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Studies on effect of weather on traditional photosensitive PTB-1 and high yielding Jaya varieties by curvilinear technique at Pattambi, Kerala

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सार — पताम्बी, केरल में पारम्परिक प्रकाश सुग्राही-पीटीबी-1 और वर्षा ऋतु में रेतीली-चिकनी मिट्टी में, खरीफ फसल के दौरान उगाई जाने वाली एवं अधिक पैदावार देने वाली, जया धान की किस्मों का अध्ययन किया गया। विश्लेषण वक्ररेखीय तकनीक पर आधारित था तथा इसमें मौसमी वर्षा, अधिकतम और न्यूनतम तापमान तथा खिली धूप की समयावधि का प्रयोग किया गया। इस अध्ययन से धान की पैदावार पर मौसम के विभिन्न घटकों के प्रभाव का पता चला है। विश्लेषण से ज्ञात हुआ कि निर्णायक वक्रों के उपयोग से मौसम के घटकों के विभिन्न औसत मानों के लिए धान की पैदावार का आकलन भी संभव है।

अध्ययन से पता चला कि जया किस्म के धान के लिए वर्षा इतनी महत्वपूर्ण नहीं है और पीटीबी-1 की तुलना में उसे अधिक धूप की भी आवश्यकता नहीं पड़ती है। दोनों ही किस्मों की धान की सर्वोत्तम पैदावार के लिए 29° सें. का अधिकतम तापमान उत्तम प्रतीत होता है।

ABSTRACT. A study was conducted with traditional photosensitive PTB-1 and high yielding Jaya varieties of rice grown during kharif crop season in sandy loam soil under rainfed condition at Pattambi. The analysis was based on curvilinear technique and seasonal rainfall, maximum and minimum temperatures and bright hours of sunshine have been used. The study enables determination of response of yield to different ranges of weather factors. From the final curves determined in the analysis it is also possible to estimate yield for different mean values of the weather factors.

The study revealed that rainfall is not that important for Jaya variety. It also does not need large amount of sunshine compared to PTB-1. For both varieties, a maximum temperature of 29°C appears ideal for optimum yield.

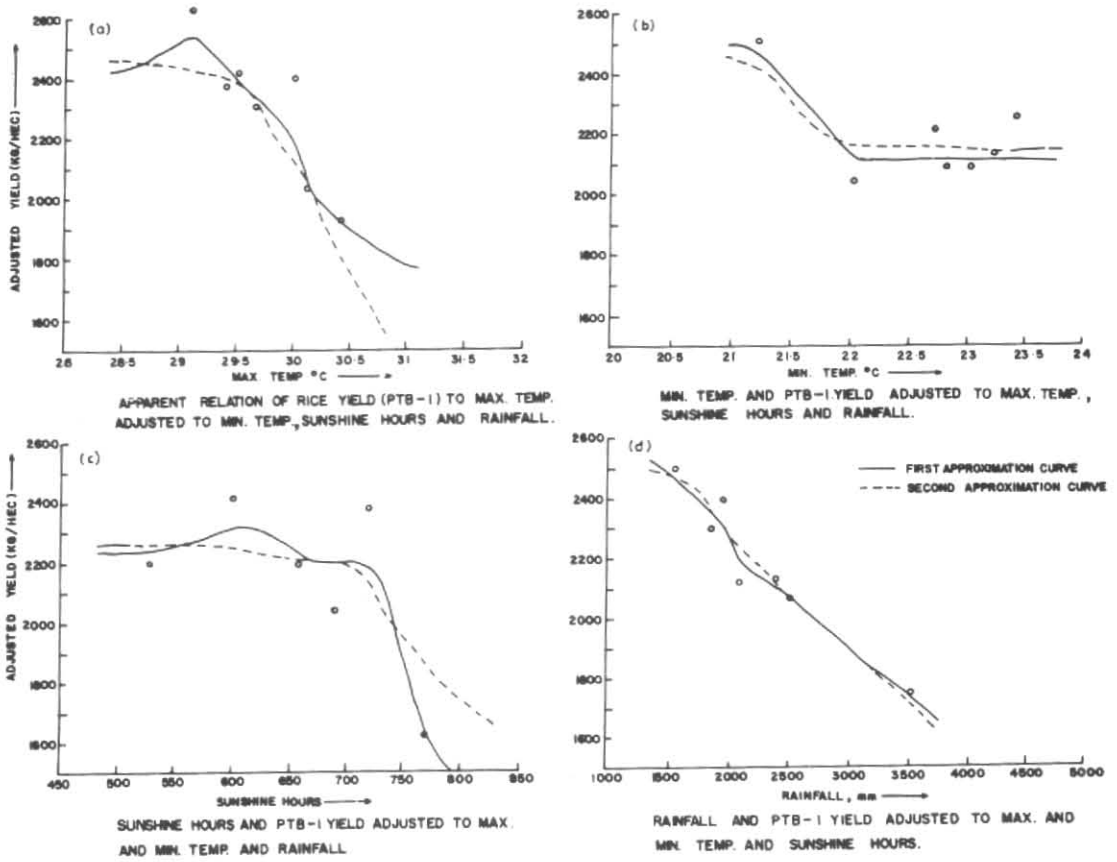
Key words — Curvilinear technique, Graphical approximation, Flowering, Transplanting, Seasonal, Jaya variety, Photoinsensitive.

1. Introduction

The rice crop is the most important cereal crop of Kerala and is the staple diet of the people. The area of rice cultivation in this state is about 579 thousand hec with a total mean annual production of 1014 thousand tons of grain, which gives a mean yield of 1750 kg/hec. Inspite of its importance, the crop seems to have been bypassed in the Green Revolution and hence relatively very little research work has been carried out on impact of weather on yield especially for Kerala where rice is grown as a major crop. Rao *et al.* (1977) developed a regression equation to forecast yield in Kerala. They found that pre-planting rainfall increase the yield but minimum temperature during flowering leads to yield reduction. High humidity and high temperature during the rainy season often favour pests and diseases outbreak. IRRI (1986) in three trials conducted at Pattambi reported that low yields are the results of heavy infestation of pest and disease which occur more dominantly in later part of the wet season. Joseph (1991) observed that weight of 100 grain was significantly higher for planting done on 20 July at Pattambi.

The crop gives varying yield due to variations in weather mainly due to variable rainfall. Though temperature remains fairly stable during the main crop season in Kerala, variations in sunshine hours caused by varying sky condition greatly influence rice production in the region (IRRI 1986). The plant breeder aims at evolving varieties which can, by and large, give the best result for a given agroclimatic zone. High yielding photo-insensitive varieties now grown widely in this region also respond differently to climatic conditions than that of traditional variety. The general trend toward adopting photoperiod-insensitive varieties considerably reduces the importance of light duration and offers flexibility in growing the crop (Lawson 1980).

Sreenivasan and Banerjee (1973) applied Fisher's technique to find out effect of rainfall on rice crop at Karjat (Maharashtra). Adopting this technique at Adhutarai and Coimbatore (Tamil Nadu), Sreenivasan and Banerjee (1978) found that additional rainfall above the normal, exerts negative influence during sowing, tillering and flowering stages of rice. Chowdhury and Gore (1991) applied curvilinear



Figs. 1 (a-d). Relationship between adjusted yield (kg/hec) of rice (PTB-1) and meteorological parameters

technique to rice crop in Bhandara district (Maharashtra), and observed that combination of seasonal mean maximum temperature of 30.5°C, 81% relative humidity and rainfall of 1000 mm during physiological growth phases, *i.e.,* between elongation and grain formation, gives optimum rice yield.

The objective of this investigation was two fold : (*i*) to examine if progress has been made in rice cultivation at Pattambi, Kerala in order to assess the impact, if any, of weather on rice yield; and (*ii*) to develop simple agrometeorological models that could be used for yield prediction.

2. Agroclimate of rice in Kerala

The regional research station of Kerala Agricultural University at Pattambi (10°48'N, 76°12'E) is located at 25 m amsl. Pattambi experiences rainfall fluctuations due to early/late onset of monsoon and hence seasonal fluctuations of wet and dry seasons, seasonal sunshine hours and radiation also are important especially in kharif season. Heavy rainfall sometimes more than 10 cm in a day do occur during the wet season which leads to the crop lodging. At this station, paddy is normally transplanted between end of June to middle of July and harvested in September to middle of November.

Kharif rice is transplanted after the heavy rains of June or early July. It received average rainfall of 2310 and 1220 mm during the crop growing seasons of PTB-1 and Jaya respectively. Average minimum temperatures were around 23°C and maximum temperatures about 30°C. Mean total bright sunshine hours were 632 and 462 hours respectively during the growing period of the two crops.

The mean rice yield of PTB-1 during the period 1950-1971 was 2189 kg/hec (C.V. = 16.6%) whereas high yielding Jaya variety the yield was about 73% higher, *i.e.,* 3802 kg/hec (C.V. = 11.5%). Considerable fluctuations in yield is seen in both the varieties, mostly due to variations in climate particularly flooding, high wind etc., climate dependent factors like pest and diseases incidence and logging due to heavy rain.

3. Data used

The rice yield data for 22 years, *i.e.,* 1950-1971 for the photosensitive PTB-1 and for 12 years, *i.e.,* 1974-1990 for Jaya variety which is photoinsensitive at Pattambi were used. The data were obtained from the records of

TABLE 1

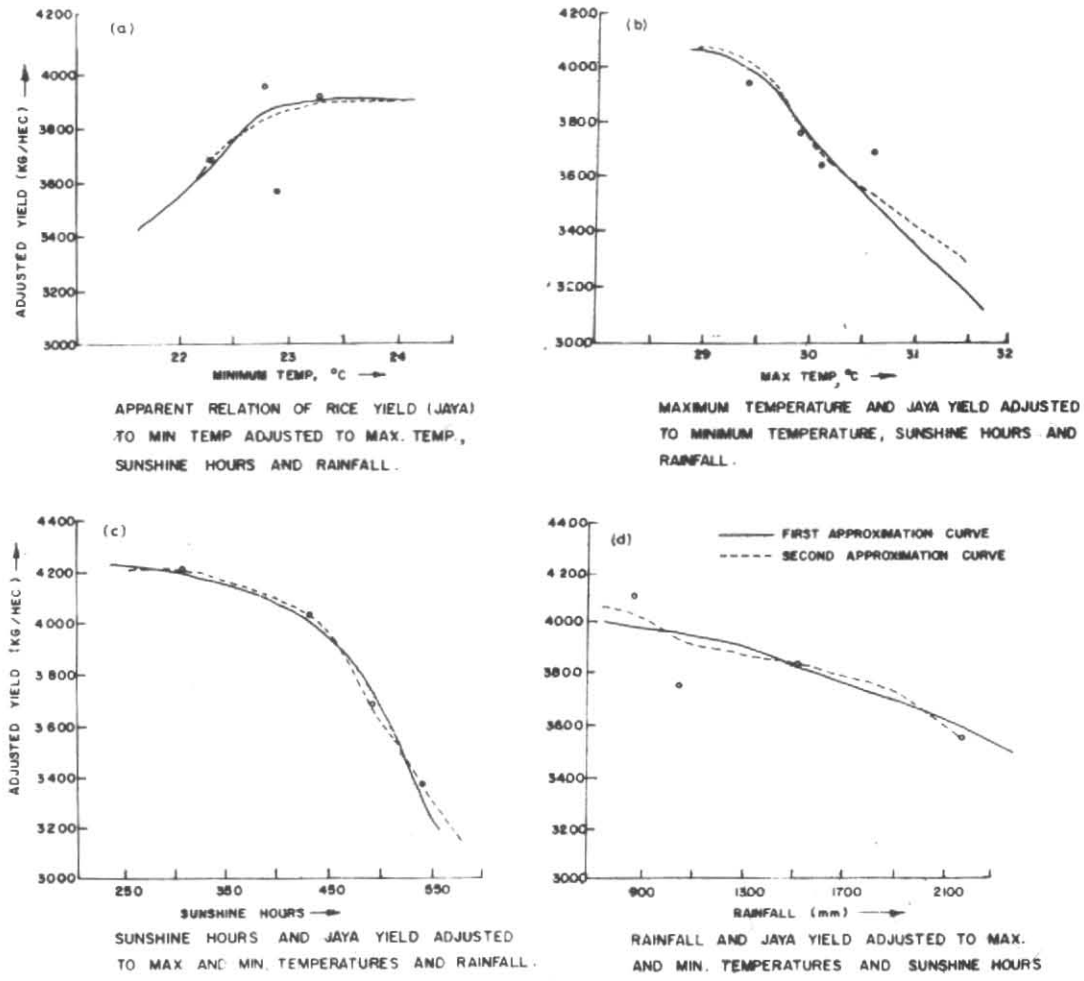
Yield of PTB-1, weather parameters and deviations of the actual yield from the regression line for the linear and curvilinear functions

Year	Yield (kg/hec)	Duration (planting-harvesting) std. week No.	Average maximum temp. (°C)	Average minimum temp. (°C)	Total bright sunshine (hrs)	Total rainfall (mm)	Deviation from			% departure of yield
							Regression line (Z')	First curve (Z'')	Final curve (Z''')	
1950	2100	27-44	28.8	22.7	533.4	3723.9	+ 18	+ 179	+ 194	9.2
1951	1416	27-44	29.6	22.9	679.7	1751.8	+ 97	— 135	— 70	2.9
1952	2019	27-44	29.7	23.0	799.4	1565.4	— 145	— 62	+ 218	10.8
1953	2159	28-45	30.0	23.1	708.4	1906.7	+ 93	— 62	— 82	3.8
1954	2643	28-44	29.5	22.6	507.5	2123.8	+ 131	+ 192	+ 297	11.2
1955	2469	27-44	28.7	22.7	527.1	1974.1	— 304	— 117	— 62	2.5
1956	2548	27-45	29.4	23.0	636.3	1930.2	+ 182	+ 12	— 18	0.7
1957	1812	26-43	30.3	23.3	727.3	2398.8	+ 78	+ 146	+ 66	3.6
1958	1812	27-43	30.1	23.4	690.2	2085.0	— 43	— 156	— 99	5.2
1959	1755	28-45	29.5	22.8	534.8	3162.8	— 302	— 306	— 251	14.3
1960	1942	26-43	30.1	22.7	638.4	2374.5	— 80	— 59	— 49	2.5
1961	1659	28-44	29.5	22.8	527.8	4397.2	+ 50	+ 23	+ 23	1.4
1962	2529	27-44	29.1	23.2	496.3	2673.0	+ 163	+ 248	+ 213	8.4
1963	1592	28-45	30.2	22.0	758.8	1938.1	— 478	— 204	— 04	0.2
1964	1761	29-45	29.7	21.1	753.9	2433.9	— 412	— 435	— 375	21.3
1965	1997	27-44	30.3	23.2	688.8	1559.1	— 121	— 139	— 165	8.3
1966	2347	27-43	30.5	23.4	607.6	1549.6	+ 194	+ 301	+ 141	6.0
1967	2106	29-46	29.8	22.4	505.4	2013.7	— 384	— 405	— 220	10.4
1968	2623	29-45	29.5	21.6	612.5	2550.3	+ 288	+ 262	+ 127	4.8
1969	3021	26-43	30.0	21.3	716.8	1946.8	+ 732	+ 620	+ 500	16.5
1970	2321	27-44	29.3	23.1	588.0	2351.9	+ 17	— 69	— 489	21.1
1971	2443	27-44	29.1	22.8	675.5	2499.6	+ 226	+ 152	+ 97	4.0
Means	2189		29.7	22.7	632.4	2310.4				

All India Co-ordinated Crop Weather Scheme and the Regional Agricultural Research Station, Pattambi. For some of the years, data could not be included for it was either missing or unreliable. The PTB-1 is of 18 weeks (transplanting — harvesting) duration and Jaya of about 14 weeks duration. Weather data for the growing period (transplanting to harvesting) were collected from the crop weather observatory at Pattambi.

4. General methodology

Linear regression analysis when applied to crop-weather relationship studies pre-supposes that a crop characteristic say number of tillers, plant height, yield etc increases (or decreases) linearly for unit increase (or decrease) in the value of a weather parameter. This increase (or decrease) in the crop characteristic does not take into account, the actual value or range of the weather element. Crop's response to weather, is not as simple and there is definitely a value of the weather element beyond which a unit increase (or decrease) in its value could have an opposite impact on the crop. In short, there is a point of inflection after which the shape of the crop weather curve changes. This type of response of the crop *vis-a-vis* weather element can, thus, be best brought out by curvilinear approach (Ezekiel



Figs. 2 (a-d). Relationship between adjusted yield (kg/hec) of rice (Jaya) and meteorological parameters

and Fox 1959). In this, if Y is the crop yield and X_i (i = 1, 2 .....) are weather parameters, then Y can be represented as :

$$Y = a + f_1(X_1) + f_2(X_2) + \ldots\ldots$$

where, a is a regression constant and $f_1(X_1)$, $f_2(X_2)$, ... are the functions representing effect of unit value of X_1, X_2 ..... respectively on the yield. It is the aim of the analysis to find the shapes of the curves $f_1(X_1), f_2(X_2)$, ... etc. This is accomplished by determining partial regression curves by successive approximate method. The residuals are determined from the net regression approximation curves at each stage. That stage when the SD of the residuals is the least, the curves are considered as final.

The final curves have been shown in Figs. 1 & 2 respectively for the two varieties of rice. The final regression thus obtained are given below for PTB-1 and Jaya varieties respectively.

$$Y = 16377.9 - 311.2X_1 - 138.8X_2 - 1.5X_3 - 0.3X_4 \quad (1)$$

$$Y = 10355.2 - 365.0\,X_1 + 267.3X_2 - 3.16X_3 - 0.3X_4 \quad (2)$$

where,

Y — Yield (kg/hec),

X_1 — Mean daily maximum temperature (°C),

X_2 — Mean daily minimum temperature (°C),

X_3 — Total rainfall (mm) in the growing season,

X_4 — Total sunshine hours in the growing season.

The values are pertaining to the growing seasons respectively for PTB-1 and Jaya varieties.

TABLE 2

Yield of Jaya, weather parameters and deviations of the actual yield from the regression line for the linear and curvilinear functions

Year	Yield (kg/hec)	Duration (planting-harvesting) std. week No.	Average maximum temp. (°C)	Average minimum temp. (°C)	Total bright sunshine (hrs)	Total rainfall (mm)	Deviation from			% departure of yield
							Regression line (Z')	First curve (Z'')	Final curve (Z''')	
1974	4054.00	26-39	29.00	22.60	359.90	2191.90	— 60	— 44	— 26	0.6
1975	4418.00	26-39	28.90	22.60	262.00	1580.80	— 198	+ 55	+ 03	0.06
1976	4074.00	28-41	30.30	22.80	496.00	901.50	+ 483	+ 386	+ 424	10.4
1977	4033.00	26-40	29.50	22.80	502.00	1105.00	+ 221	+ 50	+ 143	3.5
1979	3529.00	28-41	30.10	22.80	499.80	1242.10	— 36	— 134	— 11	0.3
1980	3987.00	26-39	29.90	23.10	451.60	1507.30	+ 184	+ 14	+ 07	0.2
1983	4175.00	31-44	29.90	23.50	423.50	1254.40	+ 111	+ 17	+ 10	0.2
1984	4119.00	29-42	29.30	22.80	522.60	918.70	+ 251	+ 241	+ 189	4.6
1985	3648.00	27-41	29.50	22.90	486.10	1022.80	— 262	— 455	— 402	11.0
1987	2891.00	27-40	30.80	22.80	574.40	759.60	— 306	— 07	— 159	5.5
1989	3111.00	27-40	30.00	22.90	534.29	937.80	— 486	— 147	— 189	6.0
1990	3589.00	26-40	30.10	21.70	433.30	1212.70	+ 100	+ 31	+ 19	0.5
Means	3802.33		29.77	22.77	462.12	1219.55				

5. Results and discussion

At second approximation, in this study, for both the crops, the SD of residuals was found the least. Hence the analysis was terminated at that stage. These final curves are given in Figs. 1 & 2 for PTB-1 and Jaya varieties and discussed below :

PTB-1 variety

Maximum temperature till about 29°C appear to be ideal for higher yield. Subsequent rise in maximum temperature has adverse impact on PTB-1 variety of rice particularly after 30°C when sharp decline in yield takes place. On the other hand, minimum temperature till about 22°C affects it negatively and yield gets stabilised on any subsequent higher minimum temperature. Sunshine hours also do not effect much till a seasonal total of 750 hours is realised. Subsequently, any increase in hours of bright sunshine brings the yield down. The crop appear to need about 150 cm of seasonal rainfall. Any rainfall above this, exert detrimental influence (Table 1).

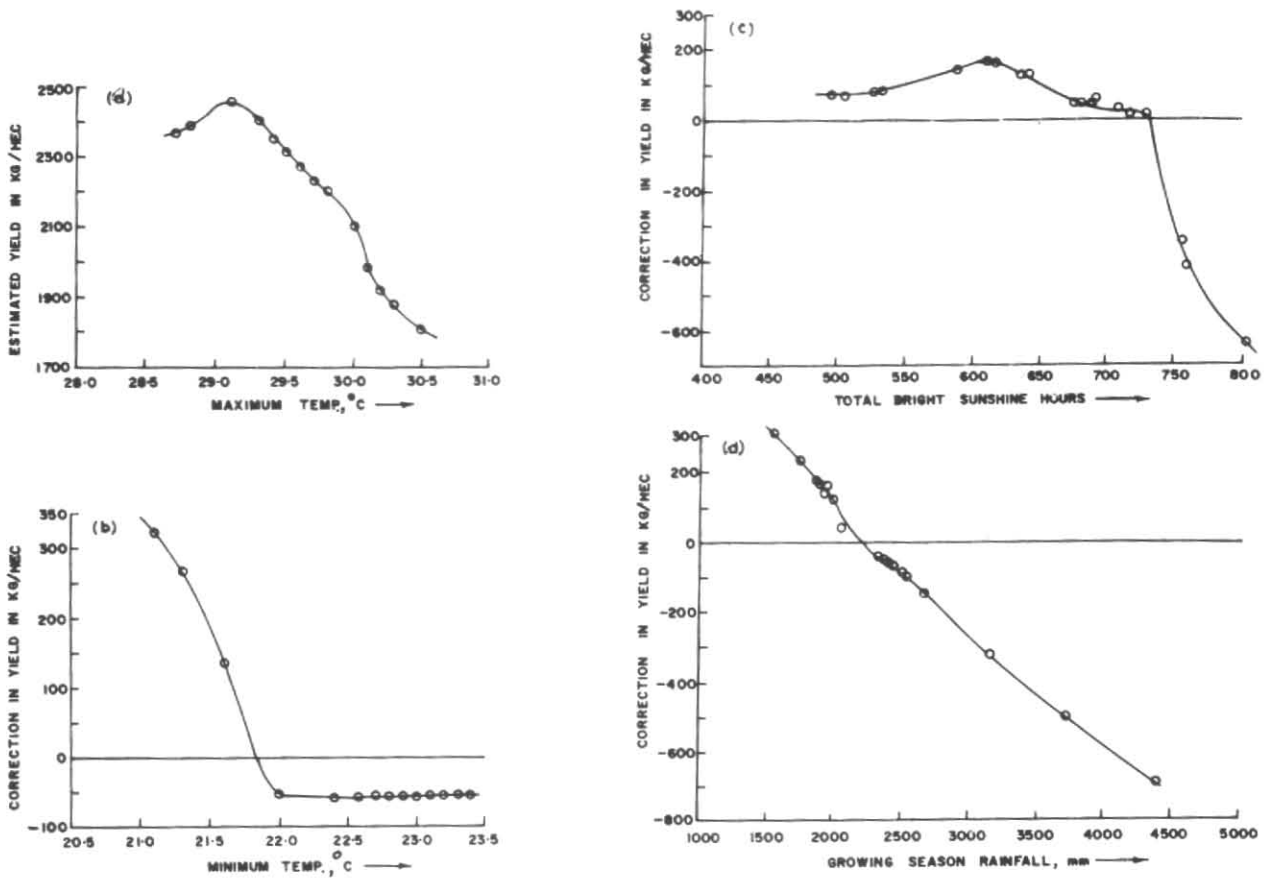
Jaya variety

In this case rise in maximum temperature above 29°C or so affect the yield adversely as in case of PTB-1. A rise in minimum temperature helps better yield till about 23.5°C but later the yield seems independent of night temperature. Number of sunshine hours increase the Jaya yield till the seasonal total of 300 hours is reached ; subsequent increase in sunshine hours leads to decrease in Jaya output. Jaya does not need much seasonal rainfall for its growth and maturity. An amount of about 90 cm appears adequate to ensure proper growth. If the rainfall exceed this threshold, it leads to drop in crop out-turn (Table 2).

It is interesting to note that for both PTB-1 and Jaya, mean ideal daily maximum temperature in the crop season is 29°C. Beyond this value, higher temperature lead to decrease in number of spiklets and hence lower the yield. Minimum temperature upto 22°C gives optimum yield for PTB-1; in case of Jaya this threshold is about 23.5°C.

Photosensitive varieties like PTB-1, perhaps, cannot tolerate a high dose of night temperature in contrast to photoinsensitive variety like Jaya which may tolerate a marginally high night temperature.

A fact that clearly emerges is that Jaya variety does not need a high value of sunshine hours compared to PTB-1, even if the total duration of the two crops are different. For the former a total of 350 hours of



Figs. 3 (a-d). Yield response curves of rice (PTB-1) at Pattambi

sunshine appears adequate to take the crop to maturity as against 750 hours needed by PTB-1. In both cases last 45-day, *i.e.*, flowering and dough stages appear critical when paddy need large amount of sunshine (Baradas 1985).

6. Yield estimation

The method also provides estimate on the yield. For this, first the most important dependent parameter is selected. The initial estimate Y_1 is then determined as,

$$\hat{Y}_1 = f_1(X_1) - M_1 + \bar{Y} \qquad (3)$$

where, M_1 is the mean of $f_1(X_1)$ computed from the final curve and Y is the mean of the yield. For finding the final estimate $\hat{Y}$ of the yield, departure of other factors from their means are numerically added to Y_1. For instance the departure of the second factor X_2 will be equal to,

$$f_2(X_2) - M_2$$

where, M_2 is the mean of X_2 from the final curve $f_2(X_2)$. Thus, the final estimate equation becomes,

$$\hat{Y} = [f_1(X_1) - M_1] + \bar{Y} + [f_2(X_2) - M_2] + [f_3(X_3) - M_3] + \ldots.$$

$$\hat{Y} = \bar{Y} + [f_1(X_1) + f_2(X_2) + f_3(X_3) + \ldots.] - (M_1 + M_2 + M_3 \ldots.) \qquad (4)$$

Example for estimating the yield for the two varieties are given below:

In case of PTB-1 the most important factor was maximum temperature. The first estimate from Eqn. (3) $\hat{Y}_1$ is given by,

$$\hat{Y}_1 = f_1(X_1) - 2276.1 + 2189.5$$
$$= f_1(X_1) - 86.6$$

while corrections for minimum temperature, hours of bright sunshine and rainfall were $f_2(X_2) - 2169.3$; $f_3(X_3) - 2158.4$ and $f_4(X_4) - 2160.5$ respectively.

In the above, $f_1(X_1)$, $f_2(X_2)$ etc are yield values read from the final curves. Similarly, the yield estimates, with minimum temperature as most important parameter for Jaya are given by,

$$\hat{Y}_1 = f_1(X_1) - 3794.6 + 3802.3$$
$$= f_1(X_1) + 7.7$$

TABLE 3(a)

Expected yield (kg/hec) of PTB-1 with varying minimum temperature and bright sunshine hours for maximum temperature 29.0°C

Min. Temp. (°C)	Bright sunshine hours					
	500	550	600	650	700	750
21.0	2868	2896	2956	2896	2817	2481
21.5	2709	2737	2797	2737	2658	2322
22.0	2471	2499	2559	2499	2420	2084
22.5	2466	2494	2554	2494	2415	2079
23.0	2465	2493	2553	2493	2414	2078
23.5	2463	2491	2551	2491	2412	2076

TABLE 3(b)

Expected yield (kg/hec) of PTB-1 with varying rainfall and minimum temperature for maximum temperature 29.0°C

Rainfall (mm)	Minimum temperature (°C)					
	21.0	21.5	22.0	22.5	23.0	23.5
1500	3118	2959	2721	2716	2715	2713
2000	2976	2747	2509	2504	2503	2501
2500	2706	2547	2309	2304	2303	2301
3000	2521	2362	2124	2119	2118	2116
3500	2356	2197	1959	1954	1963	1951
4000	2211	2052	1814	1809	1808	1806

TABLE 3(c)

Expected yield (kg/hec) of PTB-1 with varying bright sunshine hours and rainfall for maximum temperature 29.0°C

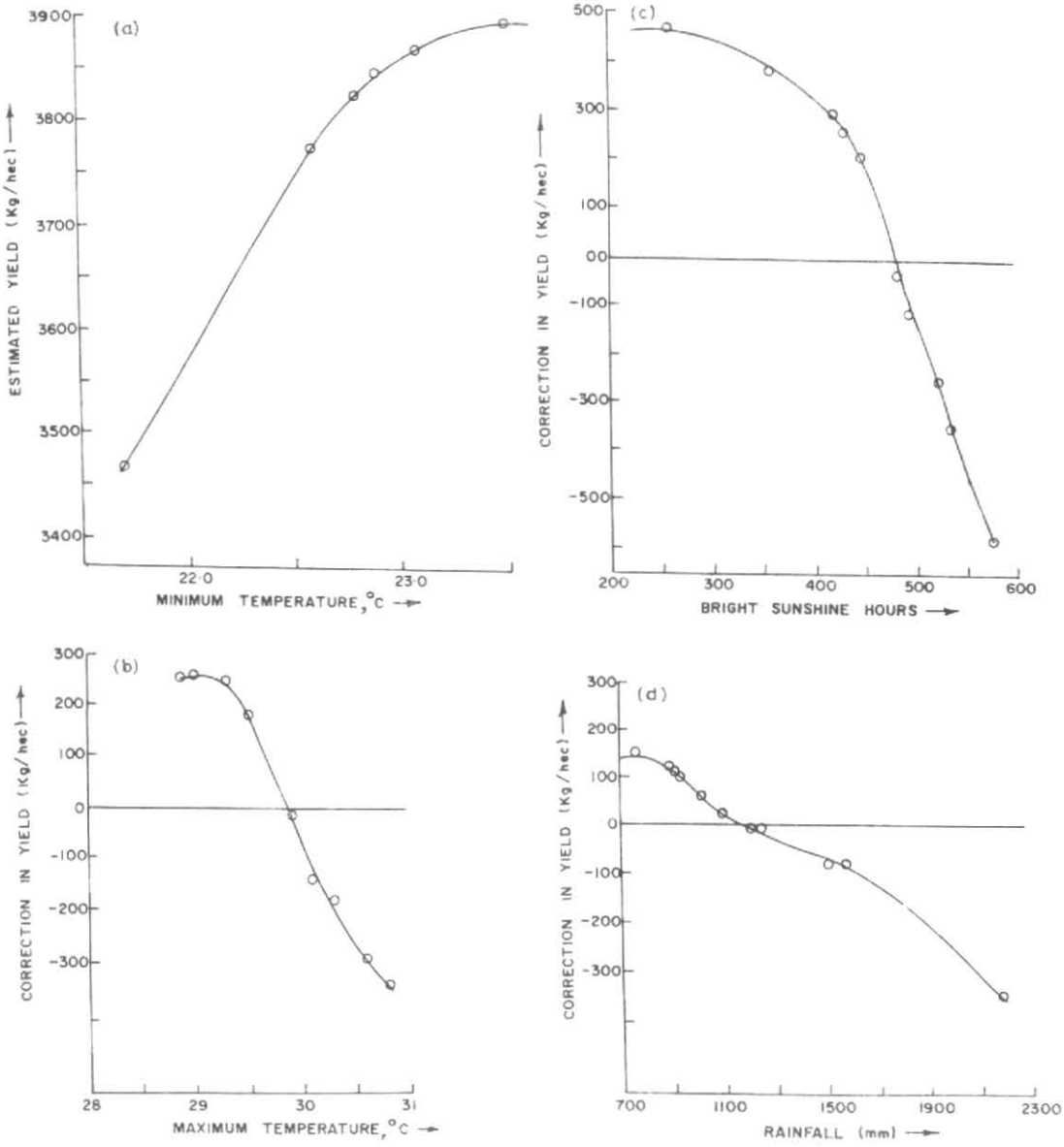
Bright sunshine hours	Rainfall (mm)					
	1500	2000	2500	3000	3500	4000
500	2848	2636	2474	2251	2086	1941
550	2876	2664	2574	2279	2114	1969
600	2936	2724	2634	2339	2174	2029
650	2876	2664	2574	2279	2114	1969
700	2737	2585	2495	2200	2035	1890
750	2461	2249	2159	1864	1699	1554

Correction for maximum temperature, hours of bright sunshine and rainfall were respectively $f_2(X_2) - 3810.4$; $f_3(X_3) - 3774.2$ and $f_4(X_4) - 3902.5$.

For a particular value of maximum temperature, *i.e.*, 29°C most probable yield estimates for minimum temperature and hours of bright sunshine; rainfall and minimum temperature and bright sunshine hours and rainfall are given in Tables 3(a-c) for PTB-1 variety. For Jaya the most important factor was minimum temperature. For a value of minimum temperature of 23.5°C most probable yield estimates for maximum temperature and sunshine hours are given in Table 4(a). These tables enable to have yield estimates for 36 different combinations of weather parameter from the optimum value of the most important weather factor.

Tables 3(a-c) show the impact of weather parameters towards the yield of PTB-1 at Pattambi. These combinations of weather parameter could be used for predicting yield of PTB-1. However, detailed discussion on Jaya variety is given below as high yielding varieties are predominantly grown now-a-days.

Table 4(a) indicates that both maximum and minimum temperatures play the most important role towards rice production at Pattambi. Highest rice yield could be expected in the rice growing season when maximum and minimum temperatures remain around 29.0°C and 23.5°C respectively. It is also interesting to note that photoinsensitive Jaya has potential to produce yield as high as 4600 kg/hec even at rather low light intensity (250 hours of bright



Figs. 4 (a-d). Yield response curves of rice (Jaya) at Pattambi

sunshine) during the crop growing season. The reduction of yield to the extend of 585 kg/hec at high sunshine hours (500 hours) may be due to the fact that break in monsoon would cause not only high sunshine hours but also water stress conditions which affect growth and yield of rice at Pattambi.

Table 4(b) shows that high yielding Jaya yield could not be affected much with variation of rainfall from 900-1900 mm in the crop growing season. However, yield would decrease considerably when maximum temperature as well as rainfall increases in the growing season. Similarly, Table 4(c) indicates that combination of heavy rainfall and more hours of bright sunshine hours in the crop growing season would be detrimental for rice yield at Pattambi. Under such climatic conditions both water stress at some stages of growth and loss of nutrients due to very heavy rainfall causing water logging and runoff at some stages of growth could cause reduction in yield.

The final results of this study are presented in simple form graphically in Figs. 3 & 4. The reliability of the curves was examined by estimating the yields from

TABLE 4(a)

Expected yield (kg/hec) of Jaya with varying maximum temperature and bright sunshine hours for minimum temperature 23.5°C

Max. temp. (°C)	Bright sunshine hours					
	250	300	350	400	450	500
29.0	4604	4583	4545	4479	4344	4019
29.3	4364	4573	4535	4469	4334	4009
29.6	4479	4458	4420	4354	4219	3894
29.9	4329	4308	4270	4204	4069	3744
30.2	4179	4158	4120	4054	3919	3594
30.5	4084	4063	4025	3959	3824	3499

TABLE 4(b)

Expected yield (kg/hec) of Jaya with varying rainfall and maximum temperature for minimum temperature 23.5°C

Rainfall (mm)	Maximum temperature (°C)					
	29.0	29.3	29.6	29.9	30.2	30.5
900	4259	4249	4134	3984	3834	3739
1100	4164	4154	4039	3889	3739	3644
1300	4114	4104	3989	3839	3689	3594
1500	4076	4066	3951	3801	3651	3556
1700	4017	4007	3892	3742	3592	3497
1900	3944	3934	3819	3669	3519	3424

TABLE 4(c)

Expected yield (kg/hec) of Jaya with varying bright sunshine hours and rainfall for minimum temperature 23.5°C

Bright sunshine hours	Rainfall (mm)					
	900	1100	1300	1500	1700	1900
250	4464	4369	4319	4281	4222	4149
300	4443	4348	4298	4280	4201	4128
350	4404	4310	4260	4222	4163	4090
400	4339	4244	4194	4156	4097	4024
450	4204	4109	4059	4021	3962	3889
500	3879	3784	3734	3696	3637	3564

the curves 3 and 4 corresponding to the observed meteorological factors. For PTB-1, only in 2 cases out of 22, the estimates were outside 20% while 68% of the estimates were within 10% of the actuals. Similarly, in Jaya variety, in 2 cases out of 12, the estimates were outside 10% and 67% of the estimate were within 5% of the actuals. This indicates that rice yield of Jaya could be estimated accurately by using meteorological parameters as independent variable with curvilinear technique.

The present study thus illustrates the ability of the curvilinear analysis to bring out a series of crop weather relationships, *viz.*, the different influence of a weather element on different varieties. This analysis also provides a basis for estimating the probable effect of a new combination of independent factors upon the dependent one.

7. Conclusions

The following conclusions could be drawn :

(*i*) The study has brought out clearly that photo-insensitive rice varieties are preferably to be grown in kharif season at Pattambi.

(*ii*) Maximum and minimum temperatures play most important role towards rice production at Pattambi. Optimum values of maximum and minimum temperatures are found about 29°C and 21-23°C respectively.

(*iii*) Photoinsensitive Jaya has potential to produce yield as high as 4600 kg/hec even at rather low light intensity (250 hours of bright sunshine) during the crop growing season.

(*iv*) An amount of about 90 cm seasonal rainfall appears adequate to ensure proper growth and yield of Jaya.

(*v*) This analysis also provides a basis for estimating the yield from different combinations of independent factors.

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