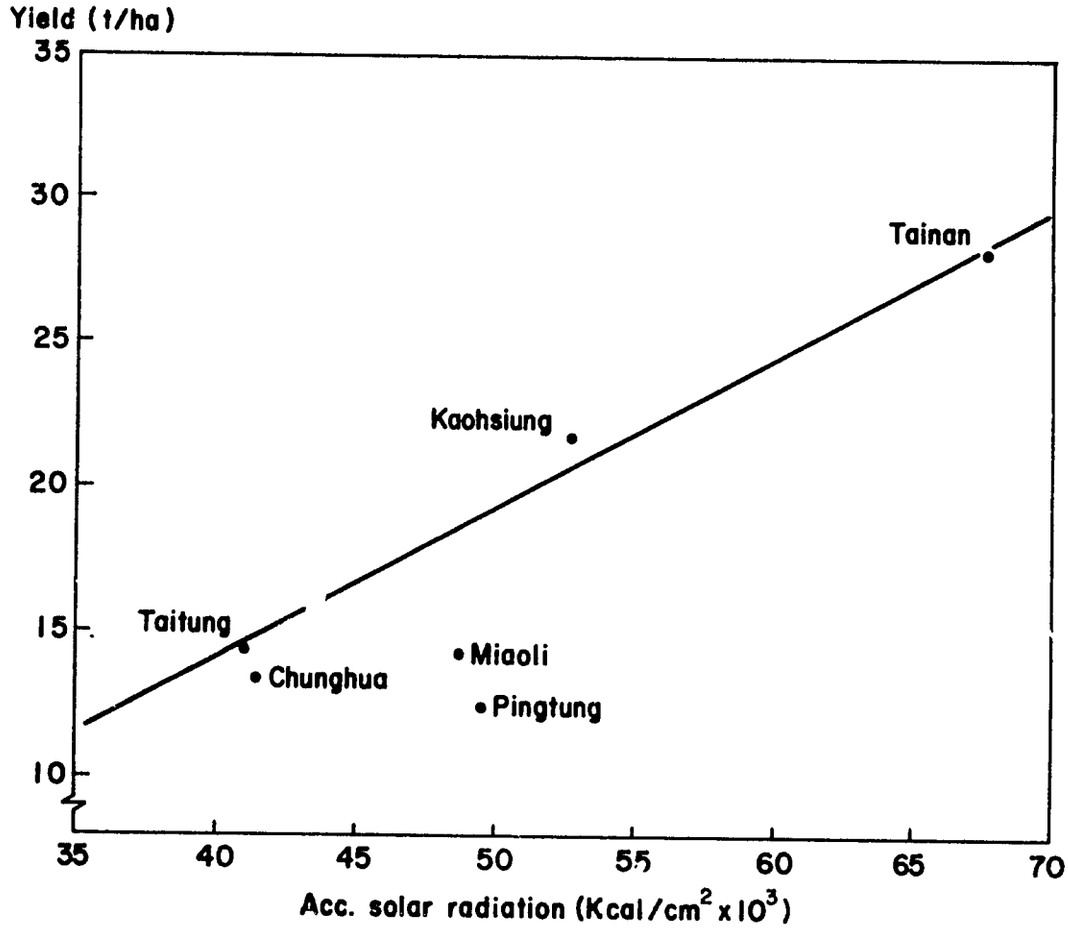

Fig. 1 Appendix I. Sweet potato survey data.

Source: See preceding table.

fall (Kaohsiung, Tainan) crops are nearly linearly related to the accumulated solar radiation received. (Fig. 1, Appendix I). The yields of the second crop (Miaoli, Pingtung) are less than would be expected based on the solar radiation they received. Presumably if wind and water stress factors could be eliminated by wind breaks and irrigation these yields could be increased. The yield of fall relay crop in Changhua is only slightly lowered by mutual shading of the rice crop.

From all the above factors, we believed a crop planted in the fall would have the most suitable growing season and crop yield. The temperature and day length during the early growing period (Oct.-Nov.) for this reason are within the desired limits. Moreover, the decreasing temperature and day length in November and December stimulate the yield of roots by inhibiting further top growth.

We expected that the yield of the first (Jan.-Feb.) planting of sweet potato would be the lowest for the four seasons because of its relatively unfavorable growing conditions.

APPENDIX II

Production environment, seedling density and yield relationships

From the survey data, we found that differing stem cutting density among districts largely depends on land quality and water source, which in turn reflect the field location and the land's suitability for the crop. Districts with inaequate water availability and low value lands have a low cutting density. This group is characterized by river beds, sea coasts, mountains and slope lands which are mostly found in Miaoli, Pingtung, and Taitung districts. Here, with few alternatives, producers consider sweet potato to be a given crop. Producers encounter more technological limitations than those in the plains districts who can invest more capital in planting, including more cuttings, under a superior production environment. However, the cutting density cannot reflect the stem cutting cost level due to the varying prices among districts. We found that the price of cuttings (0.32 US$ per 100) of the fall crops is much higher than that of the other crops (0.12US$). This difference is partly caused by variety and cutting source and partly by high demand in the fall.

It would seem that differences in stem cutting density among seasons affect the yield of sweet potato. The fall crop has an average number of 33,835 per ha, with an average yield of 24,979 kgs per ha. The first crop's density is 29,887 per ha, with a lower yield (14,275 kgs per ha) than the fall crop. The second crop, with the lowest density of cutting (23,824 per ha) among the three seasons, is also the least productive, yield 13,382 kgs per ha. However, the relay crop with both the highest density among the four seasons (35,325 per ha), and the lowest yield (13,284 kgs per ha), shows a negative relation to stem cutting density. Moreover, a contradictory situation also exists in the 2nd crop of Miaoli which dominates Pingtung in yield despite the fewer cuttings planted (20,462 in Miaoli and 27,185 in Pingtung). We also find that with similar density in Kaohsiung (30,743) and Taitung (29,887), yields are very different: 21,794 kgs and 14,275 kgs, respectively. Tainan and Changhua, likewise, do not show a relation between density and yield. In Tainan, a cutting density of 36,926 per ha produced yields of 28,163 while 35,235 cuttings per ha in Changhua yielded 13,284 kgs per ha, while 35,235 cuttings per ha in Changhua yielded 13,284 kgs per ha. Although cutting density is usually positively related to yields, we see that the differing production environments among districts are often of greater significance than stem cutting density <u>per se</u>.

APPENDIX III

Production foundations

An effective way of exploring more deeply the impact of technology with different input mixes is by using the mathematical technique known as multivariate regression analysis. This involves regressing the determined or "dependent" variable on the left hand side of the equation on more than one determining or "independent" variable on the right hand side. There is also an error term ($\underline{e}$) to represent the data points whose position off the functional form is not explained by the independent variables.

We used the linear functional form, which tests the degree to which straight lines in multidimensional space are able to include all the recorded observations. Such an equation may be written as follows:

$$Y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots\ldots\ldots \beta_n x_n + e$$

where Y = the dependent term

α = constant

β_i = the regression coefficients

x_i = the independent terms

e = error term

There is a second type of functional form called the curvilinear, which tests the degree to which curved lines in multidimensional space are able to include all the recorded observations. The curvilinear form most often used is the Cobb-Douglas, which is of the general type:

$$Y = \alpha x_1^{\beta_1} x_2^{\beta_2} \ldots\ldots\ldots\ldots\ldots\ldots x_n^{\beta_n} e,$$

where the terms are as in the previous equation. The equation above is often transformed into the following:

$$\log Y = \alpha + \beta_1 \log X_1 + \beta_2 \log X_2 + \ldots\ldots\ldots\ldots\ldots \beta_n \log X_n + e$$

where the term "log" stands for the logarithm of the variable in question. However, because of our interest in individual nutrients and power, which for many observations have a value of zero, we were not able to use it in the present analysis. This is because a zero value cannot be transformed to a logarithm without the loss of the household observation in question. Thus, the equations presented may not in fact be the best approximations of true relationships, especially if (as is often the case in agriculture) there is a pattern of non-linear response in output to the addition of more and more units of input on a fixed area of land.

Nevertheless, some general patterns and trends are evident. Tables 9 & 10 list the specific contributions of labor, capital, and power to per hectare yield which result from multiple regression analysis of the 129 households reporting production costs. In Table 8 the observations are subdivided by district and in Table 9 by soil type. To provide better information for soil and crop management specialists, capital is further subdivided into three types of inorganic fertilizer (nitrogen, phosphorus,

and potassium), compost, and other capital. Average yields in kgs per hectare describe the mean of the dependent variable sweet potato yield, upper values in each row represent the slope coefficient of each independent variable and the correlation coefficient (R^2) is given at the extreme right. The values in parentheses represent the t-values of the regression coefficients.

APPENDIX IV

Processing costs and returns

(Totals and average for three starch factories in Shanhua area, Oct. 1975-Sep. 1976)

Item	Factory A US$	Factory A %	Factory B US$	Factory B %	Factory C US$	Factory C %	Average US$	Average %
Value of output:								
S.P. 1st grade starch	163,184	39.6	101,053	26.0	88,863	41.9	117,700	34.8
S.P. 2nd grade starch	10,800	2.6	0	0	5,826	2.8	5,542	1.6
S.P. refuse	31,500	7.6	8,947	2.3	13,263	6.3	17,904	5.3
Cassava 1st grade starch	163,137	39.5	243,420	62.5	87,128	41.1	164,562	48.7
Cassava 2nd grade starch	14,216	3.5	0	0	0	0	4,739	1.4
Cassava refuse	29,804	7.2	36,026	9.2	16,804	7.9	27,545	8.2
Total	412,641	100	389,447	100	211,885	100	337,991	100
Cost of input:								
Variable cost								
Sweet potato	148,737	44.5	84,211	25.9	75,789	44.6	102,912	37.2
Cassava	166,737	49.9	204,474	62.9	76,737	45.2	149,316	54.0
Labor	15,158	4.5	27,221	8.3	12,079	7.1	18,153	6.6
Electricity	947	0.3	3,158	1.0	474	0.3	1,526	0.6
Fuel	0	0	3,526	1.1	0	0	1,175	0.4
Taxes	2,632	0.8	2,632	0.8	3,816	2.2	3,026	1.1
Interest	0	0	0	0	1,071	0.6	357	0.1
Subtotal	334,211	100	325,221	100	169,965	100	276,466	100
Fixed cost								
Maintenance of building	263	1.0	1,053	5.6	263	2.4	526	2.8
Maintenance of machinery	658	2.4	1,579	8.4	316	2.9	851	4.5
Depreciation of building	132	0.5	1,053	5.6	343	3.2	509	2.7
Depreciation of machinery	368	1.4	1,579	8.4	752	7.0	900	4.8
Taxes	789	2.9	571	3.0	448	4.1	603	3.2
Interest on equity	19,368	72.2	10,898	57.8	4,854	45.0	11,707	62.2
Management	5,263	19.6	2,105	11.2	3,816	35.4	3,728	19.8
Subtotal	26,842	100	18,838	100	10,792	100	18,824	100
Total	361,053		344,059		180,757		295,290	
Net return	51,588		45,388		31,128		42,701	

APPENDIX V

Differences between present and former sweet potato producers

Means of key indices	Producers (N=122)	Non-producers (N=68)
Family size	7.6	6.4
Agricultural work force (persons)	2.1	1.6
Non-agri. members	4.9	4.2
Operator's age	49.7	48.9
Years experience in planting sw. pot.	28.6	21.9
Operator's education years	3.7	4.6
Highest educ. level of agri. work force (years)	4.8	5.0
Total summer agri. work force's on-farm labor hours per week	91.3	68.4
Total winter agri, work force's on-farm labor hours per week	89.1	66.4
Total agri. work force's off-farm work days per year	25.0	17.1
Total occasional summer helpers on-farm labor hours per week	7.1	6.1
Total occasional winter helpers on-farm labor hours per week	6.6	6.1
Farm size	1.8	1.2
Overall cropping intensity index	85.9	66.8
Rice cropping intensity index	22.6	35.3
Field crops intensity index	32.2	25.7
Sweet potato intensity index[a]	19.6	3.1
Actual yield (kg/ha)	17,347	20,037.5
Minimum yield desired	26,569	25,401.6
Present hog production	8.6	5.0
Swt. pot. chips percentage in feed	42.9	19.0

[a]Percentage of hectare months cropped of total available hectare months. (See AVRDC Technical Bulletin 2.)

Appendix V (Cont'd)

Factors or attitudes	Producers responding (N=122)	Non-producers responding (N=68)
	----------%	----------
1. Reasons for planting sweet potato in general		
Fit cropping patterns	18	28
Fit soil condition	10	9
Fit growing season	9	7
Income	17	13
Full utilization of land	33	31
Feed	84	87
Others	40	29
2. Reasons for first planting swt. pot.		
Self consumption	89	52
Self feed	96	67
Sale as food	0	1
Sale as livestock feed	9	11
Sale to starch facotory	2	0
Alcohol	1	2
3. Varieties planted at present		
New #31	25	
#3	21	
Nian-shih	13	
Chia-yi	13	
Other (minor or without names)	0	
4. Past production problems		
Insect	23	24
Low price	36	35
Market problem	11	9
Natural constraints	22	60
Rat damage	21	13
Low yield	39	41
Long growth duration	0	0
Labor shortage in processing	2	7
Decrease in demand for starch	2	2
Farm labor shortage & others	12	12
5. Problems this year		
None	33	
Insects	19	
Low price	8	
Market problem	4	

Appendix V (Cont'd)

Factors or attitudes	Producers responding (N=122)	Non-producers responding (N=68)
	%	
Natural constraints	39	
Rate damage	5	
Low yield	16	
Long growth duration	0	
Much labor needed in processing	0	
Decrease in demand for starch	0	
Farm labor shortage	3	
Other	2	
6. Reasons for stopping sweet potato cultivation		
Competing crops	0	46
Low price	0	32
Low yield	0	29
Decrease in hog raising	0	24
Natural constraints	0	19
Concentrated feed	0	12
Labor shortage for processing	0	4
Rotation system	0	4
7. Improvements on former sweet potato land		
No improvement	0	71
Irrigation	0	10
Additional field well	0	12
Soil quality	0	9
Land reconsolidation	0	7
8. Conditions to replant sweet potato		
Unwilling to replant	0	33
Increase in hog price	0	12
Improved varieties	0	9
Feed	0	12
Favorable weather	0	5
Others	0	37
9. Condition to increase production area		
Increased sweet potato price	36	
Increased sweet potato yield	12	
Increased hog price	13	
Decreased price of competing crops	2	
Improved variety	5	
Increased farmland area	16	
Impossible vecause only one parcel	14	
Unwilling under any circumstance	18	
Other	11	

Appendix V (Cont'd)

Factors or attitudes	Producers responding (N=122)	Non-producers responding (N=68)
	%	
10. Reasons for continued planting despite problems		
Feed	33	
No proper alternative (primarily due to water shortage)	54	
Cropping system	17	
Fully utilize land	12	
Food	8	
Production problems are difficult to predict	4	
Labor-saving	6	
Low cost	1	
Income	1	
11. Main competing or replacing crops		
None	20	0
Corn	42	9
Sugarcane	23	22
Peanut	17	1
Tomato	10	3
Soybean	7	0
Garlic	4	9
Rice	2	21
12. Reasons for not planting alternative crops		
Rotation	62	
Labor shortage	35	
Natural constraints	17	
Feed	17	
Low price, low yield, high cost, market problem of alternatives	32	
Long growth duration of alternative	11	
No interest	3	
Others	5	
13. Reasons for intercropping	(37% of farmers)	(38% of farmers)
Income	60	85
Raise hogs	10	10
Secondary food	3	5
Other	27	0

Appendix V (Cont'd)

Factors or attitudes	Producers responding (N=122)	Non-producers responding (N=68)
	----------%	----------
14. Reasons for not intercropping	(63% of farmers)	(62% of farmers)
Avoid yield loss	51	88
Unsuitable land or soil	1	13
Inconvenient for labor	6	19
Low value	0	13
Other	41	41
15. Reasons for rotating plots (54% of farmers)		
Improve soil conditions	38	
Part of rotation	31	
Pest control	4	
Change in soil condition	1	
Others	1	
16. Reasons for planting in same plot (46% of farmers)		
Limited number of parcels	22	
Rainfed land	19	
Cropping pattern	4	
Others	2	
17. Percentage of farmers willing to increase the following inputs		
Fertilizer	38	
Insecticide	20	
Irrigation	31	
18. Why farmers changed varieties		
No change	23	
Low yield	45	
Low conversion rate to chips	15	
Bad root quality	15	
Varietal variation or problems in seedling source	13	
Perishability	7	
Unfit soil conditions	7	
For trial	7	
Long growth duration	3	
Other	4	

Appendix V (Cont'd)

Factors or attitudes	Producers responding (N=122)	Non-producers responding (N=68)
	----------%	----------
19. Main insect problems		
No problem	52	
Weevil	11	
Aphid	17	
Caterpillars	5	
Protoparce convolvuli	13	
Sweet potato leaf folder	8	
Omphisa illisales	2	
Sweet potato weevil or leaf beatle	2	
Moth spp.	1	
Other	8	
20. Disposal of weevil damaged root		
Hog feed	18	
Discard	75	
Sell	2	
21. Degree of weevil damage this year		
Very severe	1	
Severe	10	
Somewhat severe	5	
Slight	8	
Very slight	34	
None	43	
22. Frequency of pesticide spraying		
None	62	
1 time	18	
2 times	14	
3 times	4	
6 times	1	
7 times	1	
23. Time of most severe weevil damage		
Growth period	90	
Storage stage	4	
No occurrence	6	

Appendix V (Cont'd)

Factors or attitudes	Farm type: producers responding (N=122)	Farm type: non-producers responding (N=68)
	----------	% ----------
24. Sold to whom		
Not sold	66	
Starch factory	9	
Local shipper	15	
Neighbor	7	
Hog producer	2	
Food factory	2	
25. Transaction place		
Field	50	
Home	43	
Market	5	
Vend by cart	2	
26. Method of price-setting		
Contract	33	
Non-contract	67	