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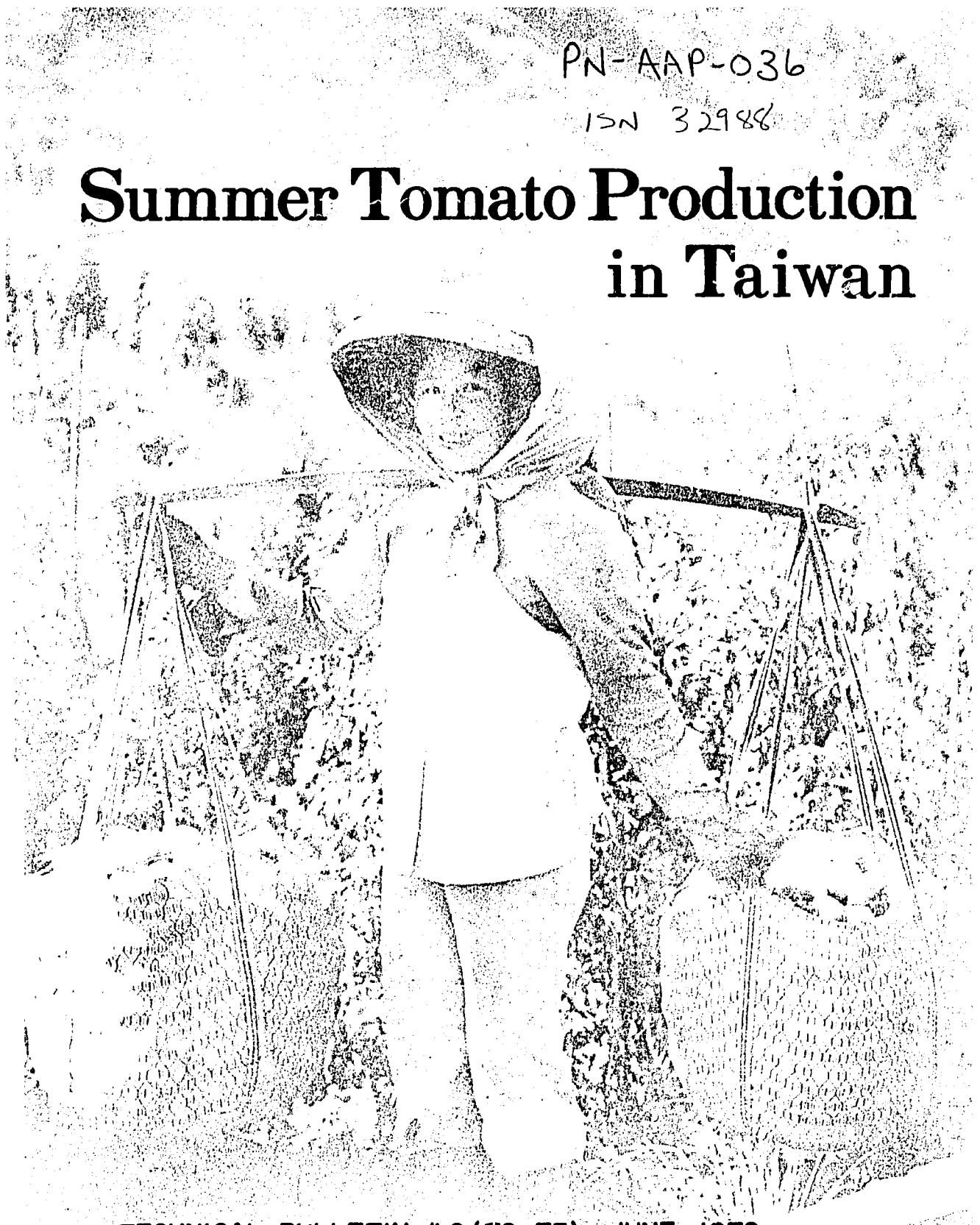
Summer Tomato Production in Taiwan



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Summer Tomato Production in Taiwan

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INTRODUCTION

The tomato is a popular vegetable in Taiwan, and the average real tomato expenditures per household have doubled in the period 1973-76 (Fig. 1). However, figure 2 shows there is great seasonality in consumption, because limited supplies in the summer (May-Sept.) result in low consumption at high prices. The low production levels derive from increased risk of crop failure due to high temperatures and rainfall. Few farmers are willing to plant during this period. By contrast, rice has a dependable yield and withstands the conditions which hinder the tomato. It also has a stable price, which between 1973 and 1976 was guaranteed at a very high level.[b]

Most tomatoes planted in Taiwan are grown during the cool season between the end of summer rice (Sept./Oct.) and the planting of spring rice for the following year (Mar./Apr.). This cropping sequence maintains full use of the land during the year. Cool season production is further encouraged by the guaranteed price and technical support of tomato processing factories in southern Taiwan, which enter contractual arrangements with farmers to supply processing tomatoes.

Unless high yielding, heat and moisture tolerant tomato cultivars can be developed, increases in the area planted to tomatoes in Taiwan during the summer are unlikely. Scientists at the Asian Vegetable Research and Development Center (AVRDC) are collaborating on breeding, pest control, and crop management trials to improve tomato cultivation under hot conditions in the monsoon season. Technologies developed will be of use not only in Taiwan, but also in other tropical areas.

In order to develop a deeper understanding of summer tomato production in Taiwan, the agricultural economics group at AVRDC conducted a survey of producers in 1977. From secondary information provided by the Provincial Department of Agriculture and Forestry and local weather stations, we defined three distinct summer sub-seasons:

a) Lowland late summer. We studied Hsihu and Yungching townships in Changhua county, which lie about 10 m above sea level, and where tomatoes are transplanted to the fields beginning in August and are harvested by late December.

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[a]Research assistant and associate agricultural economist, respectively, AVRDC.

[b]US$303/ton. Although this guaranteed price is still in effect, the percentage of the crop bought by the government in 1977 has been reduced to about 20%.

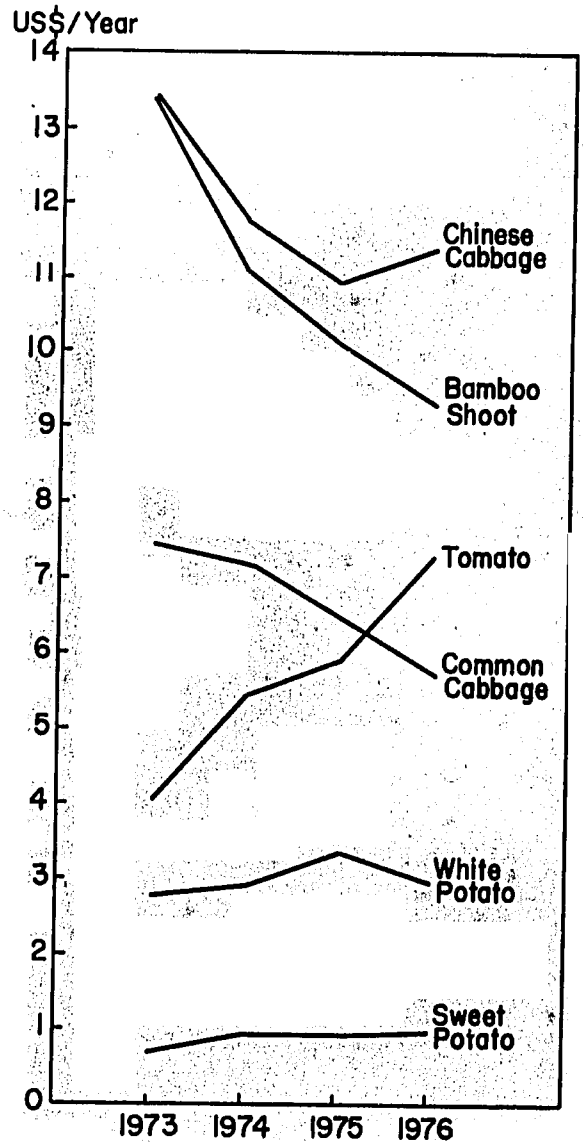

Fig. 1. Trends in expenditures on selected vegetable commodities, per household; 1973-1976 (Taipei City, Household Expenditure Survey Report, 1973-1976).

b) Upland early summer. We chose Peitou and Shihlin townships in Taipei district, which lie 350-400 m above sea level and where tomatoes are grown from the beginning of April to late July.

c) Upland full summer. We selected 3 villages in Hsinyi township, Nantou district, which lie 400-800 m above sea level; and where the tomato season is from mid-May to early September.

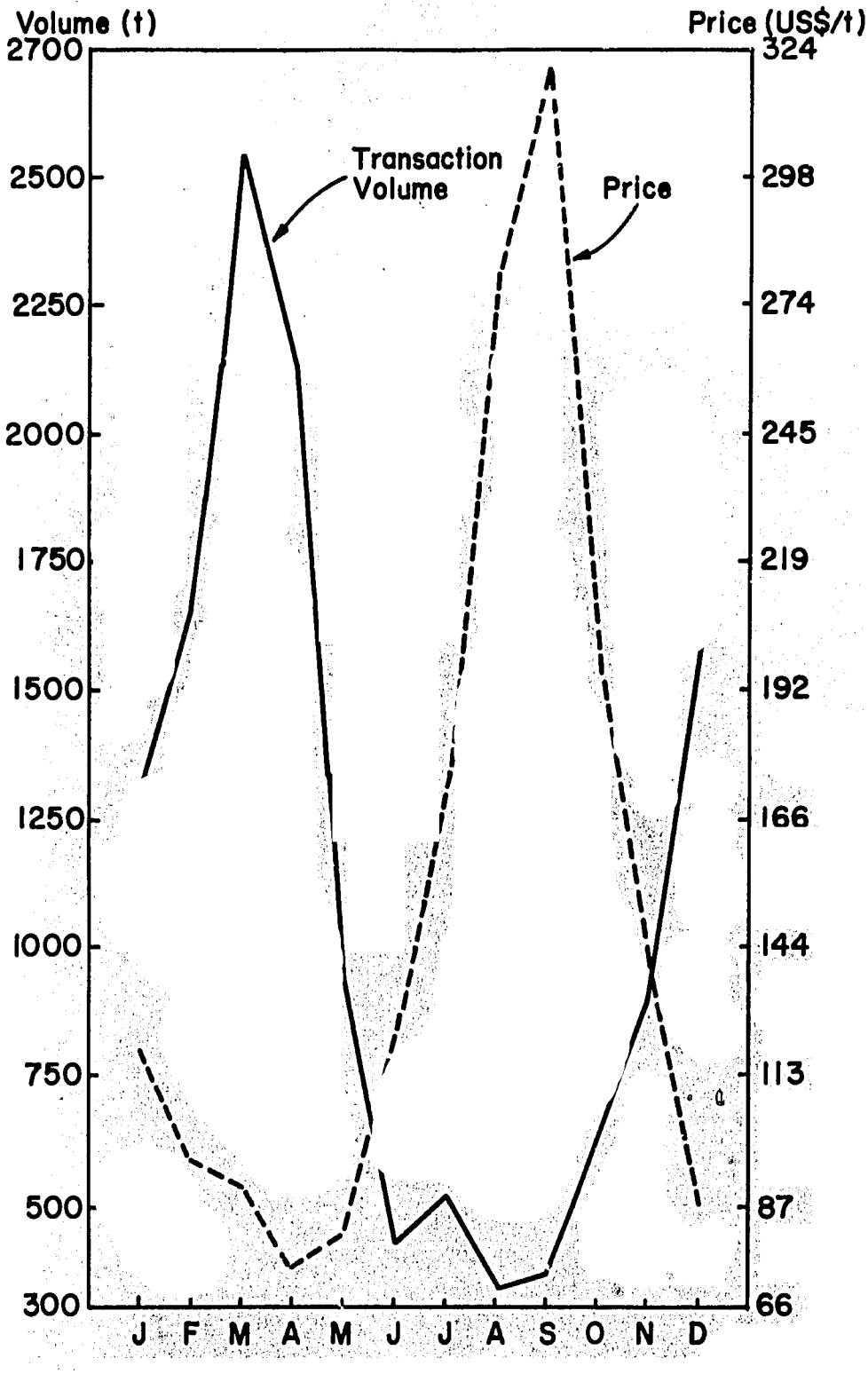

Fig. 2. Fresh tomato transaction volume and prices in Taipei City, 1976 (4).

Figures 3 and 4 show the temperature and rainfall patterns in the survey townships for the various summer tomato production seasons, with an indication of time of transplanting, flowering, and fruit set. For one or more of these critical growth stages, tomato production in each of the above seasons and locations is adversely affected by high temperatures and/or excessive rainfall.

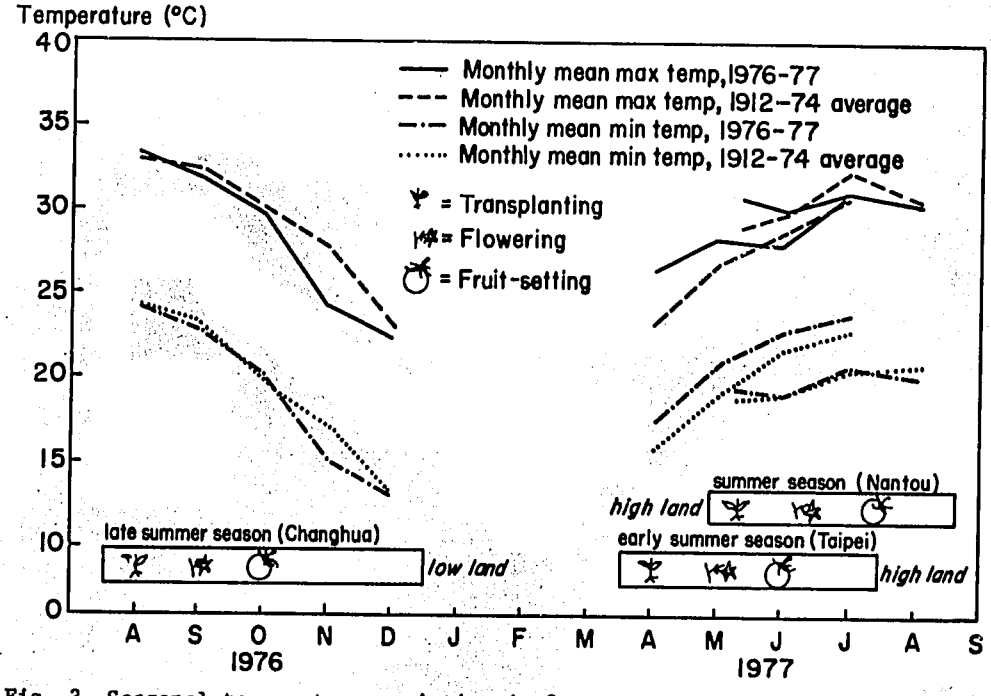

Fig. 3. Seasonal temperature variation in 3 summer tomato production districts; 1976 (Local weather station data, Changhua, Nantou, and Taipei districts).

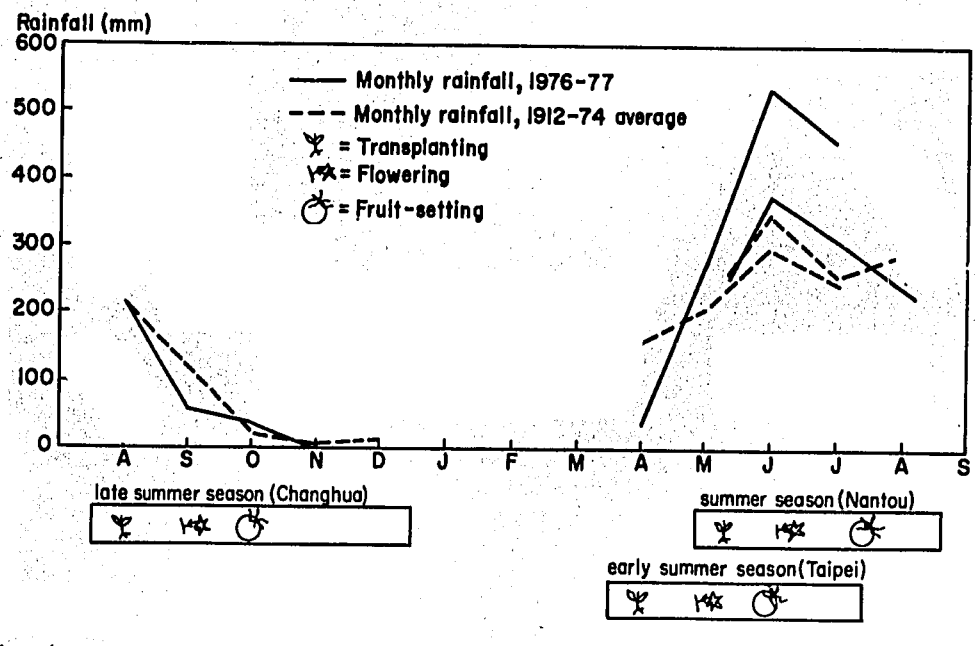

Fig. 4. Seasonal rainfall variation in 3 summer tomato production districts; 1976 (Local weather station data, Changhua, Nantou, and Taipei districts).

Specific objectives of this study were to:

a) Understand the seasonal production potential of local tomato cultivars, and measure the possibility of increased profit through yield improvement.

b) Understand by sub-season how major environmental constraints influence tomato growth and production.

c) Determine local management levels for summer tomato production and the possibility of increasing profit by reducing production costs.

d) Put summer tomato production into perspective by comparing its profitability with that of competing crops and non-summer tomato.

Accordingly, the following hypotheses were tested on our survey data:

a) Heat tolerance is the factor ranked first by farmers among cultivar selection criteria and heat tolerant cultivars yield more than non-heat tolerant cultivars by district.

b) The yield of lowland late summer tomato in Changhua is higher than that of highland summer tomato in Taipei and Nantou due to low temperature and rainfall in late summer in Changhua.

c) Yield is a function of environmental factors; therefore, fields in each district with good drainage, adequate water, favorable temperature, suitable soil, low rainfall, and no typhoon damage yield highest.

d) Pests are more serious in the highland than in the lowland due to abundant rainfall and high temperature during the growth period of summer tomato in the highland.

e) Crops with long growth duration yield more than those with shorter duration.

f) High crop density significantly increases yield

g) By increasing production costs, farmers increase yield and profit.

h) Summer tomato is more profitable than both non-summer tomato (due to favorable prices despite high management costs) and rice, the usual alternative crop.

QUESTIONNAIRE AND METHODOLOGY FOR SAMPLING

Questionnaire

The first half of the survey questionnaire collected detailed information on production costs. The second half elicited data on cultivar performance by season, and how it is influenced by soil quality, drainage, local weather, and pests.

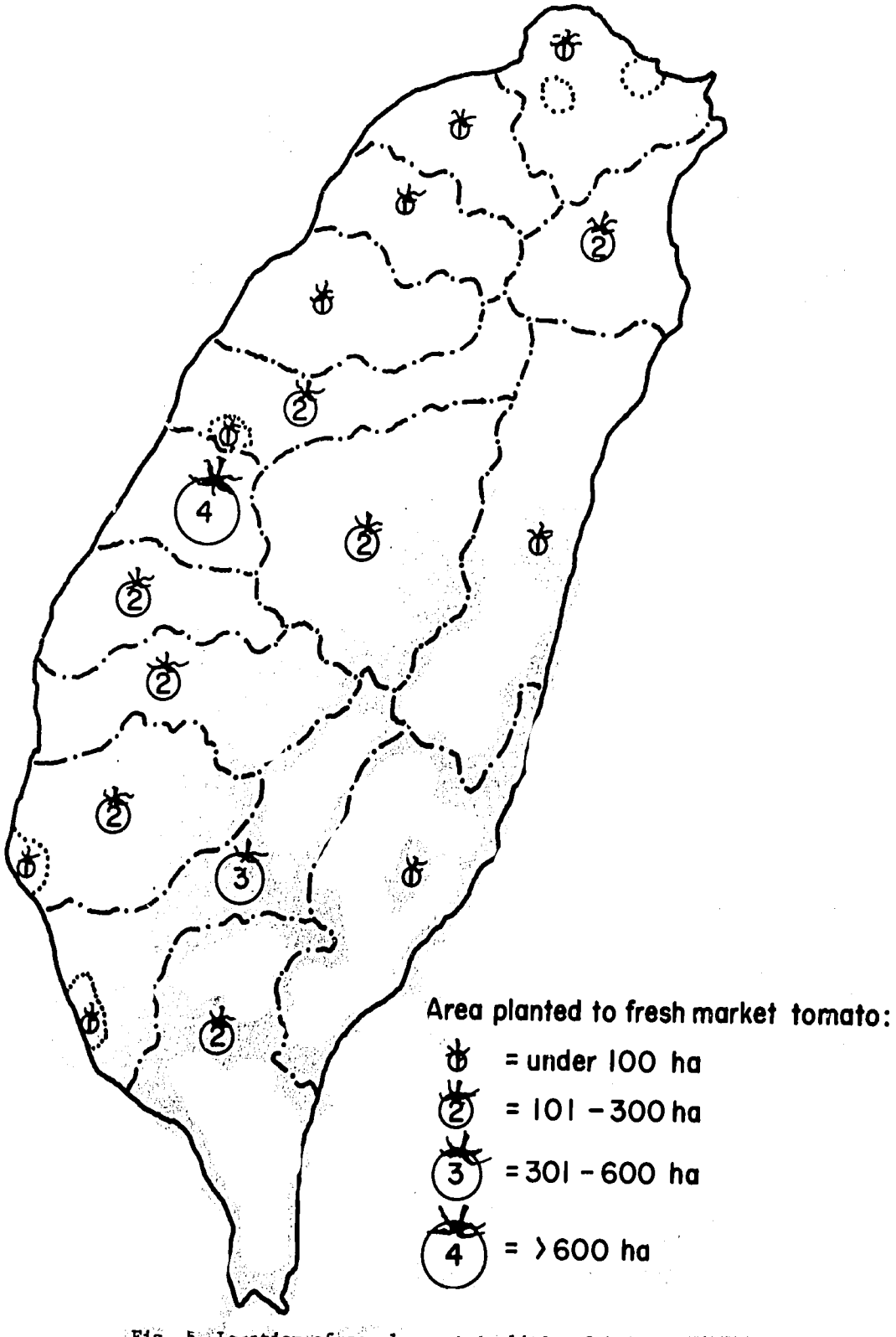

Fig. 5. Location of sample municipalities for AVRDC summer tomato survey, 1977.

Sampling Method

We surveyed 109 farmers from three districts of Taiwan (Fig. 5), who planted fresh-market tomato in the summer of the 1976-77 crop year. The sampling proceeded in three stages:

The identification of summer production districts. Unlike processing tomato, whose planted hectarage has risen dramatically in Taiwan during the past 6 years, the planted area for fresh-market tomato has remained steady with a yearly average of 3,625 ha and a nominal increase averaging 36 ha/year from 1967-1975.

According to recent statistics (1), fresh-market tomato production is concentrated in central Taiwan, including Changhua (with more than 600 ha) and Nantou districts. There is a small to intermediate area planted in each district of southern Taiwan, while most districts of the north devote under 100 ha to fresh-market tomato. Because fresh-market tomato is generally destined for retail and wholesale markets, statistics from the Taiwan Fruit and Vegetable Marketing Company serve as a guide to the major sources of supply. Of the yearly transacted volume, northern Taiwan supplies 7% (4), central Taiwan 47% (of which 51 and 36% are supplied by Changhua and Nantou districts), and southern Taiwan provides 46% (of which nearly half comes from Tainan district).

Only fresh market tomatoes produced in the summer are treated in this study. We, therefore, isolated them from the annual figures by checking both the production and marketing situations. On the production side, we checked the crop season prevalent in each major production district and the mean minimum temperature under which the crops were grown.

After the harvest of second rice, the farmers in southern Taiwan plant their fresh-market tomato as a winter crop beginning in mid-October and finishing harvest in late April (3) when mean minimum temperature drops below 16°C during the fruit setting stage (2). After referring to the typical minimum temperatures under which heat tolerant tomatoes have been cultivated in AVRDC greenhouse and field trials over the past few years, we rejected this season from study as it failed to meet the definition of "summer" tomato.

Unlike southern Taiwan, farmers in the central and northern regions grow fresh-market tomatoes through the warm to hot season usually reserved for spring and summer rice in local cropping patterns. In Changhua district, the fruit setting stage of late summer tomato falls in September, when the mean minimum temperature remains as high as 23°C (Fig. 3). In Nantou district, during the growth period of summer season tomato, the mean minimum temperature ranges between 19°-21°C from the middle of May to early September. In Taipei district, during the growth period of early summer tomato, the mean minimum temperature rises from 18°C in April to 24°C in July. Therefore, we accepted Changhua, Nantou, and Taipei districts as target areas for study of summer tomato production in Taiwan.

Selection of survey municipalities and villages. We found that the summer fresh-market tomato transacted volume at the Taiwan Fruit and Vegetable Company from May to October of 1976 was primarily supplied by

Nantou district (48% of the total transaction), with Changhua supplying 26%, Taichung 17%, and Taipei 4%. Therefore, we selected Nantou (highland) as the largest source of summer tomato in central Taiwan, Changhua to represent summer lowland cultivation, and Taipei (highland) as the sole concentrated area for summer tomato in northern Taiwan.[a]

The local farmers association and agricultural improvement stations identified Yungching and Hsihu of Changhua district, Hsinyi of Nantou district, and Peitou and Shihlin of Taipei district as the major production municipalities, and we selected these 5 municipalities for the survey.

The selection of farmers in each sample village. Each municipality in Changhua and Nantou districts and the whole Taipei district were allocated approximately equal samples (Table 1). The sample size assigned to each village was in proportion to its relative population. Accordingly, the final sample included 24 farmers in Yungching, 26 in Hsinhu, 29 in Hsinyi, 20 in Peitou, and 10 in Shihlin.

Table 1. The sample distribution; AVRDC, 1977.

Elevation	District	Municipality	No. of villages	No. of sample
Lowland	Changhua	Yungching	3	24
		Hsihu	3	26
Highland	Nantou	Hsinyi	3	30
	Taipei	Peitou	2	20
	"	Shihlin	1	9
Total			12	109

[a]The soil of Nantou district is sandy loam with a gravelly phase. Summer season tomatoes are mostly planted in mountain river beds (the most infertile soil in the survey areas). Farmers in Nantou apply the most fertilizers, but the input efficiency is least among the three production districts.

The soil of the survey area in Changhua district is clay loam. At a depth of 0-15 cm, it has a fairly loose consistency; however, in the range of 15-35 cm the soil becomes sticky and tight.

The soil in Taipei district is loam to clay loam with a pH often less than 5.6 (most acidic of the three areas). The organic matter content ranges from 1.5-3.0%, and is similar to Changhua and Nantou soils.

RESULTS OF THE SURVEY ON SUMMER TOMATO PRODUCTION

Agronomic Factors Affecting Summer Tomato Production in Taiwan

There is a distinct yield difference among the three summer tomato production seasons (Fig. 6). In this section, we will illustrate the relationship between yield and natural or technological factors.

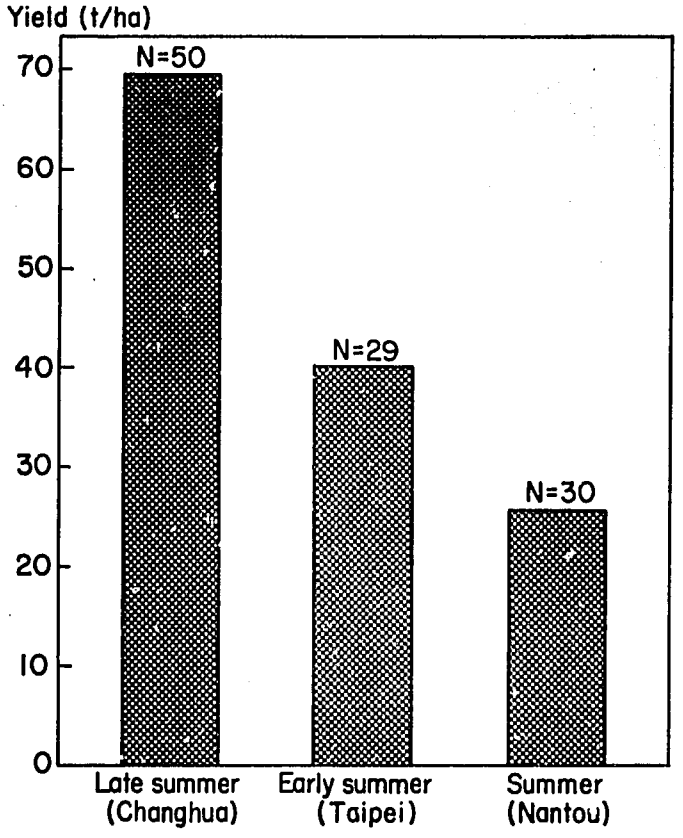

Fig. 6. Comparative productivity in 3 summer tomato production areas; AVRDC, 1977.

Cultivar and yield by season (Fig. 7). "White Skin," with a yield of 66.4 t/ha and "Hsi Kuang F_1" (77.5 t/ha) are the two dominant late summer tomato cultivars in Changhua. The proportion of farmers planting White Skin increased from 56 to 84% while those planting Hsi Kuang dropped from 20 to 14% over the past few years. Clearly yield is not the most important motivation for production in this district. Of the 30% late summer tomato producers who changed cultivars in Changhua, 47%, the largest portion, sought heat tolerance and 33%, high price. These figures are reasonable because White Skin is planted an average of 39 days earlier than Hsi Kuang and is sold at higher prices (Table 2, p.16).

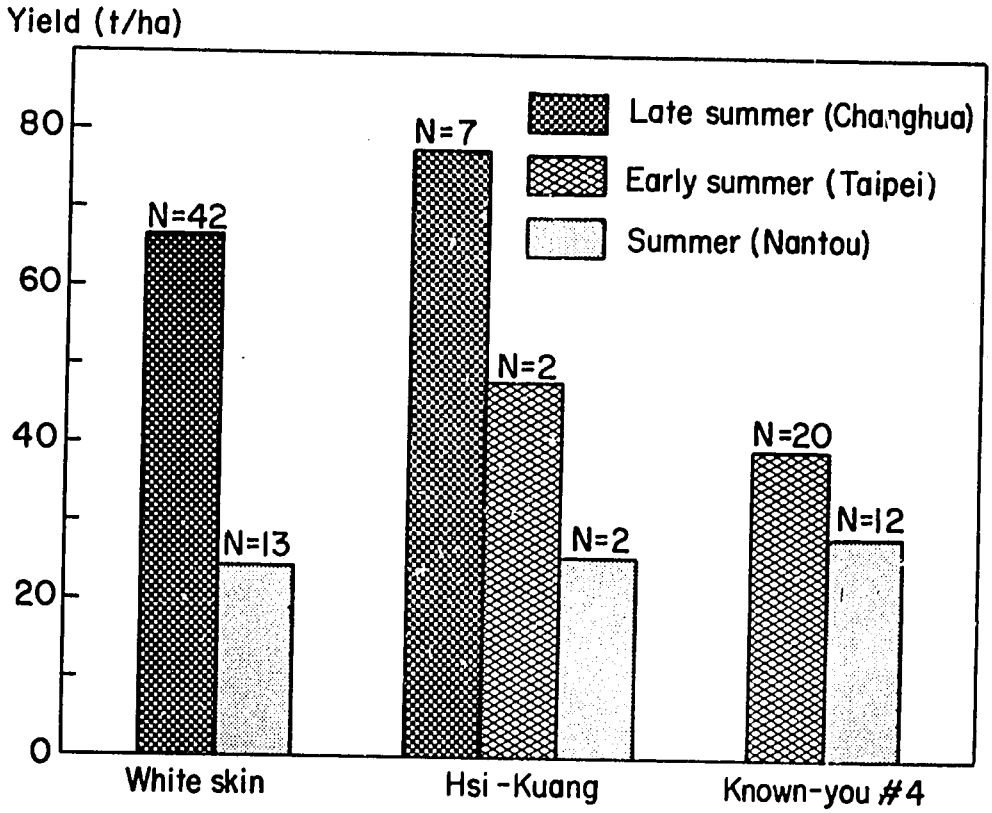

Fig. 7. Yield by cultivar in 3 summer tomato production districts; AVRDC, 1978.

In Nantou district, White Skin (average yield, 24.3 t/ha), Known-You No. 4 (28.2 t/ha), and Hsi Kuang (25.8 t/ha) are most popular. Over the past few years, the proportion of farmers planting White Skin has remained stable (47-46%), while the percentage planting Known-You No. 4 has risen dramatically from 3 to 40%. Of the 18 summer season tomato producers who changed cultivars in Nantou, 55% did so to improve product appearance. In addition, 33% sought high price, high yield, or resistance to pests.

In Taipei district, Known-You No. 4 (39.5 t/ha) and Hsi Kuang (48.0 t/ha) are the two major cultivars for early summer tomato. The percentage of households who planted Known-You No. 4 rose from 28 to 69%, while Hsi Kuang dropped slightly from 10 to 7%. Of the 23 producers who changed cultivars, 48% sought to improve product appearance, while 43% desired higher yield.

Therefore, we reject hypothesis a, that heat tolerance is an important selection criterion and is linked with high yield. Only in Changhua is heat tolerance the major selection criterion. Moreover, White Skin yields less than Hsi Kuang and Known-You No. 4 despite its relative heat tolerance. Hsi Kuang is reported by farmers not to thrive as well as White Skin at the high temperatures prevalent in July and August, however.

Temperature, rainfall, and yield by district. Figure 3, the seasonal temperature variation in the three summer tomato production districts,

shows that the temperature during the growth period in the lowland is higher than that in the highland, and moves in a different direction. Lowland summer tomatoes benefit from cool temperatures which favor fruit setting and indeterminate growth habit, while highland summer tomatoes grow under hot conditions which limit both fruit set and the growth period. Therefore, seasonal temperature patterns are a determinant of yield because of their varying suitability for growth at different stages.

There is a distinct difference between low- and highland rainfall during the summer tomato growing season (Fig. 4). In Changhua, summer tomato receives a favorable quantity of rainfall, which decreases continuously from 211 mm in August to completely dry weather in December. Summer tomato in Nantou grows under relatively evenly distributed rainfall.

Figure 8 shows a yield distinction between crops with and without rain damage. Fewer lowland summer tomato producers (24% in Changhua versus 72% in Taipei and 90% in Nantou) reported yield loss from rain damage, but percentage yield reduction was the greatest in the lowland when rain occurred. Of lowland summer tomato producers who had no yield loss from rain damage, 81% attributed their success to low rainfall and no typhoons during the crop growth period, 16% to good drainage, and 14% to high field elevation and high beds. All highland producers reported low rainfall and absence of typhoons as the only reason why they had avoided rain damage. These figures show that farmers believe yield can be improved by constructing better drainage facilities, but still much depends on the rainfall situation.

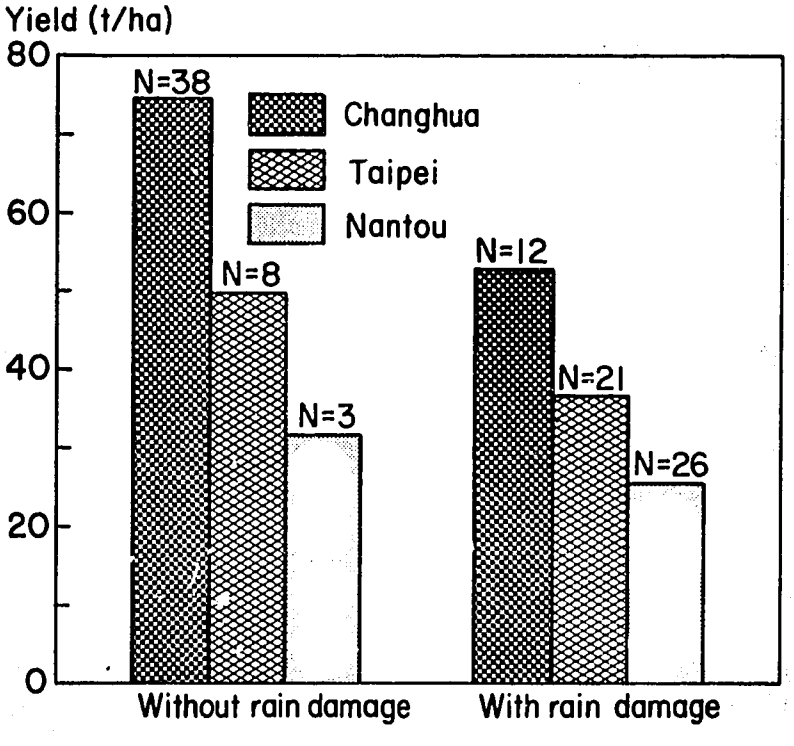

Fig. 8. Yield of crops with and without rain damage by district; AVRDC, 1978.

Therefore, we accept hypothesis b, that lowland tomato in Changhua yields more than highland due to favorable temperature and rainfall conditions.

Environmental factors and yield by district. Figure 9 shows by district the yield difference between crops with and without suitable soil, as assessed by the farmers. Suitability includes many factors such as soil type and structure, and represents an overall rating by the grower himself. In Nantou district, 20% of the producers planted on unsuitable soils and harvested about 20 t/ha, while 2% of late summer tomato producers in Changhua and 12% of early tomato producers in Taipei planted on unsuitable soil, with yields of 21 and 26 t/ha, respectively.

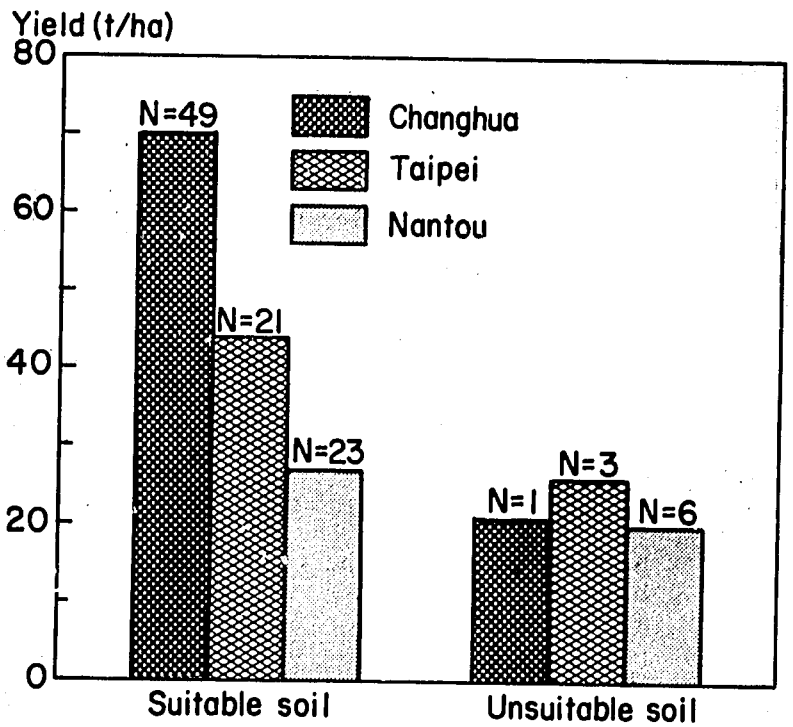

Fig. 9. Yield of crops on suitable and unsuitable soil by district; AVRDC, 1978.

Figure 10 shows a striking difference in yield between crops with and without good drainage by district. However, most crops have adequate drainage during the growth period (92% in Changhua, 97% in Taipei, and 80% in Nantou). In Changhua, farmers ranked low rainfall, drainage equipment, and high field or bed elevation as the major factors contributing to their adequate drainage system during the crop growth period. In Taipei, terraces and drainage equipment allow crops to avoid waterlogging. Farmers of summer tomato in Nantou district reported high field placement, drainage equipment, and low rainfall as the major factors in their good drainage systems.

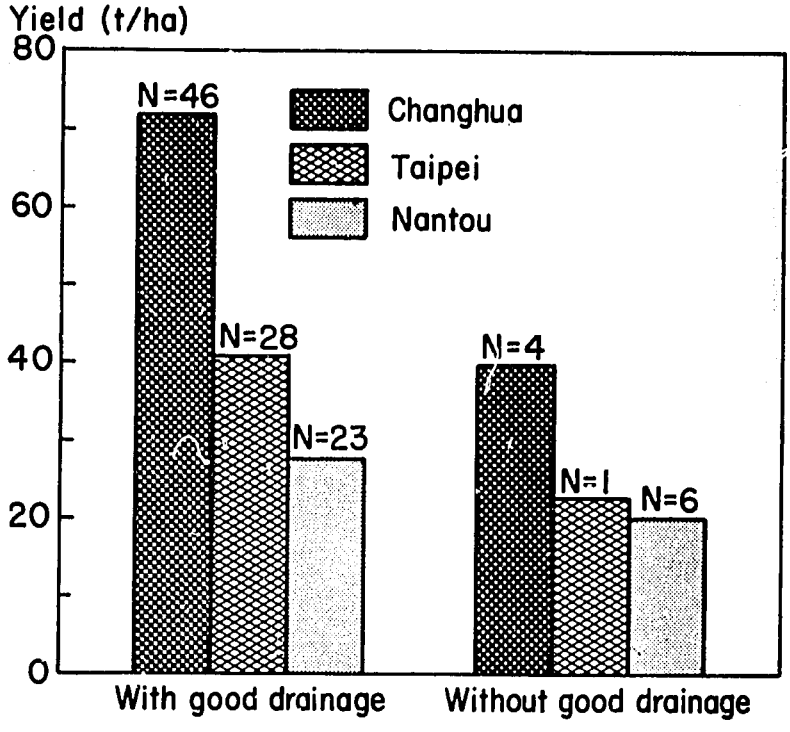

Fig. 10. Yield of crops with and without good drainage by district; AVRDC, 1978.

These data show that lowland summer tomato producers who plant their crops in the beginning of August, still in the period of summer storms and rains, are concerned enough about drainage problems to construct high beds. This prevents soil from being eroded by heavy rains and the roots from being damaged by underground water, which is usually at a high level in the Changhua area. Unlike the lowland, terraces and river beds in the mountain areas save much labor in drainage construction.

Regardless of district, pumped water, furrow irrigation,[a] and rivers are the major water sources for summer tomatoes. About 90% of the late summer tomatoes in Changhua, and 97% of the early summer tomatoes in Taipei receive adequate water during the growth period, and they yield more than those with water shortage (Fig. 11). In Nantou, however, the crops with a water shortage (40%) yield more than those without, suggesting that water supply is not as significant in determining yield as other agronomic factors in Nantou district.

A typhoon's strong winds and heavy rains can seriously reduce crop yields in the summer in Taiwan. However, only a small portion of summer tomato producers reported a yield loss from typhoons. Central Taiwan encountered no serious typhoons in the 1976-77 crop year. In Taipei, almost all farmers finished harvesting shortly before typhoons struck in 1977. Figure 12 shows a marked yield loss in crops with typhoon damage where they did occur.

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[a]Supplied through the local water users' associations, to which most farmers in Taiwan belong.

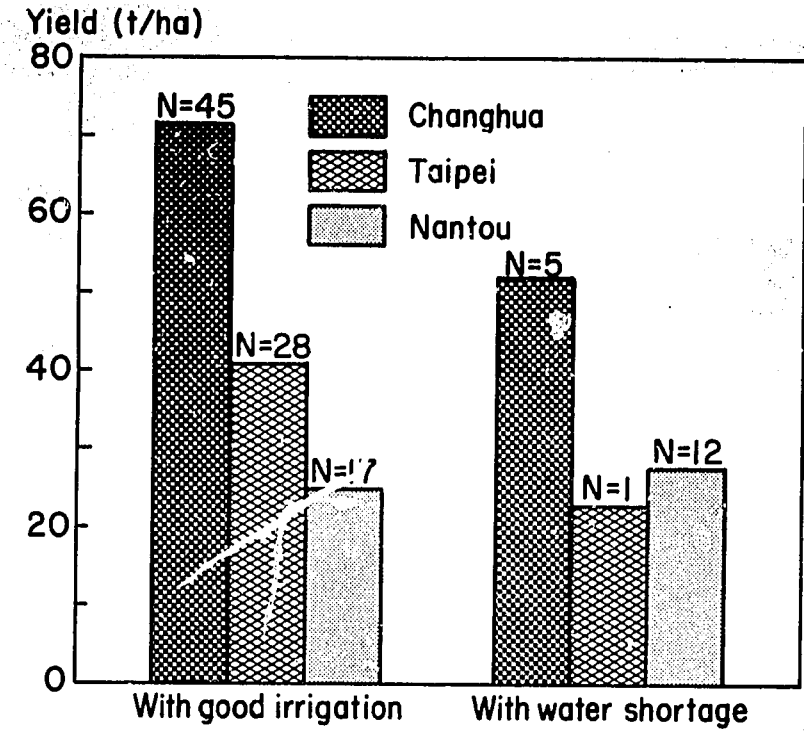

Fig. 11. Yield of crops with adequate irrigation and with water shortage by district; AVRDC, 1978.

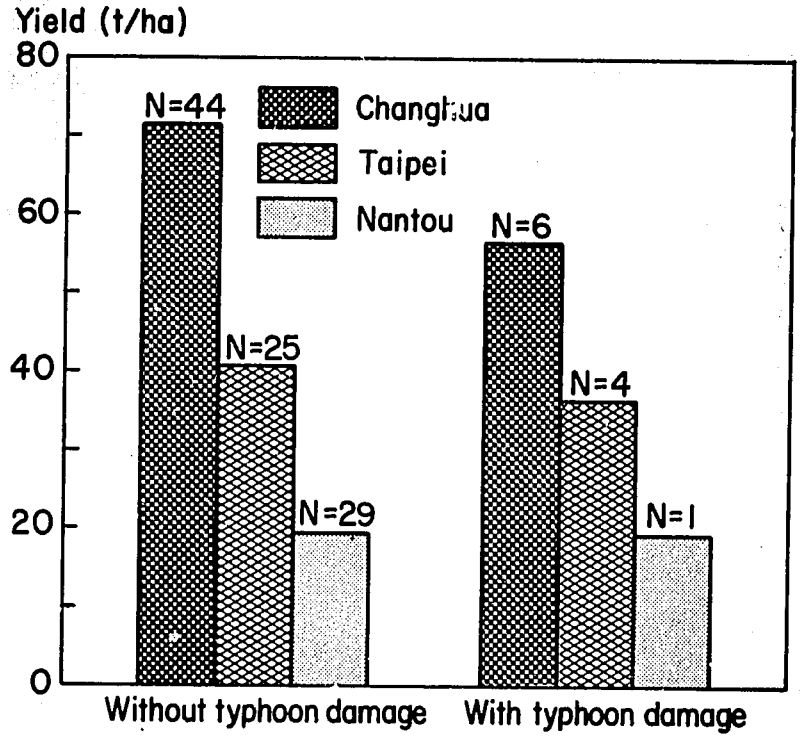

Fig. 12. Yield of crops with and without typhoon damage by district; AVRDC, 1978.

In sum, we may accept hypothesis c, that yield is a function of environmental factors. All of the environmental factors noted influence yield to some degree. What is their combined effect on yield if taken together? Discussions at local farmers associations revealed that the three main factors were sub-season, cultivar, and rain damage. These three factors included to some degree the influence of soil and typhoons. Table 2 shows means and ranges in yields/ha for the various cultivars under varying rain damage conditions for the three seasons. The highest yield is obtained with Hsi Kuang in the late summer with no rain damage, while White Skin ranks second. In this season, rain damage alone reduces the yield of White Skin by 12 t/ha, and planting in the full summer further reduces yield by 28 t/ha. Indeed, White Skin in the full summer with rain damage experiences the lowest yields of all combinations of environments and cultivars explored.

When yields are compared within each sub-season and rain damage category, very little difference is noticeable by cultivar. The table suggests that the key determinant of yield is season, followed by the extent of rain damage.

Pest incidence by season. Summer tomato is attacked by virus, early blight, bacterial wilt, grey leaf spot, and leaf mold. Blotchy ripening is also a problem. Insect damage, on the other hand, is slight. In Changhua district, 50% of late summer tomato producers reported crop disease problems. About 48% of early summer tomato producers in Taipei encountered crop disease problems more serious than those in Changhua. Summer season tomato in Nantou district had the most serious disease problems among the three production areas with 87% of producers reporting disease damage to their crops, notably from bacterial wilt.

Bacterial wilt seriously attacks highland areas of summer tomato, especially in Nantou district. White Skin, which has few disease problems in the late summer lowland, is susceptible when planted in the highland where rainfall is relatively heavy and temperature is rising during its growth period.

Therefore, we may accept hypothesis d, that pests are more serious in the highland because of environmental conditions.

Growth duration and yield by season. Late summer tomatoes in Changhua can have a long field duration only with good management. The growth duration is 149 days average, with a range of 92-229 days, and a coefficient of variation of 26%. White Skin and Hsi Kuang, indeterminate varieties of late summer tomato, continue to grow after setting fruit. The number of clusters set per plant, ranging between 4-20[a], depends on the crop growth duration which can thus be an important yield determiant. The correlation (r=0.28) between growth duration and yield is significant at the 5% level. Like lowland summer tomatoes, highland summer tomatoes set fruit 30 days after transplanting and can be harvested starting 30 days later. However, highland summer tomato has a shorter harvest period by about 32 days; the difference is caused by seasonal

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[a]Farmers usually pinch off many of these clusters so that those remaining will set large fruit.

Table 2. Yield by season, variety, and degree of rain damage, summer tomato; AVRDC, 1978.[a]

Season/location	Taipei early			Nantou full			Changhua late		
	Hsi Kuang	Known You #4	White Skin	Hsi Kuang	Known You #4	White Skin	Hsi Kuang	Known You #4	White Skin
No rain damage									
Yield (t/ha)									
Mean	45.2	49.6			30.9		75.3		64.7
Max.	45.2	65.0			30.9		120.0		143.0
Min.	45.2	36.0			30.9		40.0		16.4
Price (US$/kg)									
US$	0.37	0.38			0.30		0.07		0.11
n=	1	7	0	0	2	0	7		33
Rain damage									
Yield (t/ha)									
Mean	34.0	34.2		25.8	26.2	24.3			52.4
Max.	48.0	48.0		28.8	42.7	32.7			70.0
Min.	20.0	18.0		22.7	4.1	7.2			26.7
Price (US$/kg)									
US$	0.36	0.35		0.37	0.30	0.35			0.15
n=	2	14	0	2	11	13	0	0	12

[a]Survey data, 1977.

temperature levels. The high temperatures during the harvest period of highland summer tomato restrict crop growth; therefore, an average of six clusters per plant is usual. Unlike lowland summer tomato, the range of growth duration is 79-158 days after transplanting, with a coefficient of variation of only 14%. The correlation (r=0.05) between growth duration and yield is not significant.

Hypothesis e, that crops with longer duration yield more is true for lowland summer tomato cultivation. However, in highland production, it is only true for Taipei because high temperatures during the harvest period in Nantou reduce the feasible growth duration.

Crop density and yield by district. The correlation between crop density and yield is non-significant. However, the coefficient of variation of crop density is only 16%. Most lowland summer tomato producers manage their crops with a single stem and with a density of 21,000 seedlings/ha, which yield an average of 69.4 t/ha. In Taipei, 31% of early summer tomatoes are managed with a single stem and with a crop density of 30,000 plants/ha, which yield about 31.4 t. The remainder are managed with two stems and with a lower density, 24,000 plants/ha. The two-stem crop out-yields the single-stem crop by 12.7 t/ha. In Nantou district, farmers plant summer tomatoes at an average density of 31,000 seedlings/ha and manage their crop with a single stem, yielding 25.8 t/ha.

Although the correlation between crop density and yield is not significant in this case, a higher yield from two-stem crops managed with less crop density in Taipei encourages us to recommend management improvement by planting two-stem crops of indeterminate cultivars at lower crop densities in highland areas where production environments are relatively poor.

Thus, in the case of early summer tomato cultivation, we may accept hypothesis f, that high crop density increases yield. However, management technologies with variable crop densities from farm to farm do not significantly affect yield in Changhua and Nantou districts.

ECONOMIC FACTORS AFFECTING SUMMER TOMATO PRODUCTION IN TAIWAN

Production budgets for summer tomato by district. Table 3 shows that late summer tomato dominates the other seasons in terms of average yield. However, its relatively low price causes its total revenue, farm income, and net return to rank after highland summer tomato.

Fertilizers and pesticides are major factors in cash production costs, especially in Nantou district. Of the three production districts, Nantou's tomato production is the most capitalized, while Taipei's is the least.

Despite high overall production inputs, total production costs in Taipei are lowest due to low cash expenditures. Among non-cash production costs, labor is the major factor. Taipei tomato farmers spend the most on labor, while farmers in Nantou spend the least because wages in Taipei are highest.

Table 3. Production budgets and yield of summer tomato by district, 1976-77; AVRDC, 1978.[a]

Item	District					
	Changhua		Taipei		Nantou	
Yield (kg/ha)	69,390		40,140		25,830	
Price (US$/kg)	0.10		0.37		0.33	
Revenue (US$/ha)	6,939		15,956		8,451	
	Cash	Total	Cash	Total	Cash	Total
Expenses (US$/ha)						
A. Material	2,963	8,033	1,362	7,182	3,678	8,445
Organic fertilizers	107	112	177	233	482	488
Inorganic fertilizers	840	840	563	563	920	920
Pesticide	510	510	248	248	1,141	1,141
Staking material	383	383	252	252	379	379
Herbicide	13	13	11	11	25	25
Fuel	35	35	1	1	41	41
Hormone	79	79				
Seedlings		118		243		201
Rice straw		29				
Others	6	6	3	3	16	16
Subtotal	1,973	2,217	1,255	1,554	3,004	3,211
B. Animal power	64	81			38	82
C. Machine power	155	188		69	39	84
D. Labor	496	5,009	56	5,355	554	4,888
E. Other fixed cost	275	538	51	204	43	180
Farm income (US$/ha)	3,976		13,594		4,773	
Net return (US$/ha)	-1,094		7,774		6	

[a]Survey data, 1977.

In terms of labor hours, however, Changhua production is the most intensive (Table 4). High beds, mulching, and hormone treatments are the biggest differences between high- and lowland summer tomato cultivation. Highland areas, with good irrigation and drainage systems and without problems of high-level underground water, do not need high beds. Mulching, which keeps beds from washing down in heavy rains and reduces rain damage, could be introduced to highland areas where rain damage is a problem. In addition to pruning, tying, and harvest, labor hours used for hormone treatments is a major item, ranking after harvest.

Is it possible to promote net return and farm income by reducing production costs and improving yield? Regression analysis indicates that net return and farm income in Changhua can be promoted by both reducing production costs (hormone treatment, fertilization, and total pre-harvest costs) and elevating yield. Figure 13 shows a strong negative effect of hormone treatment[a], fertilization, and pre-harvest costs on net return. The correlations of both net return and farm income with yield are positive and significant at the 1% level.

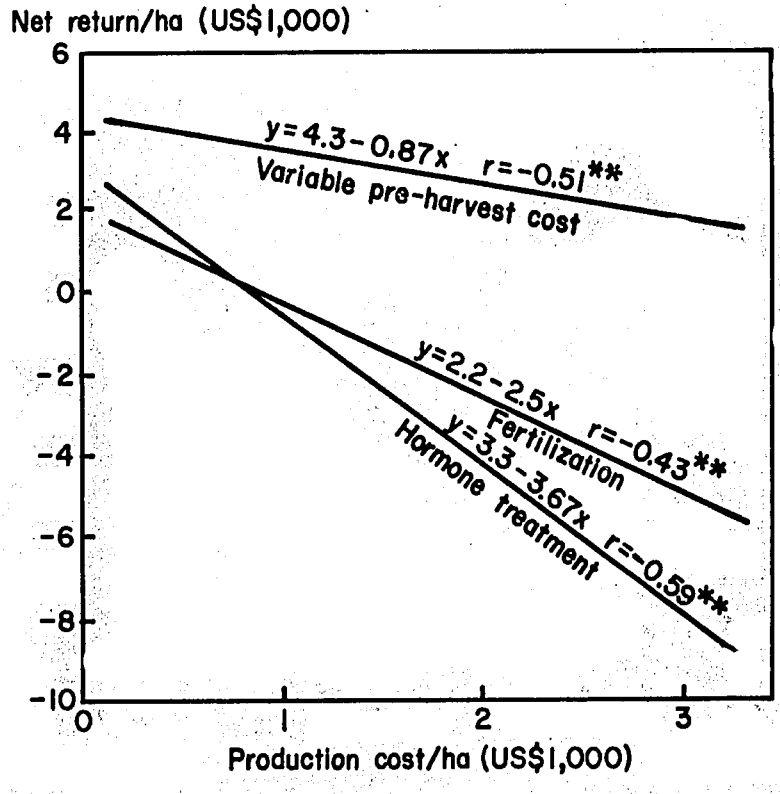

Fig. 13. The effect of hormone treatment, fertilization, and variable pre-harvest costs on net returns, Changhua; AVRDC, 1978.

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[a]The correlation reported here refers only to the late summer crop. It should be noted that in the hot humid conditions of a full summer crop in Changhua, White Skin will not set fruit without hormones. Even in the late summer there may exist the problem of simultaneous equation bias, whereby only those farmers spray who experience inevitable yield reduction. This problem underlies this and subsequent analysis, but the extent to which it influences the results cannot be estimated.

Table 4. Labor hours/hectare by operation for summer tomato production, 1976-77; AVRDC, 1978.[a]

Farming practices	Changhua (N=50)		Taipei (N=29)		Nantou (N=30)	
	hour	%	hour	%	hour	%
Land preparation	0	0	332	5	10	<1
Bed formation	529	5	242	4	283	3
Basal fertilization	135	1	94	1	121	2
Planting	170	2	199	3	175	2
Mulching	76	1	0	0	2	<1
Staking	397	4	241	3	372	5
Pruning & tying	1,911	18	1,620	23	2,195	27
Irrigation & watering	330	3	558	8	390	5
Weeding	550	5	357	5	658	8
Hormone treatment	2,297	22	0	0	0	0
Intertillage	95	1	213	3	497	6
Top dressing	361	3	408	6	425	5
Pest & disease control	806	8	423	6	892	11
Harvesting, trimming & packaging	2,710	26	2,086	30	1,868	23
Transportation	52	<1	0	0	70	1
Taking off the stakes	155	1	193	3	163	2
Total	10,574	100	6,966	100	8,121	100

[a]Survey data, 1977.

Will reducing production costs by $1 contribute more to net returns than improving yield by 10 kg (also worth $1)[a] for late summer tomato in Changhua district? The linear function of net return (Y) on hormone treatment, fertilization, variable pre-harvest costs and yield (X) is determined as : Y = a+bX, where a is the intercept, and b is the marginal return of costs on yield. The absolute marginal net returns to $1 of hormone treatment (b=-3.7) or fertilization (b=2.5) are larger than to 10 kgs of yield (b=0.1). But the returns to overall pre-harvest cost reduction (b=-0.5) are less than increasing yield 10 kg/ha. Thus, the efficiency of increasing yield 10 kg/ha is greater than that of decreasing overall costs $1, though it will be particularly worthwhile to reduce expenditures on hormone treatment and fertilization.

In Taipei, net return and farm income can be promoted by both production cost reduction (in fertilization and variable pre-harvest costs) and yield improvement. Figure 14 shows the negative effect of fertilization and variable pre-harvest costs on net return and farm income. As with late summer tomato in Changhua, increasing yield by 2.7 kg (worth $1) increases farm income and net return more than reducing production costs by $1 in the early summer season. The absolute marginal net returns to fertilization (b=-4.7) and variable pre-harvest costs (b=-1.5) are less than those from increased yield of 2.7 kg (b=39.1). For farm income as well, the absolute marginal increase to a 2.7 kg/ha increase in yield (b=39.0) is much higher than that from a reduction in pre-harvest costs (b=-0.9).

In Nantou, net return and farm income can be promoted by both production cost reduction (in spraying, fertilization, and variable pre-harvest costs) and yield improvement. Figure 15 shows the effects of variable costs on profit. The correlations of spraying, fertilizing and pre-harvest costs with net return and farm income are all negative and significant at the 1% level. Yield, however, is positively correlated with net return and farm income.

Production cost reduction increases net return more than yield improvement. The absolute marginal values of net return to spraying (b=-3.7), fertilization (b=-2.6), and variable pre-harvest costs (b=1.4) are greater than those to yield (b=1.1) improvement of 3 kg ($1). Similarly, the absolute farm income increase from spraying (b=-2.1) and fertilization (b=-1.6) is higher than that from yield improvement (b=1.0). Reducing variable pre-harvest costs (b=-0.8) would improve farm income less than increasing yield, however.

Can farmers improve agronomic yields by increasing production costs on hormone treatment, spraying, fertilization, and overall pre-harvest management? Apparently not. In every production season, the correlation between yield and production costs is not significant at the 5% level.[b]

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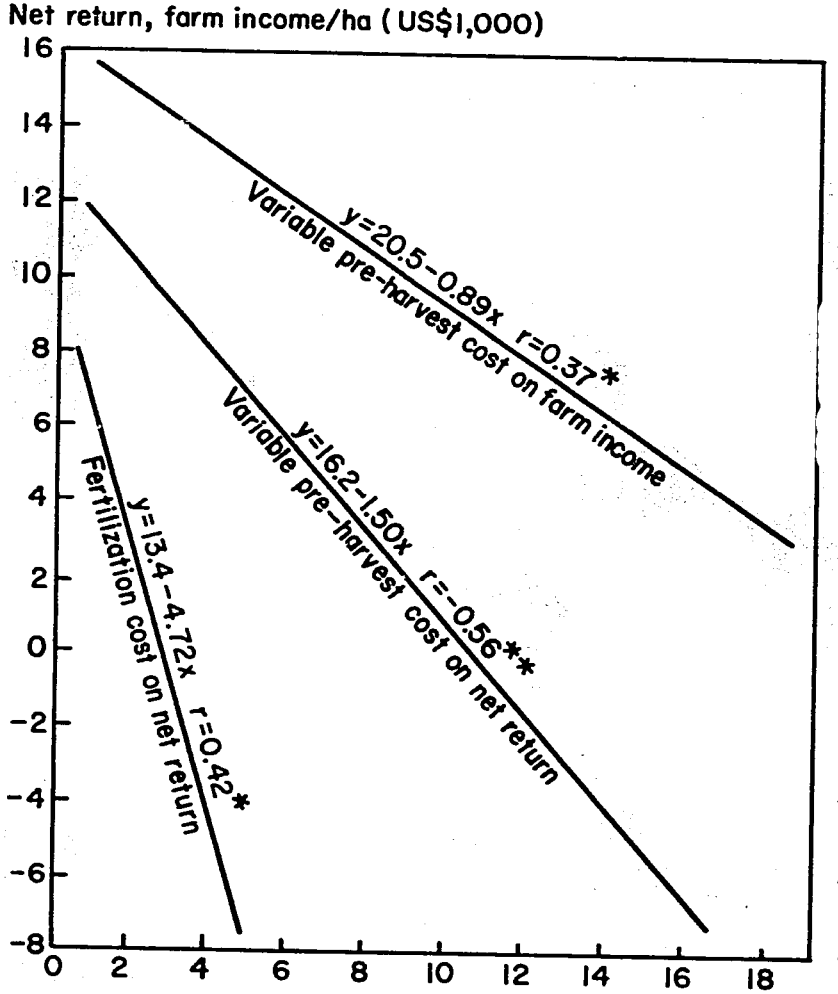
[a]The answer to this question depends on the units assigned. Clearly, increasing yield by 50% is better than reducing hormone costs by 50%. Here we use an equal value of cost reduction and yield increase as an example for comparison with other districts.

[b]See cautionary note on simultaneous equation bias, p.19.



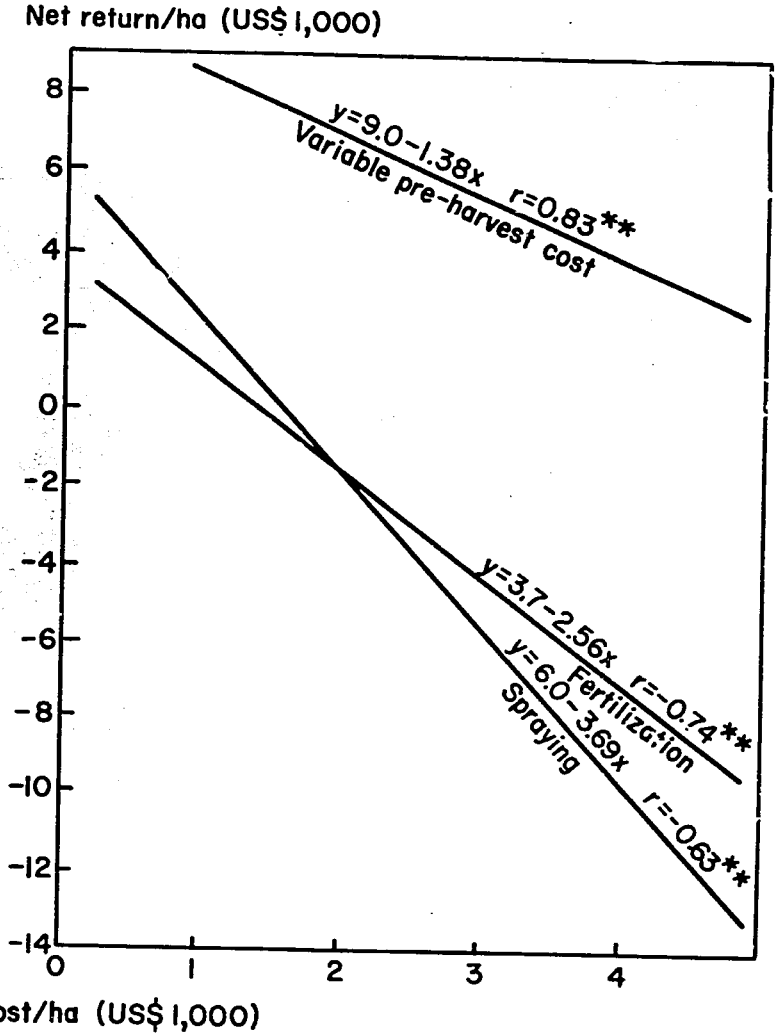


Fig. 14. The effect of fertilization and variable pre-harvest costs on net return and farm income, Taipei; AVRDC, 1978.

Fig. 15. The effect of spraying, fertilization, and pre-harvest costs on net return, Nantou; AVRDC, 1978.

Table 5. Comparison of production factors among summer tomato, non-summer tomato and rice in Taiwan, 1976-77; AVRDC, 1978.[a]

Crops	Summer tomato[a] N=109	Winter processing[b] tomato N=10	Winter fresh-market tomato[c]	Rice[c]
Yield kg/ha	49,946	32,471	48,452	4,796
Price US$/t	175	29	95	300
Revenue US$	8,722	954	4,608	1,431
Expenses US$	8,039	827	4,372	1,248
Capital	3,016	369	1,546	744
Labor	5,023	458	2,826	504
Net return US$	683	127	236	183
Farm income US$	5,769	372	3,174	817

Source: [a]Survey data, 1977. [b]Statistics from AVRDC Farming Practices Project, 1977. [c]Ref. 5.

Thus, we must reject hypothesis g, that farmers may increase yield and profits by increasing production costs. In the early summer, yield improvement is more effective in increasing profit than cost reduction. In the other two seasons, cost reduction is more effective.

Comparative profitability among summer tomato, non-summer tomato, and its competing crops (Table 5). Spring rice in Taipei and Nantou, and summer rice in Changhua are the usual competing crops with summer tomato. Table 5 shows that we may accept hypothesis h, that summer tomato is more profitable than either non-summer tomato or rice.

Sales outlets of summer tomatoes by district. In Changhua (Table 6), the major transaction places are wholesale markets (94%), local assemblage lots (38%), and the home (22%). In Taipei, 83% of early summer tomatoes are sold at home and 17% are sold at local assemblage lots. In Nantou, most of the crop is transacted at road-sides near the farm (97%) and only a small portion (3%) is sold at home. Almost all early summer tomatoes in Taipei (99%) are sold wholesale to the Taiwan Fruit and Vegetable Marketing Company. In Changhua and Nantou, about 80% of the crop is sold wholesale for domestic consumption and about 20% is exported.

These export patterns help to explain changing areas planted to various cultivars in the three locations sampled. White Skin has good post-harvest quality and is sought by export agents. Farmers in Changhua, who export 20% of their crop, have increased their planted area to White Skin from 56 to 84% (see bottom page 9). There has been no increase of White Skin planting in Nantou, but production is already greater than export requirements. Similarly, the Taipei area produces large red tomatoes with "green shoulders", preferred by local consumers. Known-You No. 4 and Hsi Kuang are both of this type and it is not surprising that the area planted to the former has increased from 28 to 69%.

Table 6. The outlets of summer tomato bv district, 1976-77; AVRDC, 1978.[a]

Outlets of commodities	District		
	Changhua	Taipei	Nantou
	%		
Home consumption	<1	1	<1
Gift	<1	<1	<1
FA[b] marketing cooperative	1	0	0
Wholesale for domestic consumption	78	99	78
Wholesale for export	21	0	22
Total	100	100	100

[a]Survey data, 1977. [b]Farmers' Association.

CONCLUSIONS

1. Lowland summer tomato producers prefer the White Skin cultivar. Under moderate rainfall during its growth period, it can set fruit in a temperature range between 23-33°C in September. Known-You No. 4 is planted mostly by summer tomato producers in the highland, where it outyields White Skin.

2. Lowland summer tomato producers seek heat tolerant cultivars for early planting to gain higher prices. Highland producers, on the other hand, seek improvement in appearance, yield, and resistance to pests.

3. Lowland summer tomato is more productive than highland because of more serious disease problems in the latter area.

4. High- and lowland production districts are generally equipped with adequate water-supply and drainage systems. However, more crops in Nantou district are planted on unsuitable soils than Changhua and Taipei.

5. Temperature and rainfall variation, cultivar and soil quality were the major factors affecting summer tomato production in Taiwan in 1976-77.

6. Yield depends on agronomic factors and not on economic factors such as production costs.

7. The promotion of farm income and net return depends on yield improvement, especially for early summer tomato cultivation in Taipei and late summer production in Changhua. Reduction in production costs can promote farm income and net return, especially for full summer season tomatoes in Nantou. Summer tomato producers tend to use too much capital and labor, especially in Changhua and Nantou. Still, summer tomatoes dominate competing crops and non-summer tomatoes in profitability. They are largely sold wholesale for domestic consumption and export.

RECOMMENDATIONS

Research Institutes

1. Researchers should work to develop cultivars superior to Known-You No. 4 in resistance to rain damage, fruit crack, pests, and high temperature for summer tomato production in the highlands. If such cultivars cannot be introduced, highland summer tomato producers should replace White Skin with Known-You No. 4, which has more productive potential at high elevations.

2. For lowland summer tomato producers, researchers should develop cultivars superior in heat tolerance to White Skin to allow farmers to get higher prices by planting earlier.[a]

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[a]In preliminary experiments on sandy and silt loam soils in southern Taiwan, the AVRDC selection C11d-1-0-2-2-0 can already outyield White Skin.

3. Because yield is very significant to farm income and net return, especially in early and late summer, production technologies to improve farmers' yield should be developed.

4. In order to make final recommendations on hormone treatment to farmers, research workers should conduct experiments to show the effect of hormone treatment on yield, farm income, and net return.

Growers

1. Because the yield of summer tomatoes depends more on agronomic than on economic factors, producers should focus on such technologies as varietal change, soil selection, crop management with mulching, plant density and stem number, water supply and drainage system, and precautionary measures against weather to improve yield.

2. Producers should mulch in the highland where there is serious rain damage, and manage their tomato as a two-stem crop at lower seedling density.

3. Analysis of available farm-level data suggests that farmers should experiment with reduced investments in hormone treatment, spraying, fertilization, and variable pre-harvest costs to improve net return from summer tomato production.

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