Pertanika 6(1), 83–92 (1983)

Climatic influences on the variations of wet paddy (*Oryzae sativa* L) yields in the various states of Peninsular Malaysia

ONG HEAN TATT[1]
Plant Science Branch, MARDI, Serdang, Selangor.

Key words: climatic influences; wet paddy yields; Peninsular Malaysia.

RINGKASAN

Pengeluaran padi basah bagi negeri-negeri di Semenanjung Malaysia berhubungan dengan perubahan-perubahan curahan hujan, kemarau, sinaran matahari, suhu maksimum dan minima semasa musim 1975/76 dan luar musim 1976 telah dikaji dengan menggunakan pendekatan sistem. Faktor-faktor iklim yang mempengaruhi pengeluaran padi telah dikenalpasti sebagai curahan hujan pada bulan kedua hingga kelima sebelum penuaian, min suhu tertinggi sebulan sebelum penuaian dan min suhu terendah bulan kedua sebelum penuaian. Kesemuanya ini melibatkan 83.9 peratus daripada perubahan-perubahan di dalam pengeluaran padi basah. Kedapatan juga bahawa negeri-negeri Semenanjung Malaysia mempunyai perbezaan yang konsisten dari tahun 1946 hingga 1977 dan perbedaan pengeluaran mengikut wilayah ini nampaknya adalah disebabkan oleh perubahan-perubahan curahan hujan dan suhu-suhu udara.

SUMMARY

The wet paddy yields in the states of Peninsular Malaysia during the 1975/76 main and 1976 off seasons were studied in relation to changes in rainfall, dry spells, sunshine, maximum and minimum temperatures through the principles of system approach. The main climatic factors influencing the yields were identified as rainfall during the 2nd to 5th months before harvest, the mean minimum temperature of the 4th month before harvest and the mean maximum temperature of the month before harvest, accounting for 83.92% of the variations in the wet paddy yields. The various states of Peninsular Malaysia had consistent differences in wet paddy yields since 1946 to through 1977 and these regional differences in yields appeared principally due to the climatic changes in rainfall and air temperatures.

INTRODUCTION

In Peninsular Malaysia, certain states traditionally have consistently higher or lower wet paddy yields than other states. Although these differences have been partly attributed to soil differences, climatic changes were also indicated (Samy, Gopinathan and Vamadevan, 1980). There is evidence that soil factors may not be important in accounting for variations in wet paddy yields in different locations (Grist, 1975; Yoshida and Parao, 1976). In India, irrigation was found to account for about 42% of the variations in wet paddy yields (Desai and Thingalaya, 1965). In Japan a number of workers found that locational differences in wet paddy yields were mainly regulated by interactions between solar radiation and average daily mean temperatures (Murata, 1976; Munakata, 1976; Tanaka, 1976).

Recently workers have adopted the system approach, which utilises measurements of yields in naturally varying environments to work out by statistical correlations how climate affects the yields, for sunflower (Smith, Anderson and Harris, 1978), cereals (Nix, 1975) and pasture grass (Fitzpatrick and Nix, 1970). The present paper sought to use the system approach to determine the climatic factors which account for the regional differences in wet paddy yields in Peninsular Malaysia of the 1975/76 main and 1976 off seasons.

MATERIALS AND METHODS

Data

Average wet paddy yields of the eleven states of Peninsular Malaysia from 1946 to 1977 were obtained from the Malaysian Agricultural Journal

[1] Present address: 104, Jalan SS2/75, Petaling Jaya, Selangor, Malaysia.

Key to author's name: H.T. Ong.

and Paddy Statistics issued by the Ministry of Agriculture and Fisheries, Malaysia. There were inevitable changes in methods of assessment of paddy yields through the years. Nevertheless, the paddy yields from 1946 to 1977 still gave a reasonable picture of the variations of yields between the states. This is borne out in the results which show that the differences in yields between the states were remarkably consistent from season to season; and from year to year.

The traditional main season for paddy cultivation begins with transplanting during the later half of the year with the harvest in the following year; and takes advantage of the seasonal rains. Off season cultivation became more practised when irrigation facilities improved and usually took place in mid-year.

Wet paddy yields of the 1975/76 main and 1976 off seasons were used to study the climatic effects. Each state has a number of major padi localities with some differences in periods of cultivations. These periods were noted from the Paddy Calendar issued by the Ministry of Agriculture and fisheries, Malaysia and averaged (Table 1).

The average harvest periods were determined; and relevant meteorological data for the varying

Table 1
Yields of paddy and average periods of harvest in various states in Peninsular Malaysia in 1975/76 main and 1976 off seasons.

	Yield mt/ha	Period during which paddy harvested	Location of meteorological station*
Main season:			
Johore	2.04	Oct. to Dec. '75	Kluang
Kedah	3.37	Jan. to March '76	Alor Star
Kelantan	1.86	Feb. to April '76	Kota Bahru
Malacca	2.16	Jan. to Feb. '76	Malacca
Negri Sembilan	2.71	Jan. To April '76	Seremban
Pahang	1.88	Sept. '75 to Jan. '76	Kuantan
Perak	2.68	Dec. '75 to March '76	Ipoh
Penang	3.29	Jan. to May '76	Penang
Perlis	3.30	Nov. '75 to March '76	Kangar
Selangor	3.12	Feb. to May'76	Kuala Lumpur
Trengganu	1.91	March to May '76	Kuala Trengganu
Off season:			
Johore	1.97	Jyly to Sept. '76	
Kedah	4.16	Aug. to Sept '76	
Kelantan	2.33	Sept. '76	
Malacca	2.09	July to Aug '76	
Negri Sembilan	2.62	Aug. to Oct. '76	
Pahang	2.11	July to Aug. '76	
Perak	2.59	July to Sept. '76	
Penang	3.16	July to Dec. '76	
Perlis	4.14	Aug. to Sept. '76	
Selangor	3.12	Aug. to Oct. '76	
Trengganu	1.90	Aug. to Oct. '76	

* Towns where stations were located. 'Penang' and 'Malacca' are names both of the towns as well as the states. Where the harvest period is one month, meteorological data would be taken for one month periods at monthly intervals before harvest. Where the harvest period stretched over say two months, then what were taken were the monthly averages of the two months periods, shifted at monthly intervals backward. Similar computations were made where the harvest periods were longer.

periods before the average harvest periods were obtained from the Malaysian Meteorological Department. The maturation periods of the paddy varieties averaged 130 to 145 days. The climate covering the period five months before harvest was considered. The climatic factors studied were monthly mean rainfall, sunshine hours, maximum and minimum temperatures and dry spells (estimated as days per month without rains).

Analysis

Wet paddy yields from 1946 to 1977 were averaged for various periods (Table 2). Friedman's Rank Method was used to determine the nature of the differences in yields of the different states during the various periods. Spearman's Rank Correlation analysis was then carried out to establih whether the differences were persistent over the periods 1946 to 1977.

Yields of the 1975/76 season were pooled with those of the 1976 off season. Simple correlations were carried out with Spearman's Rank Correlation Method between yields and climatic changes at the different months before harvest. Significant simple correlations were further examined through the Kendall Partial Correlation Method to eliminate spurious climatic effects. The relationships were then reanalysed and summarised into a multiple regression equation.

RESULTS

Differences in wet paddy yields

During the 1946 to 1958 main seasons, the highest yields were in the states of Kedah, Perlis and Selangor while the lowest yields were in Johore, Pahang and Trengganu (Table 2). For the 1960 to 1968 main seasons, the highest yields were in Selangor, Perlis and Kedah while the lowest yields were in Trengganu, Pahang, Kelantan and Johore. From the 1971 to 1977 main seasons the highest yields were in Kedah, Perlis, Selangor

Table 2
Yields of wet paddy of various states of Peninsular Malaysia from 1946 to 1977

	Average yield, metric tons/ha				
	Main season			Off season	
	'46/'47 to '57/'58	'60/'61 to '67/'68	'71/'72 to '76/'77	65 to '68	'71 to '71
Perlis	2.19^{d}	3.10^{de}	3.22^{bc}	2.74^{b}	3.45^{cd}
Kedah	2.22^{d}	3.01^{de}	3.32^{c}	2.81^{b}	3.66^{d}
Kelantan	1.64^{abcd}	1.64^{ab}	2.01^{a}	2.41^{a}	2.57^{abc}
Trengganu	1.40^{ab}	1.50^{a}	1.80^{a}	2.37^{a}	2.21^{abc}
Penang	1.74^{bcd}	2.87^{cde}	3.19^{bc}	2.87^{b}	3.24^{abcd}
Selangor	2.01^{cd}	3.29^{c}	3.21^{bc}	3.09^{b}	$3\ 39^{bcd}$
Perak	1.59^{abc}	2.37^{abcd}	2.57^{abc}	2.32^{a}	2.69^{abcd}
Pahang	1.29^{ab}	1.58^{a}	1.60^{a}	2.24^{a}	1.93^{a}
Negeri Sembilan	1.83^{bcd}	2.58^{bcd}	2.46^{abc}	2.78^{b}	2.59^{abcd}
Malacca	1.70^{abcd}	2.30^{abcde}	2.26^{ab}	2.59^{ab}	2.26^{abc}
Johore	1.12^{a}	1.83^{abc}	2.28^{abc}	2.57^{ab}	2.14^{ab}
Analysis by Friedman's Procedure*:					
X^2 :	34.6	66.3	45.9	33.9	39.8
P :	0.001	0.001	0.001	0.001	0.001

*Values in each column not having the same letter are significantly different at 0.05, as computed by Friedman Test for paired comparisons (Langley, 1970).

and Penang while the lowest yields were in Trengganu, Pahang and Kelantan.

In the 1965 to 1968 off seasons, the highest yields were in Perlis, Kedah and Selangor while the lowest yields were in Trengganu, Kelantan and Pahang. In the 1971 to 1977 off seasons the highest yields were in Kedah, Perlis and Selangor while the lowest yields were in Pahang, Johore, Malacca and Trengganu.

Some states showed high yields repeatedly while other states had lower yields. Table 3 indicates that the yield differences of one period correlate positively with yield differences of other periods. The differences in wet paddy yields of the sates have been persistent since 1946.

Effects of rainfall

Rainfall, when not excessive, is expected to be beneficial to padi yields (Grist, 1975). Preliminary scatter diagrams indicates that the yields of the 1975/76 main and 1976 off seasons in the states of Peninsular Malaysia tended to show curvilinear relationships to rainfall; the 1975/76 main season paddy yields of Trengganu, Kelantan and Pahang tended to be low and appeared to be associated with excessive rainfall. The exclusion of the yields of these three states in the 1975/76 main season led to the other yields falling into linear relationships with the rainfall. It was necessary in this paper to utilise simple correlation coefficients in partial correlations. As both the simple and partial correlations involve linear relationships it was necessary in the initial sections of the paper to exclude the 1975/76 main season yields of these three states from the simple and partial correlations. In the final sections of the paper, when climatic factors which were thought to affect the yields had been narrowed down, a reanalysis was made through curvilinear regressions. At this juncture the yields of the main season of the three states, which had been excluded, were reintroduced and reexamined in the light of the overall yields of the main and off seasons of all the states.

Table 4 shows that the effects of a one-month rainfall were greatest at the fourth month before harvest. However, more significant correlations were obtained when the effects of two or more consecutive months were considered together. The most significant simple correlation occurred between yields and the four months rainfall of the second to fifth months before harvest ($r_s = 0.7092$). Where rainfall in consecutive months or its various combinations showed significant correlations to the yields, it was necessary to determine which period of rainfall was the more meaningful; it was assumed that the less meaningful period was due to autoregressions to the real effects of rainfall. In this paper the 'more meaningful' period was taken to be that period which showed a higher correlation between rainfall effects and yield paper.

Table 3
Simple correlations between yields of wet paddy of various states in Peninsular Malaysia of one period to yields of other periods*

	'60/'61 to '67/'68 main season	'65 to '68 off season	'70/'71 to '76/'77 main season	'71 to '77 off season
'46/'47 to '57/'58 main season	0.872^{e}	0.752^{d}	0.745^{d}	0.882^{e}
'60/'61 to '67/'68 main season		0.839^{e}	0.891^{e}	0.818^{d}
'65 to '68 off season			0.657^{c}	0.652^{c}
'70/'71 to '76/'77 main season				0.855^{e}

*Yields of various states of one period correlated to yields of other periods through Spearman's Rank Correlation Method.

'c', 'd', 'e' denotes respectively coefficients significant at 0.025, 0.01 and 0.005.

Table 4
Simple correlations of yields of wet paddy of the various states of Peninsular Malaysia to monthly changes in rainfall, dry spells, sunshines and temperatures[1]

Month(s) before harvest[2]	Rainfall	Dry spell	Sunshine hours	Temperatures	
				Mean maximum	Mean minimum
1st	−0.0707	0.2657	0.0312	0.4564[b]	0.1387
2nd	0.2361	0.0466	−0.2081	−0.2354	0.1751
3rd	0.3173	−0.899	−0.4072[a]	−0.2106	0.4206[a]
4th	0.4436[b]	−0.2301	−0.2777	0.1591	0.5150[b]
5th	0.3105	−0.3061	−0.3322	0.0601	0.4748[b]
All 5 months	0.6386[c]	−0.1564	−0.2893	−0.0197	0.2725
2nd to 5th months	0.7092[c]	−0.1895	−0.2965	−0.1246	0.3996
3rd to 5th months	0.4511[b]	−0.2331	−0.3215	−0.0864	0.4845[b]
4th to 5th months	0.5825[b]	−0.3128	−0.2893	0.0211	0.4973[b]
2nd to 4th months	0.5579[b]	−0.1741	−0.3179	−0.1384	0.4132[a]
3rd to 4th months	0.5859[b]	−0.2749	−0.3179	−0.1797	0.4718[b]
2nd to 3rd months	0.3439	−0.2004	−0.2652	−0.1215	0.2026
1st to 2nd months	–	0.1834	–	–	–

[1] Yield is correlated to average monthly value of various climatic factors during various periods before harvest by the Spearman's Rank Correlation method

'a' denotes correlation coefficient significant at 0.10

'b' denotes correlation coefficient significant at 0.05

'c' denotes correlation coefficient significant at 0.01

[2] Data for Trengganu, Pahang and Kelantan during the main season not used in analysis (qv text for explanation).

Effects of dry spells

Dry spells had no effects on the yields during the 1975/76 main and 1976 off seasons..

Effects of sunshine

No sunshine records were available for the states of Negri Sembilan and Perlis. Simple correlations were thus carried out only for the other states between sunshine and the yields. Only sunshine of the third month before harvest showed a weak negative correlation to the yields.

Effects of temperatures

Significant correlations were found to exist between yields and the mean maximum temperatures of the first month before harvest. Yields could be correlated to mean minimum temperatures of the third, fourth and fifth months as well as for longer periods of third to fifth; fourth to fifth; second to fourth; and third to fourth months before harvest. The greatest minimum temperature effect was with the fourth month before harvest ($r_s = 0.5150$).

Partial Correlation Analysis

The Kendall coefficient for the third month sunshine effect was −0.2578 (Table 5). After partial correlation to account for the effects of rainfall (second to fifth months), the Kendall Partial coefficient for the sunshine effect dropped to −0.0196. Thus the sunshine effect was not real but was due to associations with the rainfall effect.

Effects of the maximum temperature of the first month were more significant after partial correlations accounted for the rainfall of second to fifth months and minimum temperatures of the fourth month. There were interactions between the rainfall and the fourth month minimum

Table 5
Partial correlations of yields to various climatic factors

Unfixed climatic variable	Kendall correlation coefficient	P[1]	Fixed climatic variable	Kendall partial correlation coefficient	P[1]
2nd to 5th months rainfall	0.4712	0.0019	3rd month sunshine	0.4086	0.0059
3rd month sunshine	−0.2578	0.0571	2nd to 5th months rainfall	−0.0196	ns
1st month rainfall	−0.0712	ns	2nd to 5th months rainfall	−0.1684	0.1469 (ns)
1st month maximum temperature	0.2948	0.0344	2nd to 5th months rainfall	0.3407	0.0179
1st month maximum temperature	0.2948	0.0344	4th month minimum temperature	0.3291	0.0212
4th month minimum temperature	0.3421	0.0174	2nd to 5th months rainfall	0.2634	0.0526
2nd to 5th months rainfall	0.4712	0.0019	4th month minimum temperature	0.4243	0.0045

[1] 'P' denotes probability.
'ns' denotes insignificant coefficient at 0.10.

temperatures as the significance of the correlation was slightly reduced after the partial correlation between maximum temperature effects for the first month as rainfall of the second to fifth months had been parcelled out.

These partial correlations thus identify those climatic factors which were involved in the differences in wet paddy yields of the states; rainfall of the second to fifth months; maximum temperatures of first month and minimum temperatures of the fourth month before harvest (Table 6).

Multiple Regression Analysis

The three main climatic factors identified from the partial correlations analysis were reanalysed to determine the linear, quadratic and cubic terms of their relationship to the yields. In this analysis, the 1975/76 main season yields of Trengganu, Kelantan and Pahang were now reintroduced. The multiple regression analysis involved the main and off season yields of all the states.

Table 7 shows that the cubic terms were not significantly involved. When the linear and quadratic terms of the three climatic factors were considered together for their combined influences on the yields as in Table 8.a., the following multiple regression equation was obtained:

$$Y_1 = -53478 + 2.58R - 0.0034R^2 + 4228M - 65.8M^2 - 1344m + 31.48m^2$$

Y_1 – expected yield in metric tons/ha

R – rainfall in mm per month, averaged over 2nd to 5th months before harvest

M – maximum temperatures, daily mean, of 1st month before harvest, °C

m – minimum temperatures, daily mean, of the 4th month before harvest, °C.

The total regression of the equation was significant at 0.5% probability and had a coefficient of determination of 0.7326. However, it was found that the residual deviations of the above equation could still be accounted for as in Table 8.b. The residual

Table 6
Yields of wet paddy of various states and the monthly changes in the main affecting climatic factors*

	Yield metric tons/ha	Rainfall of 2nd to 5th month before harvest mm	Maximum temperature of 1st month before harvest °C	Minimum temperature of 4th month before harvest °C
1975/76 *main season*				
Johore	2.04	163.4	30.50	22.20
Kedah	3.37	217.9	31.87	22.97
Kelantan	1.86	412.0	29.80	22.73
Malacca	2.16	201.9	31.05	22.50
Negri Sembilan	2.71	185.1	31.60	20.38
Pahang	1.86	238.2	30.62	22.44
Penang	3.29	197.5	31.44	22.94
Perak	2.68	201.9	32.05	22.58
Perlis	3.30	213.5	31.16	23.16
Selangor	3.12	198.9	32.18	22.30
Trengganu	1.19	421.3	30.23	21.50
1976 *off season*				
Johore	1.97	170.1	30.87	22.63
Kedah	4.16	224.1	31.50	23.55
Kelantan	2.33	111.6	31.80	23.70
Malacca	2.09	151.4	30.95	21.85
Negri Sembilan	2.62	163.0	31.17	23.50
Pahang	2.11	90.0	32.25	22.10
Penang	3.16	223.9	30.75	23.45
Perak	2.59	166.9	32.73	22.83
Perlis	4.14	171.8	31.45	23.55
Selangor	3.12	163.5	31.93	22.57
Trengganu	1.90	152.4	30.80	22.83

*Values of climatic factors given are average monthly values of various relevant periods before harvest.

deviations were found to be related to Y_1, divided by the square of the maximum temperature at the quadratic level. This was significant at 0.5%. When this relationship was introduced into the original multiple regression equation, a new multiple regression was obtained:

$$Y = -51920 + 2.886R - 0.0039R^2 + 4072M - 63.2M^2$$
$$-1192m + 27.72m^2 - 3793\left[\frac{Y_1}{M^2}\right] + 4478\left[\frac{Y_1}{M^2}\right]^2$$

where Y is the final expected yield in metric tons per ha. The total regression of this equation accounted for about 84% of the variations in the paddy yields of the various states of Peninsular Malaysia during the 1975/76 main and 1976 off seasons and is significant at 0.5%.

DISCUSSIONS

During the 1975/76 main and 1976 off seasons, the variations in the wet paddy yields among the states of Peninsular Malaysia were due to rainfall, maximum and minimum temperatures, but not dry spells and sunshine. The variations of rainfall in the fourth month before harvest had eventual effects on the padi yields. This indicates that the early part of tillering was particularly

Table 7
Analysis of variance of correlations of yields to various climatic factors[3]

Source of variation	df	SS	MS	F	P[1]
a) *Rainfall, 2nd to 5th months before harvest*					
Total	21	279856			
Linear	1	4915	4915	0.3576	
Deviation from linear	20	274941	13747		
Quadratic	1	70977	70977	6.6118	2.5%[2]
Deviation from quadratic	19	203963			
Cubic	1	2020	2020	0.1801	
Deviation from cubic	18	201942	11219		
b) *Maximum temperature, 1st month before harvest*					
Total	21	279856			
Linear	1	51163	51163	4.4745	5%
Deviation from linear	20	228692	11434		
Quadratic	1	35584	35584	3.5012	10%[2]
Deviation from quadratic	19	193107	10163		
Cubic	1	13059	13059	1.3056	
Deviation from cubic	18	180048	10002		
c) *Minimum temperature, 4th month before harvest*					
Total	21	279856			
Linear	1	54196	54196	4.8034	5%
Deviation from linear	20	225659	11282		
Quadratic	1	43577	43577	4.5472	5%[2]
Deviation from quadratic	19	182082	9583		
Cubic	1	6124	6124	0.6266	
Deviation from cubic	18	175957	9775		

[1] 'P' denotes probability. Other F values not showing probability levels are not significant at 10%.

[2] The X_{max} for the rainfall, maximum and minimum temperatures is, respectively, 255 mm, 31.80°C and 21.59°C per month.

[3] Analysis done for all eleven states over both 1975/1976 main and 1976 off seasons.

sensitive to the rainfall changes. However, the greatest response to rainfall was obtained when the first four months of the paddy growth were considered together, indicating that the whole vegetative stages of paddy growth, including the nursery stage and also the young panicle formation stage, as a whole, were sensitive to the rainfall changes. The optimal amount of rainfall over the 1975/76 main and 1976 off seasons appeared to be about 255 mm per month, over the four months period, which confirms the findings of Grist (1975) who noted that rainfall in many areas accounted for 80% of the 700 to 1800 mm water required for the whole paddy cycle. It also agrees with what is known of the beneficial effects of rainfall as well as injurious effects due to excessively heavy rains (Grist, 1975; IRRI, 1976).

Variations in minimum temperatures during the fourth month before harvest affected paddy yields of the states. This indicates that the early stage of tillering is also sensitive to changes in night temperatures. Grist (1975) has noted that low temperatures during the seedling stage lead to reduced tillers. Higher maximum temperatures during the first month before harvest also

Table 8
Multiple regression of the relation of the yields to various climatic factors

[a] Relation of yields to the linear and quadratic terms of rainfall, maximum and minimum temperatures

i) *Coefficients*

Intercept	−53478.3880
Rainfall, linear	2.5836
quadratic	−0.0034
Maximum temperature,	
linear	4228.2399
quadratic	−65.8341
Minimum temperature,	
linear	−1344.0468
quadratic	31.4886

ii) *ANOVA*

Source of variation	df	SS	MS	F	P
Total	21	279856			
Regression	6	205040	34173	6.8515	0.5%
Residual	15	74815	4987		

[b] Relation of residual deviations (from (a)) to interaction of expected yields (from (a)) with maximum temperature

i) *ANOVA*

Source of variation	df	SS	MS	F	P
Total	21	74815			
Expected yield (maximum temp.)^2 :					
linear	1	0.4	0.4	0.0001	
deviation from linear	20	74817	3740		
quadratic	1	28273	28273	11.5418	0.5%
deviation from quadratic	19	46543	2449		
cubic	1	1566	1566	0.6267	
deviation from cubic	18	4497	2498		

ii) *Coefficents*

Intercept	−1462.4230
Exp. yield max. temp.^{2} :	
linear	8979.1231
quadratic	−16992.6601

influenced paddy yields. This indicates that higher day temperature's favour ripening or grain-filling which conforms with the findings of Murata (1964), Hanyu *et al.*, (1966) and Murakami (1973). The optimal maximum temperature was 31.80° C.

The finding that sunshine had no significant effect on the yields supports the conclusions of the Yoshida and Parao (1976) experiments in Philippines. Yoshida and Parao (1976) found that at the normal range of solar radiation in the tropics of 300–400 $kcalm^{-2}$ and above, wet paddy yields should be about 6 tons/ha and above. They also found that yields in the dry season would not be higher than yields in the wet season unless the leaf area index exceeds 4 to 5, corresponding to a yield of at least 5 to 6 tons/ha. Yoshida and Parao (1976) concluded that solar radiation in the tropics is not a limiting factor in view of the fact that the current wet paddy yields in the tropics are far below 6 tons/ha.

The insignificant effects of dry spells indicate that during the 1975/76 and 1976 off seasons the natural range of dry spells in themselves may not be severe enough to cause significant differences in the yields in the states of Peninsular Malaysia.

As the evidence indicate, the different states of Peninsular Malaysia show consistent differences in wet paddy yields from 1946 to 1977. The states of Perlis, Kedah and Selangor often had the highest yields while Kelantan, Trengganu and Pahang tended to have the lowest yields. For the 1975/76 main and 1976 off seasons, at least 83% of the yields variations could be accounted for by rainfall and temperature changes. In spite of the so called equitible temperatures of the tropics, temperature changes appear to constitute nearly half the climatic influences on the wet paddy yields. This study indicates that climatic influences play a predominant role in accounting for the regional differences in the wet paddy yields of the states of Peninsular Malaysia.

REFERENCES

DESAI, B.A. and THINGALAYA, N.K. (1965): Irrigation factor and yield variability in rice growing districts in India. *Indian J. Agr. Econ.* **20**:63-65.

FITZPATRICK, E.A. and NIX, H.A. (1970): The climatic factor in Australia grassland ecology. In "Australian Grasslands" (Moore, R.M., ed.). pp. 3-26, A.N.U. Press. Australia.

GRIST, D.H. (1975). *Rice.* (5th Edn.). London. Longmans.

HANYU, J., UCHIJIMA, T. and SUGAWARA, S. (1966): Studies on the agroclimatological method for expressing the paddy rice products. Part 1. An agroclimatic index for expressing the quantity of ripening of the paddy rice. *Bull. Natl. Tohoku Agr. Exp. Stn.* **34**:27-36.

IRRI. (1976): Proceedings of the Symposium on Climate and Rice. Los Banos, Philippines. pp. 565.

LANGLEY, R. (1979): *Practical Statistics.* London and Sydney. Pan Books.

MALAYAN METEOROLOGICAL SERVICES. (1975, 1976): Summary of Observations for Malaysia.

MINISTRY OF AGRICULTURE, MALAYSIA. (1976): Paddy Calendar.

_____ Paddy Statistics. (various issues).

MUNAKATA, K. (1976): Effects of temperature and light on the reproductive growth and ripening of rice. *Proc. Symp. Climate and Rice.* IRRI. Philippines. pp. 187-210.

MURAKAMI, T. (1973): Paddy rice ripening and temperature. *Jpn. Agric. Res. Q.* **7(1)**: 1-5.

MURATA, T. (1964): On the influence of solar radiation and air temperature upon the local difference in the productivity of paddy rice in Japan. *Proc. Crop. Sci. Soc., Japan.* **35**:59-63.

NIX, H.A. (1975): The Australian climate and its effects on yield and quality. *Aust. Field Crops* **1**:183-226.

SAMY, J., GOPINATHAN, B. and VAMADEVAN, V.K. (1980): Strategy in agronomy programme – the study of environmental factors in rice production in Peninsular Malaysia. *Persidangan Padi Kebangsaan Malaysia.* Kuala Lumpur. (Working paper No. 8.)

SMITH, R.C.G., ANDERSON, W.K. and HARRIS, H.C. (1978): A system approach to the adaptation of sunflower to new environments. IV. Yield variability and optimum cropping strategies. *Field Crops Res.* **1**:229-242.

TANAKA, A. (1976): Comparisons of rice growth in different environments. *Proc. Symp. Climate and Rice.* pp. 429-448.

YOSHIDA, S. and PARAO, F.T. (1976): Climate influences on yields and yield components of lowland rice in the tropics. *Proc. Symp. Climate and Rice.* pp. 471-494.

(Received 5 November 1983)