WEATHER PADDY CROP RELATIONSHIP

BY

S. KRISHNAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science (Agricultural Statistics)

Faculty of Agriculture

Kerala Agricultural University

Department of Statistics

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

Mannuthy - Trichur

1981

DECLARATION

I hereby declare that this thesis entitled "WEATHER PADDY CROP RELATIONSHIP" is a bona fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or fellowship or other similar title, of any other University or Society.

Mannuthy,

31-7-1981.

S. Krishnan

S. KRISHNAN.

CERTIFICATE

Certified that this thesis entitled "WEATHER PADDY CROP RELATIONSHIP" is a record of research work done independently by Sri. S. Krishnan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Mannuthy,

31-7-1981.

Dr. P. U. SURENDRAN,
Professor of Statistics
(Chairman, Advisory Board).

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude and indebtedness to Dr.P.U.Surendran, Professor of Statistics, College of Veterinary & Animal Science and Chairman of the Advisory Committee for his extremely valuable guidance and help in the preparation of this thesis.

The help rendered and valuable advice given by Dr.P.Balakrishna Pillai, Professor of Meteorology College of Hortivulture are gratefully acknowledged.

My sincere thanks are due to Dr.K.C.George, Associate Professor of Statistics, and member of the Advisory Committee, to Sri. M.P.Abdurazak, Assistant Professor of Statistics and member of the Advisory Committee and to Sri.R.Balakrishnan Asan former member of the Advisory Committee for the interest evinced by them in the preparation of this thesis.

I am very much fortunate in having been able to secure the valuable suggestions of Dr.C.Sreedharan, Professor of Agronomy, College of Agriculture,Vellayani.

I take this opportunity to express my sincere gratitude to him.

I am thankful to Sri.P.H.Lathif, Junior Assistant Professor, Agricultural Research Station, Vyttila and Miss. C.C.Annamma, Junior Assistant Professor of Statistics for the help rendered by them.

I will be failing in my duty if I do not express my heartfelt thanks to Mrs.K.P.Santha Bai, Technical Assistant for her sincere and unstinted help.

S.KRISHNAN.

CONTENTS

****

INTRODUCTION

INTRODUCTION

In his presidential address to the Annual Conference of the Indian Society of Agricultural Statistics, 1973, Dr.M.S.Swaminathan, Director General of ICAR, New Delhi, stated: "There was a general feeling until 1972, that the country is at long last on the path of self sufficiency in food requirements, in spite of the rapid growth in population. Suddenly, spirits dampened in July and optimism was replaced by alarm as it became apparent that the behaviour of the monsoon is likely to be aberrant". In the words of the Director General of the Food and Agricultural Organisation "it is intolerable that this world of the 1970's with all its significant progress and its slowly growing sense of common purpose, should go on enduring a situation in which the chances of enough decent food for millions of human beings may simply depend on the whims of one year's weather". (Report of National Commission of Agriculture, 1976). The two statements very aptly sum up the dependence of food production on weather. In a predominantly agricultural country like, India, national progress is vitally linked with increasing production of agricultural crops. A major factor influencing growth, sustenance and yield of crop is weather;

in fact weather controls every phase of agricultural activity from tillage to harvest and storage. Successful farming therefore calls for appropriate decisions in relation to weather for choice of crop, sowing, transplanting, scheduling of irrigation, fertiliser application, use of pesticides, etc.; A knowledge of risk due to adverse weather conditions such as drought, floods, hailstorm, frost and environmental conditions conducive to pests and disease incidence is essential. In India only 20% of the net area sown has irrigation facilities and even this is not wholly assured (Sharma, 1970). The crop production is thus dependent on the vagaries of weather. The steep fall in food grains out put experienced during the drought years of 1965-66 and 1966-67 from 89 million tonnes in 1964-65 to 72 and 74 million tonnes in 1965-66 and 1966-67 respectively, shows the extent to which production could go down in a bad year. Subsequently, with more or less normal weather in 1967-68 the production picked up and a harvest of 95 million tonnes was reaped and this exceeded the previous peak production of 1964-65 by 6 million tonnes. Next year the production went down slightly to 94 million tonnes again because of unfavourable weather conditions over a large part of the country. Similar instances can be seen in Kerala also. That our corpping pattern is heavily dependent on rainfall was clearly brought out in Evaluation series No.22, 1975(page 2).

Quantitative studies on crop-weather relationship attracted attention in the beginning of the centrury(Report of National Commission on Agriculture,1976) when certain data were collected on groundnut and cotton crops in Egypt and interpreted in terms of weather factors. This was followed by a comprehensive crop-weather study in Britain in 1922. The broad object of these studies could be said to have been whether the plant itself can be used as an indication of its own yield. It is not difficult to visualise that the play of weather factors starts right from the time the seed is sown. Every weather sequence favourable or adverse, has its impact on the growth and development of the plant. The easiest way to visualise this is to examine any cross-section of a log of wood which contains many concentric rings, each of which represents an annual growth of vascular bundles, which are used by the tree for translocation of food material. The distance between any two rings is an indication of the type of weather which a particular tree has experienced in a particular year. Compared to the life cycle of a tree, the life of a crop plant is very much shorter, but even in this case, the variation in height, the intensity of branching or the quickness or the delay in the time of flowering all vary from year to year depending upon weather. Analysis of agricultural growth are usually concerned with three major questions(a) what have been the direction and magnitude of changes in production and productivity over time and how stable are they? (b) What is the contribution of different inputs, weather and other factors to these changes? And (c) What are in some sense, the more basic factors determining the rate and pattern of absorption of inputs and technology and, hence, of agricultural growth (Vaidyanathan, 1979)? These questions have long been and continue to be the focus of research among economists and agricultural statisticians. There are not many definite answers yet; in fact many issues remains contraversial. The assumption in fitting a trend line for measurement of plant growth (Dey,1975; Reddy,1978) is that the weather are truely random in character. According to the report of the National Commission on Agriculture, 1976, it is believed that weather as a single factor is estimated to be responsible for as much as 50 percent of variations in yield which occur from year to year, the remaining 50 percent being due to other factors like irrigation, manuring and plant protection measures, etc.

A number of research institutes and Organisations are at present engaged in the study of crop-weather relationships. The Indian Meteorological Department is studying various aspects of drought, forecasting of crop yields, dry farming, etc. A crop weather Studies Unit has been set up in the Directorate of Economics and Statistics in the Ministry of Agriculture and Irrigation to concentrate on the publication of long term comparable data on crops and weather, derivation and computation of rainfall indices, analysis of crop weather relationship between weather and crop production, etc. The IARSI and IARI are engaged in experimental work on crop weather relationships. Some of the agricultural universities have also been engaged on studies in this important field.

Crops are generally dependent on weather during the periods of growth and particularly in the critical phases like germination, flowering, seed setting, maturing etc. For healthy growth and good yields certain optimum conditions of rainfall, temperature, wind, sunshine, soil moisture, etc. are essential. However the problem is complex and much work would have to be done to arrive at dependable relationships in quantitative form between these factors and yields of crops. Such studies are being actively pursued in many countries. In the U.S.A. crop yield studies are made using regression techniques, both linear and curvilinear (Report of National Commission on Agriculture, 1976). In addition to weather factors, technological trend is used both in its linear and quadratic forms. In the USSR crop yield forecasts, using curvilinear techniques, are issued. Besides weather parameters, soil moisture, stage of crop development, soil type and evapotranspiration are also considered. Research work in this field is being carried out in Canada and Australia also. In India, data collected under the All India Co-ordinated Crop Weather Scheme introduced in 1945 have been statistically analysed using the techniques of regression, Fishers' response curves, probability distribution of meteorological factors and curvilinear regression. The studies have brought out the relatively large dependence of crop growth and yield on rainfall and its distribution in various phases compared to other meteorological parameters. At Niphad(Maharashtra), Dharwar (Karnataka) and Powerkheda(Madhya Pradesh) rainfall above normal in the month preceding sowing and in germination phases has been found to have beneficial influence on wheat yield. At Niphad and Jalgaon (Maharashtra) an idea of the final yield in wheat could be had from the nature of germination and shoot growth when the crop is two months old. An early study on the influence of rainfall distribution on cotton yields at Akola and Jalgaon has shown that an additional inch (2.54 cm) of rain in the fourth week of May has an adverse effect. Heavy and continuous rainfall in the latter half of July and the first half of August affects the yield adversely as it gives rise to weeds and water logging and delays weeding and interculture operations. Heavy rain at the end of September or early part of October damages the cotton crop by causing the shedding of bolls. These and various other studies were carried out with data from experimental stations over limited periods. They were severly conditioned by non-availability of uniform data over long periods.

In Kerala most of the holdings are small. Usually the sowings are done with the first showers of the monsoon expecting a minimum amount of rainfall in the subsequent periods. Paddy is one of the main crops of the State and it is a crop which is very sensitive to inadequate water supply at various stages. If the rainfall after the first showers is inordinately delayed, the yield may go down considerably. Not only paddy but other crops also are sensitive to inadequate water supply. S.N.Joshi and M.M.Kabaria in 1972 had examined the effect of rainfall distribution on the yield of groundnut. It was found that a decrease in 1 mm. rainfall during a particular week reduced the yield by 3.27 Kg/ha. Similarly the yield and quality of cotton are affected by the soil moisture, rainfall and atmospheric humidity and cotton is susceptible even to their minor fluctuations. The effect of rainfall on cotton was studied by Quareshi and Hussani(1955) and Kalamkar and Satakopar (1940), who found a close relationship between yield and rainfall. Ranga Rao and Pandit Rao(1959) obtained the average dates for the beginning and end of rainfall at the four district head quarters and examined the correlation co-efficients between the amount of rainfall at the earlier stages and that for the later periods of the season at all the places of their study. There are instances(Cummings and Ray,1969) where the weather is measured exclusively in terms of rainfall. Thus our aim centres round the establishment of an efficient method for the estimation of rainfall which can give a clue to the farmers for future course of action. So the immediate question that now arises is the selection of an appropriate period for such estimation. It has been found that weekly rather than seasonal or monthly observations on rainfall are more revealing.

The crop growth and yield are governed to a large extent by the weather complex. Even for anyone weather element there is an optimum value at which the maximum response takes place and this response continually decreases with values either above or below the optimum and ceases when the higher and lower threshold values are reached. In this biological phenomenon the change in the rate of decrease with the increase or decrease from the optimum value may perhaps be evaluated by fitting curvilinear multiple regression curves.

It is often felt necessary to decompose the numerous meteorological variables in one or at most a few composite variables in the form of "Index Numbers" which could be conveniently handled in the production equations. It was noted that temperature and rainfall are generally two most important factors affecting crop yields(Dubey, 1972). But both of these change so very frequently that short period observations are required to be considered for their effect on yields. But it is difficult to include the individual weekly rainfall data and weekly mean temperature as such in an equation which has other explanatory variables in it. Often the time series is too short to accommodate more than a few variables. Attempts have been made by many authors to solve this difficulty by constructing different types of indexes which could be used instead of the numerous meteorological variables.

The estimation of weather parameters especially rainfall, summarising weather in terms of a single number- a weather index - and a study of the overall effect of weather on crops, through various seasons deserve a serious study.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An indepth examination of weather crop relationship attracted the attention of scientists in the beginning of this century (National Commission on Agriculture,1976). By the experiments conducted on different crops it was found that the weather parameters like temperature, rainfall, sunshine hours, etc., have effect on the growth and yield of crop. Some of the recent publications on this topic are sharma(1970), Louis (1970), Sreenivasan *et al.* (1970), Raulo and Das (1978), Finlay and Wilkinson (1963), Joshi and Kabaria(1972), Singh *et al.*(1970), Sen and Das Gupta(1970), Krishnan and Kushwaha,(1973), Sreenivasan (1973), Sahu(1969), and Avatar Singh and Pavate (1968).

Finlay and Wilkinson(1963) was one of the earlier research works on the adaptability of crop varieties to different seasons and places. The crop on which they worked was barley. Their method was based on linear regression. Let y_{ij} be the mean yield of the i^{th} variety in the j^{th} place. Assume that x_j is the mean of the the yields of all varieties at the j^{th} place. Then the linear regression on y_{ij} on x_j can be written as $y_{ij} - \bar{y}_i = b(x_j - \bar{\bar{x}})$ where, of course $\bar{y}_i$ is the mean of the i^{th} variety in the experiments and $\bar{\bar{x}}$ is the grand mean of the yields of all varieties in all the experiments. x_j measures the total effect of the weather at the j^{th} place and can be called weather metameter(Rao, 1957). If this changes by one unit and the change is equal to the change in yield of a particular variety say the i^{th}, the latter has a change equal to the change in the average yield of the varieties; i.e. the variety in question is open to average change which is same as saying that the variety has average adaptability. Since the regression equation can be written in the alternative form $(y_{ij} - \bar{\bar{y}}) / (x_j - \bar{\bar{x}}) = b$, in the above situation b will have a value equal to unity. Therefore a variety will have average adaptability when b is near unity.

If corresponding to a unit change in x_j the change in the yield of the variety is less than one unit, then the interpretation is that the variety under consideration is subject to less variation than the average of all varieties or it amounts to saying that the variety under consideration is more adapted to weather than the average of all varieties; i.e. for b less than unity the variety will have better adaptability to the places.

As before let x_j change by one unit. If the corresponding change in the yield of the variety is larger than one unit it is more than the change in the average of all the varieties. This amounts to the assertion that the change in the variety is more than the change in the average and b is greater than unity. Therefore, if b is greater than unity, the variety is said to have less than average adaptability. Summarising, a variety has average, better than average or less than average adaptability, according as b is 1, less than 1 or greater than 1.

Based on the above approach the authors studied the adaptability of a randomly chosen group of 277 varieties of barley from a world collection, grown in replicated trials for several seasons at three sites in South Australia. For each variety a linear regression of individual yield on the mean yield of all varieties for each site in each season was computed. The basic yields were measured on logarithmic scale, since it was found that a high degree of linearity was thereby induced in the regression of individual yields on the site means. Use of a logarithmic scale also induced a reasonable degree of homogeneity of experimental error. The mean yield of all varieties for each site and season provided a quantitative grading of environments, and from the analysis described varieties specifically adapted to good or poor seasons and those showing a general adaptability were identified.

The study of adaptation of the whole population of varieties were facilitated by the use of a scatter diagram with mean yield and regression co-efficient as co-ordinates for each variety.

Varieties characterised by regression Co-efficient of the order of 1.0 had average stability over all environments. For example, the variety Atlas showed average stability with a linear regression co-efficient (b) of 0.90. It produced above average yields in all seasons at all sites which indicated that it had general adaptability. On the other hand, BR 1239 also had a regression Co-efficient approximating 1.0 (b = 1.05) but consistently produced below-average yields. It was poorly adapted to all environments.

Provost was typical of varieties which were very sensitive to changes in the environment(below-average stability): small changes in the environment produced large changes in yield. The variety yielded very little grain in a low-yielding environment, but as the environment improved, thus favouring higher yields, Provost's yield increased at a rate well above the average for the group. Under the most favourable conditions it became one of the highest yielding varieties. Provost was, therefore, described as being specifically adapted to high yielding environments and characterised by a regression co-efficient significantly greater than 1.0 (b = 2.13).

Bankuti Korai exhibited the opposite type of adaptation, with very little change in yield despite large changes in the environment (above-average stability). The variety produced above-average yield in low-yielding envoronment, but insensitive to environmental changes, it yielded relatively little grain in a high yielding environment. Bankuti Korai with a regression co-efficient significantly less than 1.0 (b = 0.14) therefore typified varieties specifically adapted to low-yielding environments.

Following Finlay and Wilkinson, Eberhart and Russell(1966) proposed the model

$$Y_{ij} = \mu_i + \beta_i I_j + \eta_{ij}$$

involving a stability co-efficient I_j for variety assessment. β_i in the above model was taken as a regression co-efficient measuring the change in response of the i^{th} variety due to change in environment I_j. The regression co-efficient was thus taken as a measure of stability of the performance of any variety with changing environment, the relationship being the less the value of the regression co-efficient for a variety, the more the stability.

Rawlo and Das (1978) exploited the above approach for interpretation of the data collected from groups of experiments, and experiments on cultivators' fields. The data collected from an experiment conducted over a number of years or places were used to obtain two induces, viz.(i) treatment index and (ii) environment index. The treatment index for a treatment in an experiment was taken as the mean yield of that treatment and the environment index was taken as the grand mean of that experiment and hence the same for each treatment in the experiment. For each treatment there was thus as many pairs of values as the number of years or localities or their product. Taking the treatment index as the dependent variable and the environment index as the independent variable the regression of the treatment index on the environment index was computed. The regression co-efficient which gave a measure of the change in response to the treatment per unit change in the environment index was thus taken as the stability index for that treatment. Assessment of the efficacy of a treatment was made according to the nature of the stability index, that is, the less the regression co-efficient for a treatment the more stable being that treatment under varying environments. A treatment showing a higher performance and small regression co-efficient was very much desirable as the effect of adverse environment was likely to be resisted by it. Thus the usual regression of treatment index on environment index gave the change in effect of the treatment per unit change in the environment. The stability index for the i^{th} treatment was taken as $1/|b_i|$, 'b'_i being the regression co-efficient of the i^{th} treatment. This was an improvement over the results of Finlay and Wilkinson (1963), by the authors. If b_i were unity the inverse of b_i was unity, the interpretation of which was that the i^{th} treatment had average stability i.e. the treatment response change was as much as the environment index. If b_i were greater than unity the inverse of b_i was less than unity which was interpreted as that the corresponding treatment had less stability in the sense that any change in the environment caused greater change in the treatment response. In that situation the treatment response was to some extent unpredictable as much as the environment. If b_i were less than unity the inverse of b_i was greater than unity thereby meaning that the treatment had got more stability, that is, when the environment changed considerably the treatment response lagged behind.

Strictly speaking stability index indicates as to whether changes in weather has influence over the yield of the crop. This in effect is equivalent to examining the effect of seasons over the varieties. An alternative method therefore, could be given by the analysis of groups of experiments (Cochran and Cox, 1957; Panse and Sukhatme, 1954). Where there is interaction between seasons and varieties it certainly is indicative of the differential effect of season on varieties and consequently lack of stability of at least some of the varieties. However absence of interaction does not indicate stability of the treatments. But it would indicate stability provided the seasonal effects are not significant. Therefore, test of stability in the analysis of groups of experiments would amount to testing seasonal or place effects and interaction between varieties and seasons. The different situations arising in the analysis of groups of experiments were extensively treated in Cochran and Cox (1957) and Panse and Sukhatme (1954).

An absolutely common place approach was adopted by Sharma (1970), to bring out the influence of weather on crop. He indicated a close relation between yield of food grains and weather conditions. Primarily this was due to lack of irrigation facilities to lion's share of the cultivated land. To illustrate his point it was pointed out that there was steep fall in food grains output during the drought years of 1965-66 and 1966-67 from 89 million tonnes in 1964-65 and to 72 and 74 million tonnes respectively. This was in spite of the continuing efforts like increasing the area under irrigation, introduction of new varieties, application of fertilizers, etc. He has, therefore, suggested that attempt should be made first to distinguish between the contributions made by weather and technology towards increased production. His second suggestion was that methods should be evolved to predict the current years' production by studying the weather crop relationship of the previous years. It was pointed out that if weather data over long periods of time were studied, symmetrical features and sometimes cyclical fluctuations could be identified. If these could be identified on the basis of such an analysis it should be possible to forecast weather in the next year or two or three years and through this to predict the crop production in the years that follow. This then could be the third area of study. The fourth area for study, according to him was by delineating the country into homogeneous crop weather regions which would enable a closer and more meaningful study of crop weather relationships. But it was found difficult as the country cannot be delineated into homogeneous regions because of the wide variations in the conditions of the soil, climate, geography, etc.

Considerable similarity was observed between Sharma (1970) and Louis (1970). The latter reviewed the long time weather and crop data for many countries and particularly for India, which revealed much evidence of repetition in cyclical trends. Statistical devices to meet the need for weather and crop forecasting, such as trend, projections and the search for cycles with fixed amplitudes and periodicities have proved fruitless. There was much evidence to show the existence of repeating patterns and that may last for 5 or 15 years before new ones assert themselves. The more astonishing discovery, however, was that there were points of symmetry, points beyond which the annual variations and their cyclical trends took the form of the variations just preceding those points best described by a 180° turn. Thus for the statisticians interested in time series correlations, the above statement meant another form of autocorrelation, in which the lag or time-interval was an expanding instead of a fixed one.

The interest of Sreenivasan et al. (1970) was more realistic than that of Sharma and Louis. They analysed the crop weather data on two varieties of wheat at Jalgaon and Niphad from 1947 under, co-ordinated crop weather scheme by adopting the linear and curvilinear multiple regression methods. The two varieties were N.P.4 and Gulab in Jalgaon and N.P. 4 and Vijay in Niphad. The study revealed the differential response of (i) the wheat crop at these two stations (ii) the varieties at the same station and (iii) the N.P. variety at the two stations. The difference in gain in information by resorting to the curvilinear technique instead of the usual linear multiple regression was brought out for the two stations.

The effect of rainfall distribution in the 52 weeks of the year commencing with January on the wheat grown in winter months of November to February at the two crop weather stations namely Jalagaon and Niphad were investigated with the help of the data extending over a period of 22 years commencing from 1947. The rainfall response curves obtained by using Fishers' well known method of regression function indicated that, by and large, the curves for both the varieties of wheat at the two stations showed similar pattern of response both before and after removing the trend and the multiple correlation co-efficient was of the order 0.8.

In general, there was a positive response to an additional unit of rainfall in any week but the magnitude of response was more for the additional rainfall after sowing and during the summer months.

The influence of rainfall on the yield of cotton grown in the Government Experimental Farm, Jalgaon, under crop-weather scheme since 1947 were also statistically analysed by the authors adopting Fisher's response curve techniques, taking into consideration the rainfall in all the 52 weeks of the year. The multiple correlations were of low magnitude 0.67 before removal and 0.55 after removal of progressive changes in the variety Jarilla and 0.42 before removal and 0.36 after removal of trend in the variety Virnar.

From the above discussions it is quite clear that meterological factors have a significant effect on the growth and yield of crops. But it may not be possible always to have a clear picture of the true effect of the various meteorological factors if we are supplied with the data on the individual factors. Further a comparitive study of the effects of the various meteorological factors on the yields of different crops may not always become possible. Again to draw a rapid conclusion based on the various factors is really difficult. So it has often been felt necessary to fuse the numerous meteorological variables into one or at most a few composite variables in the form of "Index Numbers" which could be conveniently handled in the production or supply equations (Dubey, 1970).

Not all these factors are important and they are to some extent interrelated. From the view point of influence on the yields of crops, temperature and rainfall are most important (Dubey) 1970). Attempts have been made by many authors in constructing different types of indexes which could be used instead of the numerous meteorological variables.

Mischard suggested (Dubey, 1970) a moisture temperature index as a measure of the combined effect of the two variables on yield. The index was given as a measure of the change in yield per unit change in temperature and the ratio of the total rainfall and total evaporation during a particular crop period. Lange, assuming that the effectiveness of rainfall was directly proportional to total precipitation and inversely proportional to the mean temperature, suggested a simple formula $I = P/T$. De Martonne made an improvement in the Lange formula by adding 10 to the denominator to avoid getting negative values of I. Koppen suggested three other modifications, viz.,

$I = \frac{8P}{13\,T + 120}$; $I = \frac{2P}{T + 3}$ and $I = \frac{P}{T + 7}$.

$\frac{P}{1.07\,T}$ was the index due to Angstrum.

Ovry suggested that a weather index, which he called avidity index, could be computed with a comparable scale using monthly precipitation and average monthly temperature for n monthus thus:

$$I = \sum_{i=1}^{n} (P_i)12/n + \sum_{i=1}^{n} (T_i/n + 10); \quad i = 1, 2, \ldots n$$

Knetsch used drought index as an explanatory variable in his yield equations. He defined a drought day to occur when the available moisture in the soil reached a point of zero availability as measured by the difference between daily precipitation and evapotranspiration. A weighted average of the drought day intensity during a crop season with the weights based on the correlation between drought occurance and yield, was used to calculate drought index.

Thornth Waite gave another index based on moisture ratio which can be given as the ratio of the difference between precipitation and potential evapotranspiration, to potential evapotranspiration, viz: M = P/e-I.

Hypothesising that the meteorological variables were a weighted function of time, Ram Dayal and J.P. Doll separately suggested a scheme of collapsing the weekly or fortnightly observations on rainfall and temperature into a single variable, if the relationship were assumed to be linear or a few composite variables, which could be used as an explanatory variable in yield equations. The composite variable can be made into a weather index so that whatever be the number of composite variables, the same can be reduced to one variable.

Shaw and Stallings separately constructed their weather indexes, not from the periodical weather data, but from the yield data. These indexes were based on the ratio of actual yields to trend yields. The trend used could be linear or higher degree polynomial or some type of moving average.

Thornthwaite (1948) introduced the concept of Potential Evapotranspiration (PET). According to his concept the loss of moisture in the form of evaporation and transpiration, in case its supply were unlimited depended on the atmospheric conditions. This loss was referred to as PET. For estimating the values of PET, Thornthwaite suggested some empirical relations based on two meteorological parameters namely the mean temperature of the day and its length. Alternative methods for estimating PET were also suggested by some other authors including Ramdas (1957). By utilising such information, the moisture availability periods could be classified into different categories by comparing the amount of rainfall received during the past 24 hours for each day with extent of PET assessed for the same 24 hours to indicate the adequacy or deficiency of available moisture. The World Meterological organisation in their Technical Bulletin No.86 suggested a classification in terms of three periods as follows:-

(i)Preparatory:

This is a period for which rainfall is more than PET/10, but doesnot exceed PET/2 so that in this case

$$PET/10 < Rainfall \leq PET/2$$

(ii)Intermediate:

This is a period for which rainfall is more than PET/2 but does not exceed PET, there being two such periods viz; one at the beginning of the rainy season and another at the end of the rainy season. Thus in this case

$$PET/2 < Rainfall \leq PET$$

(iii)Humid:

This is a period for which rainfall exceeds PET or equivalently.

$$Rainfall > PET$$

Here it is to be noted that intermediate periods and the humid periods constitute the moist period.

Bhargava et al.(1978) attempted to examine the extent of influence of different periods on the yield of Jowar and loss in normal yield due to the deviation of the date of cessation of'humid' period from mean cessation date. The study was based on 26 years of data on rainfall and records of V.S.Pan evaporimeter for 11 years for the Jalgaon district. The season considered for the study was 'Ist May to 31st October'. The choice of this period was made in view of the fact that it coincided with the crop season of Jowar and also about 90 per cent of the total annual rainfall were received during that period. The available data on U.S.Pan evaporimeter readings were converted to PET by a method given by Ramdas (1957). Further, based on a comparison of rainfall with PET, the entire period of Khamif season (viz; May to October) was classified into three categories of moisture availability periods depending on whether the moisture availability were surplus or deficient. The commencement and cessation of such periods (viz; moist and humid) were studied. It was found that the span of the humid period extended between the third week of June to second week of September while that of the moist period extended between second week of June to the end of September. The mean cessation date of humid period was seen to be september 15 and it was found that the termination of humid period prior to September 15 appeared quite likely to cause a depression in the crop yield.

Through a graphical technique adopted to determine the minimum number of moist/humid days it was found that the requisite number of moist days was 30 while that of humid days was 25.

It is a foregone conclusion that the data on rainfall, temperature and humidity are useful for the purposes of planning crop rotations and particularly in introducing new crops in a given area. The data on likely rainfall and temperature conditions including hours of sunshine at critical periods of crop growth are required for the successful introduction of new cropping patterns. By substituting the long duration variety of rice by a short duration variety in coastal districts of Andhra Pradesh it has become possible to grow rice in fallows. Such changes would require the knowledge of the chances of occurance of rain or no rain at the time of sowing and at the critical periods of crop growth.

Another area in which an analysis of crop weather relationship is useful relates to the incidence of pests. It has been found that attack of certain pests and diseases are highly correlated with the occurance of certain weather conditions. If such relationships could be identified with sufficient confidence they may help the farmer to adopt prophylactic measures to protect their crops against pests and diseases.

As mentioned earlier rainfall and temperature have been identified as two major factors of weather. It would therefore, be useful if methods are developed for estimating rainfall. The pattern of distribution and estimation of rainfall have attracted the attention of several researchers. Some were interested in the effect of distribution of rainfall on yield of crop.

Joshi and Kabaria (1972) studied the effect of rainfall distribution on yield of bunch groundnut in Saurashtra during 1945-70. They found neither the total rainfall nor the distribution of rainfall had any effect on the yield. This was due to no rainfall during 30 percent of the total experimental period and the period of the growth, 51-65 days, of the crop. However, they observed significant correlation between rainfall from the full pegging to the pod development (51-80 days) during favourable years of rainfall which occured once in three years. The most critical period was the week from full pegging to early pod development(51-57 days). A decrease in 1 mm rainfall during that week reduced the yield by 3.27 kg per ha.

Singh et al. (1970) made a study on the total and monthly rainfall in the cotton growing period and the relation of rainfall to the yield of seed cotton for 35 years at Indore and for 43 years at Khandwa. The highest mean cotton yield of 704 kg per ha was obtained at Khandwa in 1930, when the annual rainfall was 679 mm with a distribution of 99 mm, 251 mm, 119mm, 185mm, 29mm respectively during the 5 months span, June to October. With the same annual rainfall of 679 mm at Indore in 1956, the highest yield per ha was 564 kg when the distribution of the rainfall was 114 mm, 268mm, 84mm, 177 mm, 35mm, from June to October. High rainfall at the time of sowing and germination in June at Khandwa favourably influenced the yield of cotton. But the highest rainfall at the time of vegetative growth in July, August, September and October adversely affected the yield at both Khandwa and Indore. The adverse effect was more pronounced at Indore and this was attributed to the heavier soil and poor drainage of the place.

Sreenivasan (1973) used a different technique. The data were analysed by the Fisherian technique of regression intergral and the technique of selection by significant direct correlation and regression function. The trend yield found at Khandwa was removed by the Fisherian technique. Five out of six rainfall distribution constants for Khandwa and three out of six for Indore had significant correlation with yield. The regression of rainfall distribution constants before and after removal of trend were significant for Khandwa but insignificant for Indore. For both the stations additional rain during growth and boll formation periods was detrimental to the crop. The method of analyses brought out the sensitive weeks in the elongation through boll formation period of 16 weeks.

Effect of water regimes on the main shoot of rice varieties attracted the attention of Sen and Das Gupta (1970). They considered three varieties grown in different seasons. Their conclusions were that irrespective of the varieties and seasons, the final length of the internodes and the main shoot, and the grain yield per plant, were minimum under deficient water supply and maximum under differential supply of water at various stages of growth, with shallow sub mergence only during the tillering phase.

Performance of dwarf indica and ponlai rice varieties in the rainy and dry seasons at Bhubaneshwar was discussed by Sahu (1969). Temperature summation was the parameter considered. He observed that the dwarf indicas 'Taichung Native 1' and 'IR-8' and the ponlai 'Tainan 3' were thermophasic. 'IR-8' required a temperature summation of 2340°C and 'Taichung Native 1' and ponlai varieties 2200°C from seeding to the flowering stage. 'Taichung Native 1' and 'IR-8' behaved as early maturing varieties in the kharif and as medium duration varieties in the rabi season.

An analysis of the distribution of area of rice in different states, production and rice yield per unit area in India was made by Chatterjee and Maiti(1979). They found that the distribution pattern of area under rice and the production potentiality of the crop in the different parts of the country were apparently governed by the onset and withdrawal of monsoon, the distribution of rainfall and the extent of irrigation facilities available in the different regions. Further it was observed that the practice of rice cultivation was greatly influenced by the pattern of rainfall distribution. The same observation was made by Grist (1975) with reference to tropical countries. According to him the water supply for about 80 percent of the World's area planted to paddy came directly from rainfall. The high variability of tropical rain rendered the success of paddy cultivation uncertain in areas other than the great deltas and basins of large rivers.

Ramiah (1954) pointed out that there was no relationship between the total quantity of rain and yield in countries such as Egypt, Italy, Australia and the United States which are characterized by moderate rainfall but provided with irrigation facilities.

Tullis *et al*. (1934) have reported that high temperature accompanied by increased wind velocity on clear bright days cause scald of paddy. Studies of Yamagupta (1958) revealed that the number of tillers and ears increased with the intensity and quantity of light. Stansel (1967) found that favourable yield response to high levels of applied nitrogen occurs only when the crop receives high light levels. The findings of Tanaka *et al*. (1966) were that in the rainy season growth rate was higher at early stages but it became slower and sometimes even negative at later stages. On the other hand in dry season the growth rate was slow at early stages, but it was kept almost constant till the end. Generally a high early growth, whether caused by a varietal character, having nitrogen or seasonal effect was frequently associated with slower rate at later stages resulting in lower grain yield.

A high positive correlation of grain yield with solar radiation and a negative correlation with mean daily temperature during the 25 days period before flowering was observed at IRRI. A high correlation of 0.834 was found between grain yield and solar radiation during ripening period (IRRI, 1974). Murata (1964) and Tanaka and Vergara (1967) reported that there was a negative correlation between rice yield and mean daily temperature.

It was reported by Ghosh (1970) that neither the rainfall nor the number of rainy days showed any appreciable effect on yield probably because the crop was grown under irrigation. However, a strong detrimental effect on the number of rainy days at the ripening phase was evidenced.

Murata and Togari (1972) got a negative correlation of grain yield with rainfall at the ripening period. A similar finding was reported by Srinivasan (1974) on the effect of heavy rainfall in Orissa on the grain yield.

The correlation coefficients worked out with various meteorological elements at different phases show that minimum and maximum air temperature at vegetative phase were negatively correlated with grain number (Sreedharan 1975). He further found that minimum air temperature at reproductive phase and summation of minimum air temperature throughout the crop growth period was negatively correlated with grains/m^2. A negative correlation was found between yield and total rainfall during the crop period. It was found that the yield was lowest in the sowing months when rainfall during the crop period was maximum.

Ghosh (1970) observed that neither the total rainfall nor the number of rainy days showed any appreciable effect on the grain yield. On the other hand a strong detrimental effect on number of rainy days was evidenced at the ripening phase.

In a crop weather correlation study, utilising the data accumulated at the Rice Research Station, Pattambi, Pillai (1980) found that the monthly weather parameters were correlated with yield of paddy in two seasons. The result showed a significant positive correlation between monthly rainfall during June and yield of paddy for one variety in the Autumn season. There was significant positive correlation between number of rainy days during October and yield of PTB-20 in the winter season. There was strong negative correlation between rainfall received during July and yield of Autumn crops. Among the various weather parameters studied, rainfall was found to be the major factor contributing to variations in yield. It was found that at least one third of the variations in yield of the Autumn crop could be explained through the flustuations of monthly rainfall during the months of May, June and July.

Probability of occurance of deficient rainfall periods within the main rainy season and their persistency in the arid zone of Jodhpur and in the semi and zone of Jaipur formed the subject matter of the discussion by Krishnan and Kushwaha (1973). A simple Markov Chain Model was fitted to the data for standard pentads of daily rainfall of the two places during 1901-60.

The twin objectives of the study by Singh and Pavate (1968) were: (i)The rainfall pattern at two cotton growing centres, Amravati and Coimbatore and (ii) Suggesting a suitable variety along with the optimum timings for the various cultural operations based on the rainfall pattern at these centres.

The data on the monthly rainfall of the two places showed that the frequency distributions were highly positively skewed in the case of Amravathi and highly negatively skewed in the case of Coimbatore.

The values of β_1 and β_2 calculated for the raw data of the two centres showed that the distributions were highly skew and far from normal. While β_1 was highly significant for the raw data of both the centres, $\gamma_2 = \beta_2 - 3$ was highly significant only for the raw data of Coimbatore. None of the β_1 and γ_2 were significantly high for the transformed data, which showed that normal approximation was satisfactory.

After the transformation of the data, the mean ($\bar{x}$) and the standard deviation(s) for each month over the available number of years were calculated. The above values together with the appropriate values of 't' provided confidence limits of monthly rainfall on the new scale. The actual limits were obtained by conversion. The expected values outside the range were worked out on the basis of the level of confidence and the total number of years for the month.

Prediction of monthly and annual precipitations at Pattambi was the interest of Thomas (1977). He further examined the distribution of rainy days during a normal year. Mean was taken as the estimate. Confidence intervals at different confidence levels were also estimated. The study was based on the records of monthly rainfall and number of rainy days per month maintained at the Rice Research Station, Pattambi for the period 1927-76.

The mean annual precipitation at Pattambi was found to be 2603.3 mm and the standard deviation of the amount of precipitation was 536.05 mm. The mean number of rainy days per year was 118.24 and the standard deviation was 13.52 days.

The results also showed that with 80% confidence, the amount of rainfall that can be expected at Pattambi in a normal year would be between 1919 mm and 3293 mm. At 90% confidence total expected precipitation would be less than 1919 mm and with 75% confidence it would be above 2245mm. Further it was found that the probability of annual rainfall exceeding 3293 mm was 0.10 and the same for exceeding 2960mm was 0.25.

Patro *et al*. (1975) were of the opinion that crop planning in rainfed agriculture were largely dictated by the amount and distribution of rainfall. So the prediction of rainfall amounts expected at various levels of probability for different periods was of vital importance. It was found that the rainfall and run off data followed the logarithmic normal distribution. Thus the objective of the authors were to predict the weekly rainfall amounts at Bhubaneshwar at three levels of probability viz; 10% 50% and 80%.

The rainfall values for any period were arranged in order of size with the largest first. The plotting positions were computed using the California method and Hazen's method. In California method $F_a = \frac{100m}{y+1}$ and in the other $F_a = \frac{100(2m-1)}{2y}$, where '$F_a$' is the plotting position percent, 'm' the rank number and 'y' the number of years of record. The abscissa (normal probability scale) of lognormal probability paper was used for plotting positions and the ordinate (log normal) for rainfall values. A best fit straight line was drawn by the eye through the plotted points.

Frequency lines were drawn by both California and Hazen's mthods for each meteorological week of the year. The plots were observed to be straight line, approximately. The rainfall amounts corresponding to 10%, 50% and 80% probability were determined from the frequency plots.

The rainfall amounts predicted at 80% probability could be taken as the minimum assured a value. The rainfall values predicted at 50% probability suggested the limit of maximum risk that the crop planner could take in assuming that amount of rainfall available for planning. During rabi season, there was no assured rainfall, the one could expect some amount at 10% probability which if occurs would improve the corp yield considerably.

An improvement over the procedures of estimation of weekly rainfall of a place was suggested by Surendran *et al.*(1977). Two general methods of estimation of weekly rainfall of a place based on probability considerations were proposed. It was found that the California and Hazen's methods were particular cases of procedures developed by them.

In their method weekly rainfall data were arranged in discending order of magnitude and the results were obtained under the following assumptions: If X stands for the rainfall during the arbitrary year, (i) for any given X_i and X_{i+1} the probability is 'p' that, $X_{i+1} \leq X \leq X_i$, $i = 1, 2, \ldots, (Y - 1)$.

ii) p_1 is the probability that $X > X_1$ and,

iii) p_2 is the probability that $X < X_Y$, clearly

(2.1) $p_1 + p_2 + (Y - 1) p = 1$

If P(n) is the probability that the minimum rainfall of a year is X_n, it should satisfy the relation;

(2.2) $P(n) = p_1 + (n - 1) p$

Assigning different sets of values to 'p'$_2$ and p_1 subject to the relation (2.1) when p_1 will be automatically determined, different expressions for P(n) can be obtained.

Of these only the following two have been adopted.

(2.3) $p_1 = \frac{2}{k(Y+1)}$ and $p = \frac{1}{Y+1}$, for $k \geq 2$ and

(2.4) $p_1 = \frac{1}{Y} - \frac{1}{rY}$ and $p = \frac{1}{Y}$ for $r \geq 1$.

Making use of (2.3) and (2.4) successively in (2.2) and denoting the resulting forms of p(n) respectively by p_n and p_n' it is easy to see that,

(2.5) $p_n = \frac{1}{k(Y+1)} \left\{ 2 + k(n-1) \right\}$ and

(2.6) $p_n' = \frac{1}{rY} \left\{ (r-1) + r(r-1) \right\}$

The corresponding confidence percentages F_n and F_n' were obtained by multiplying the R.H.S. of (2.5) and (2.6) by 100. Thus

(2.7) $F_n = \frac{100}{k(Y+1)} \left\{ 1 + k(n-1) \right\}$

(2.8) $F_n' = \frac{100}{rY} \left\{ (r-1) + r(n-1) \right\}$

On putting K = 2 in (2.7) and r = 2 in (2.8) they reduced respectively to the California and Hazen's approaches.

Now as Uniform probability were attributed to any rainfall between X_i and X_{i+1} whose confidence percentages were taken as C_i and C_{i+1}, the minimum rainfall X corresponding to a confidence coefficient C, for which $C_i < C < C_{i+1}$ could be estimated from the relation

$$X = X_{i+1} + \frac{(X_i - X_{i+1})}{(C_{i+1} - C_i)} (C_{i+1} - C), \; i=1,2 \ldots (Y-1).$$

MATERIALS AND METHODS

MATERIALS AND METHODS

Investigation of influence of meteorological factors on crop needs data. The data required for the examination of weather paddy crop relationship were collected from the Rice Research Station, Pattambi. These related to the permanent manurial trials on Jaya Variety of rice from 1973-79 for the _kharif_ and _rabi_ seasons. The information on 1974 _rabi_ crop was missing and therefore the same could not be used for the study. So altogether there were data from 13 seasons - 7 _kharif_ and 6 _rabi_ - on jaya variety (Dwarf _Indica_). As long _indica_ is not in current use, no attempt was made to include the same in the analysis. The experiment for all the seasons were layed out in a 4 - replicate randomised block design with 8 treatments. A uniform spacing of 15 cm X 15 cm was adopted. The gross plot size was 7.80 X 5.25 Sq m and the net plot size 7.6 X 4.95 Sq m. The treatments were aw given below.

Treatments

1. Cattle manure at 18,000 kg/ha to supply 90 kg N/ha
2. Green leaf at 18,000 kg/ha to supply 90 kg N/ha
3. Cattle manure at 9,000 kg/ha + Green leaf at 9000 kg/ha to supply 90 kg N/ha
4. Amonium Sulphate to supply 90 kg N/ha

5. Cattle manure at 9000 kg/ha + Amonium Sulphate to supply 45 kg P_2O_5/ha + 45 kg K_2O as M.O.P.(Muriate of Potash)

6. Green leaf at 9000 kg/ha + Amonium Sulphate to supply 45 kg N/ha + Super phosphate to supply 45 kg P_2O_5/ha + 45 kg K_2O as M.O.P.

7. Cattle manure 4500 kg/ha + Green leaf 4500 kg/ha + 45 kg N as Amonium Sulphate + 45 kg P_2O_5/ha + 45 kg K_2O/ha

8. Amonium Sulphate to supply 90 kg N/ha + Super Phosphate to supply45 kg P_2O_5/ha + M.O.P. to supply 45 kg K_2O/ha. (Amonium sulphate to be applied half as basal and the rest as top-dressing at panicle initiation).

The same experiment was repeated from season to season. The response to these treatments may remain steady or may depend upon the season. That is to say the treatment response may depend upon wether. These are two approaches for studying the weather paddy-crop relationship.

Let x be the mean yield of the same treatment in the p^{th} season and y the mean yield for all treatments in the same season. Then the regression of x on y is (Finlay and Wilkinson,1963)

$$x - \overline{x} = b (y - \overline{y})$$

Consider a unit change in the value of y. This represents average variation in the average response of all treatments. If now the corresponding change in x is also 1 unit, $b = \frac{(x - \bar{\bar{x}})}{(y - y)} = 1$, as x and y are measured in the same unit, i.e. change in the average response of all treatments is equal to change in a treatment. Hence we can say that this treatment has only average variation when $b = 1$.

When the average change of $y - \bar{\bar{y}}$ is larger than the average change in $x - \bar{\bar{x}}$, the relative change in the treatment is $b < 1$ and we say that the treatment has better than average consistency in different seasons.

In the same way if the change in $x - \bar{\bar{x}}$ is greater than the change in $y - \bar{\bar{y}}$, $b > 1$ and the treatment has lower consistency(stability).

A regorous justification of the aptness of the method to measure consistency(stability) can be given as follows:-

$$x - \bar{\bar{x}} = b\,(y - \bar{\bar{y}})$$

$$b = \frac{\operatorname{cov}(x, y)}{V(y)}$$

$$= \frac{\operatorname{cov}\left(x_1, \frac{x_1 + x_2 + \dots + x_v)}{v}\right.}{}, \quad \dots\; y = \frac{1}{v}\Sigma x_1$$

$$= \frac{\frac{1}{v}\, V(x_1)}{\frac{1}{v^2}\Sigma V(x_1)}$$

$$= \frac{V(x_i)}{\frac{1}{v}\sum V(x_i)}$$

$$= 1, \text{ if } V(x_i) = \frac{1}{v}\sum V(x_i)$$

$$< 1, \text{ if } V(x_i) < \frac{1}{v}\sum V(x_i)$$

$$> 1, \text{ if } V(x_i) > \frac{1}{v}\sum V(x_i)$$

Therefore it follows that in the place of 'b' we can make use of $\dfrac{V(x_i)}{\frac{1}{v}\sum V(x_i)}$

Hence a treatment has got average, less than average, greater than average consistency according as the variation in that treatment is equal to, greater than or less than the average of the variations of all the treatment.

The above method was employed to ascertain the stability of the eight treatments applied to the Jaya variety at Pattambi. The same problem was approached from a different angle, by using the technique of analysis of groups of experiements. When the data were grouped the design obtained was one of two-way classification with multiple but equal observations per cell. Assuming equality of variances the analysis can be derived as follows:

The linear model for analysis is

$$y_{ijk} = \mu + \alpha_i + \tau_j + \delta_{ij} + \epsilon_{ijk},$$

$i = 1, 2, \ldots, r;\ j = 1, 2, \ldots, v;\ k = 1, 2, \ldots, p,$

where

μ = general effect

α_i = effect of i^{th} replication

τ_j = effect of j^{th} treatment

δ_{ij} = interaction between i and j classifications and

y_{ijk} = yield of the k^{th} plot of the i^{th} replication receiving treatment j and ϵ_{ijk} are $IN(0, \sigma^2)$

Then if $\hat{\mu}, \hat{\alpha}_i\ \hat{\tau}_j\ \hat{\delta}_{ij}$ are respectively the least square estimates of μ, α_i, τ_j and δ_{ij},

$$y_{ij.} = p\,(\hat{\mu} + \hat{\alpha}_i + \hat{\tau}_j + \hat{\delta}_{ij}), \text{ where } y_{ij.} = \sum_k y_{ijk}$$

Thus by Markoff's theorem (Kempthorne, 1952),

$$(3.1)\quad \sum_{ijk}(y_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\tau}_j - \hat{\delta}_{ij})^2 = \sum_{ijk} y_{ijk}^2 - \sum_{ij}\frac{y_{ij.}^2}{p} = S^2,$$

is a $\chi^2\sigma^2$ with $(p-1)rv$ degrees of freedom. This is independent of any hypothesis. (3.1) is called the within cell sum of squares. Hence the variations due to the i and j classifications are completely contained in the between cell sum of squares. Their study should, therefore, be based on the analysis of cell totals. The linear model for this is (Das and Giri, 1979),

$$Y_{ij.} = p(\mu + \alpha_i + \tau_j + \delta_{ij}) + \epsilon_{ij} \quad \text{or}$$

$$\frac{Y_{ij.}}{p} = \mu + \alpha_i + \tau_j + \lambda_{ij} \quad \text{where} \quad \lambda_{ij} = \delta_{ij} + \frac{\epsilon_{ij}}{p} \quad \text{and}$$

$$V(\lambda_{ij}) = \sigma_\delta^2 + \frac{\sigma^2}{p} = \frac{p\sigma_\delta^2 + \sigma^2}{p} = \sigma_1^2 \quad \text{(say)}$$

The normal equations for the estimation of α_i, τ_j, μ are

$$\frac{Y_{...}}{p} = rv\,\bar{\mu} + v\sum\bar{\alpha}_i + r\sum\bar{\tau}_j$$

$$\frac{Y_{i..}}{p} = v\,\bar{\mu} + v\,\bar{\alpha}_i + \sum\bar{\tau}_j$$

$$\frac{Y_{.j.}}{p} = r\,\bar{\mu} + \sum\bar{\alpha}_i + r\,\bar{\tau}_j \quad \text{and if}$$

$$s_1^2 = \sum_{i,j}\left(\frac{Y_{ij.}}{p} - \bar{\mu} - \bar{\alpha}_i - \bar{\tau}_j\right)^2$$

$$= \frac{1}{p}\left[\left(\sum_{i,j}\frac{Y_{ij.}^2}{p} - \frac{Y_{...}^2}{prv}\right) - \left(\sum_i \frac{Y_{i..}^2}{pv} - \frac{Y_{...}^2}{prv}\right) - \left(\sum_j \frac{Y_{.j.}^2}{pr} - \frac{Y_{...}^2}{prv}\right)\right], \text{ it is a } \chi^2\sigma_1^2 \text{ or}$$

$$\left(\sum_{i,j}\frac{Y_{ij.}^2}{p} - \frac{Y_{...}^2}{prv}\right) - \left(\sum_i \frac{Y_{i..}^2}{pv} - \frac{Y_{...}^2}{prv}\right) - \left(\sum_j \frac{Y_{.j.}^2}{pr} - \frac{Y_{...}^2}{prv}\right) \text{ is}$$

a $\chi^2\sigma_2^2$ with $(r-1)(v-1)$ degree of freedom where $\sigma_2^2 = p\sigma_1^2$

To test $\tau_1 = \tau_2 \ldots = \tau_v = 0$, we minimise,

$\sum_{i,j}\left(\frac{Y_{ij.}}{p} - \mu - \alpha_i\right)^2$ with respect to μ and α_i.

This leads to $s_2^2 = \left(\sum_{i,j}\frac{Y_{ij.}^2}{p} - \frac{Y_{...}^2}{prv}\right) - \left(\sum_i \frac{Y_{i..}^2}{pv} - \frac{Y_{...}^2}{prv}\right)$ is a $\chi^2\sigma_2^2$

with $r(v-1)$ degree of freedom and therefore when the hypothesis is true $s_2^2 - s_1^2 = \left(\sum_j \frac{y^2_{.j.}}{pr} - \frac{y^2_{...}}{prv} \right)$ is a $\chi^2 \sigma_2^2$ with $(p-1)$ degree of freedom.

Similarly when $\alpha_1 = \alpha_2 = \ldots = \alpha_r = 0$, $\left(\sum_i \frac{y^2_{i..}}{pv} - \frac{y^2_{...}}{prv} \right)$ as a $\chi^2 \sigma_2^2$ with $(r-1)$ degree of freedom. Hence we have the following ANOVA.

Source (1)	df (2)	SS (3)	MSS (4)	F (5)
1 Bet. α_i's	$(r-1)$	$\sum_i \frac{y^2_{i..}}{pv} - CF$	B	
2 Bet. τ_j's	$(v-1)$	$\sum_j \frac{y^2_{.j.}}{pr} - CF$	T	
3 Interaction	$(r-1)(v-1)$	(4,3)-(1,3)-(2,3)	I	I/E
4 Bet.cells	$(rv-1)$	$\sum_{i,j} \frac{y^2_{ij.}}{p} - CF$		
5 Error	$(p-1)rv$	(6,3)-(4,3)	E	
6 Total	$prv-1$	$\sum_{i,j,k} y^2_{ijk} - CF$		

In order to develop tests it is required to find expectations of the various sums of squares. It is easy to show that,

$$E\left(\frac{y^2_{\cdots}}{prv}\right) = prv\,\mu^2 + \sigma^2 + p\,\sigma_\delta^2,$$

$$E\left(\sum_i \frac{y^2_{i\cdot\cdot}}{pv}\right) = prv\,\mu^2 + pv\sum_i \alpha_i^2 + pr\sigma_\delta^2 + r\sigma^2$$

$$E\left(\sum \frac{y^2_{i\cdot\cdot}}{pv} - \frac{y^2_{\cdots}}{prv}\right) = pv\sum_i \alpha_i^2 + p(r-1)\sigma_\delta^2 + (r-1)\sigma^2, \text{ or}$$

$$E(\text{ MSS due to } \alpha_i\text{'s}) = \sigma^2 + p\sigma_\delta^2 + \frac{pv}{(r-1)}\sum_i \alpha_i^2,$$

$$E\left(\sum_j \frac{y^2_{\cdot j\cdot}}{pr} - \frac{y^2_{\cdots}}{prv}\right) = pr\sum \tau_j^2 + p(v-1)\sigma_\delta^2 + (v-1)\sigma^2 \text{ and}$$

$$E(\text{MSS due to } \tau_j\text{'s}) = \sigma^2 + p\sigma_\delta^2 + \frac{pr}{(v-1)}\sum \tau_j^2$$

$$E\left(\sum_{i,j} \frac{y^2_{ij}}{p}\right) = prv\,\mu^2 + pv\sum_i \alpha_i^2 + pr\sum_j \tau_j^2 + prv\,\sigma_\delta^2 + rv\,\sigma^2 \text{ and}$$

$$\therefore E\left(\sum_{i,j} \frac{y^2_{ij\cdot}}{p} - \sum_i \frac{y^2_{i\cdot\cdot}}{pv} - \sum_j \frac{y^2_{\cdot j\cdot}}{pr} + \frac{y^2_{\cdots}}{prv}\right)$$

$$= (v-1)(r-1)\sigma^2 + \sigma_\delta^2(\,prv - pv - pr + p)$$

$$\therefore E(I) = \sigma^2 + p\,\sigma_\delta^2.$$

$$E\left(\sum_{i,j,k} y^2_{ijk} - \sum_{i,j} \frac{y^2_{ij\cdot}}{p}\right) = (p-1)\,rv\,\sigma^2,$$

and E (Mean error SS) $= \sigma^2$.

Thus the mean sum of squares due to each of i and j classifications shoudl be compared against interaction sum of squares for testing significance. For examining the presence of interaction, the mean sum of squares due to it should be compared against mean error sum of squares. This procedure may have to be modified when the variances associated with the different experiments are not equal.

Since the error sum of squares in the analysis of the 13 groups of experiments is simply the sum of error sums of squares in the analysis of individual experiments the data for the 13 seasons were first analysed as randomised block designs. The mean error sums of squares for seasons were tested for homogeneity by Bartlet's test. (Saxena and Surendran, 1973).

The errors were found to be heterogenious and the straight forward combined analysis of variance had to be modified. The mean of a treatment in the i^{th} season was weighted with $W_i = \frac{r}{E_i}$ where r is the number of replications of each treatment in every season and E_i the mean error SS in the analysis of the experiment in the i^{th} season. Then W_i is the inverse of the variance of the mean of a treatment at the i^{th} season. We shall denote by V_{ij}, the mean of the j^{th} treatment at the i^{th} season and $P_i = \sum_j V_{ij}$ is the total of all the treatment means of that season. Let $S_i = \sum_j V_{ij}^2$.

Then Total SS $= \sum_{i} W_i \, s_i - CF$ where $CF = \dfrac{(\sum W_i P_i)^2}{v \sum_{i} W_i}$

SS due to places $= \dfrac{1}{v} \sum_{i} W_i P_i^2 - CF$

SS due to treatments $= \sum_{i} \dfrac{(\sum_{j} W_j \, V_{ij})^2}{\sum_{j} W_j} - CF$

The sum of squares for interaction was obtained by subtracting from the total sum of squares, the sums of squares for the places and treatments. Let this be I. Then if n is the uniform degree of freedom for error in the analysis of experiment in any season, $\dfrac{(n-4)(n-2)I}{n(n-v-3)}$ is a chi-square with $\dfrac{(n-1)(v-1)(n-4)}{(n+v-3)}$ degree of freedom.

In case the interaction is significant the means of the treatments for the different seasons should be set out in a two-way table and the simple analysis of variance carried out. The treatment mean square is compared with the interaction mean square to test for the significance of treatment differences.

The daily rainfall and temperature data for a period of 31 years, from 1949 to 1979, were collected from the Rice Research Station, Pattambi, for computing a weather index and for suggesting a method for the estimation of rainfall.

A weather index should be such that it should account for the variations in weather from time to time. The weather is determined in terms of a vector of characters, the variations of which will be indicated by their dispersion matrix. Therefore, any function of the weather characters which accounts for the maximum variation in the dispersion matrix can be used to compute the weather index. When the function is linear it necessarily gives the first principal component of the vector of weather characters. As mentioned earlier the precipitation and the temperature were assumed to be the most important characters determining the weather and hence the first principal component (which accounts for the maximum variation) of the vector of these two characters was used to compute the weather index. Separate indices were calculated for distinct seasons. For the calculation of the dispersion matrix, seasonal means of temperature and rainfall were made use of in the case of first season and total rainfall and mean temperature in the case of the second.

Let C be the vector which corresponds to the maximum root of the dispersion matrix Λ of the vector of characters $\begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$ for a season. Then if $C' = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix}$ the weather index for the season in a year is $c_1 \bar{\bar{x}}_1 + c_2 \bar{\bar{x}}_2$, where $\bar{\bar{x}}_1$ and $\bar{\bar{x}}_2$ are the mean values of the characters, units of $\bar{\bar{x}}_1$ and $\bar{\bar{x}}_2$ being same as those employed for computing Λ.

July 1 to October 15 was taken as the first season and October 1 to January 15 as the second. Thirty-one years of data were available for the computation of index for the former season. However only 28 years of data could be procured for the latter.

The exact duration of the crop was taken into account for the computation of kharif and rabi indices.

The usual weather index, P/T, P being the precipitation of a place and T the temperature suggested by Lange(Dubey, 1970) were also computed. Further correlations were worked out between yield and the weather indexes by both the methods.

Similarly weather indexes by both the above methods were computed for the rabi season. As in the kharif season, the correlations were also worked out with the mean yield of treatments.

Daily record of rainfall for 31 years' from 1949 to 1979 was used to estimate weekly rainfall. The daily rainfall observations were fused into weekly totals. For given data from an unknown population the general approach for determination of distribution was given by Karl Pearson (Kendall and Stuart, 1957). The assumptions underlying this approach are

(1) Frequency distributions of homogenious populations are unimodal, i.e. within the range of admissible values of the variate there is one and one value (the mode) at which the frequency attains a maximum.

(2) The frequency curve of a continuous variate may be represented by a continuous function of the variate.

(3) The frequency curve has got high contact with either of co-ordinates at the extreme points.

(4) The frequency curve f (x) is always positive within the range of admissible values of the variate and is such that

$$\int_a^b f(x)dx = N,$$

where N is the size of the population.

The form of the Pearson distributions therefore can be given as

$$\frac{1}{p(x)} \quad \frac{dp(x)}{dx} = \frac{x - b}{B_0 + B_1 x + B_2 x^2}$$

The solution of the above equation is straight forward since it takes the standard variable separable form. But the form of the solution varies according to the nature of the root of the quadratic $B_0+B_1x+B_2x^2=0$ ie, according to the discriminant of the quadratic can be greater than, equal to or less than zero.

(3.2) ie. $k = \left| \frac{B_1^2}{4B_0B_2} \right| \gtrless 1$

On the basis of β_1 and β_2, k can be expressed as

(3.3) $$k = \frac{\beta_1 (\beta_2 + 3)^2}{4(2\beta_2 - 3\beta_1 - 6)(4\beta_2 - 3\beta_1)}$$

According to the different values of k different distributions are obtained. For predicting the weekly rainfall of a place quickly with a specified confidence coefficient C, in any future year, the method of Surendran et al.(1977) has been adopted with modifications.

Let $X_1, X_2, \ldots, X_y$ be the arrangements of logarithm of weekly rainfall in descending order of magnitude for Y years. In cases where some rainfall values are zero, log (X + 1) is taken. Now if, C_i is the percentage confidence in getting X_i, $i = 1, 2, \ldots, Y$; it is evident that

$$C_1 < C_2 < \ldots < C_Y$$

The confidence coefficients were calculated by the California approach as also by the Hazen's approach (Patro *et. al.*). In the California approach, C_n has been taken as F_n and in the Hazen's approach it has been assigned the value F_n' where,

$$F_n = \frac{100n}{Y+1} \text{ and } F_n' = \frac{100\,(2n-1)}{2Y}$$

Now assuming uniform probability log rainfall between X_i and X_{i+1}, whose confidence percentages are C_i and C_{i+1}, the minimum value of X, corresponding to a confidence coefficient C for which C_i C C_{i+1}, can be estimated from the relation

$$X = X_{i+1} + \left(\frac{X_i - X_{i+1}}{C_{i+1} - C_i}\right) (C_{i+1} - C), \; i = 1, 2, \ldots (Y - 1).$$

Antilogarithem of this value (if necessary after subtracting 1) will give the minimum rainfall corresponding to confidence coefficient C.

In order to facilitate assessment of the effect of distribution of rainfall on yield a wet day was defined as a day having at least 3mm of rainfall (Bhargava *et al.*(1973). The effect itself was estimated by computing the correlation between wet days and the yield.

The multiple correlation was made use of to examine the relation between yield and weather parameters. Wherever necessary correlations were used to assess the direct relationship between variables.

RESULTS

RESULTS

The eight treatments applied to the Jaya variety in 13 seasons - seven *kharif* and six *rabi* - will hereafter be denoted as Treatment 1, Treatment 2, ..., Treatment 8 respectively in the order in which they are described in the materials and methods. The mean yields of the Jaya variety of paddy from plots of size 9.6 x 4.95 sq.m by the eight treatments are given in Table 1.

The mean responses per plot of the variety to the treatment 1 were respectively 13.77500 kg, 14.22500 kg, 16.20000 kg, 14.17500 kg, 15.87500 kg, 18.02500 kg, and 14.00000 kg in the seven *kharif* seasons from 1973 to 1979. For the same treatments the mean responses during the six *rabi* seasons from 1973 to 1979 were 7.82500 kg, 9.75000 kg, 13.87500 kg, 11.02500 kg, 12.12500 kg and 11.17500 kg. Its overall mean for 13 seasons was 13.23462kg.

For treatment 2, the mean responses ranged from 10.30500 kg to 16.02500 kg during the *kharif* seasons and from 6.12500 kg to 11.32500 kg during the *rabi* seasons. On an average *kharif* response was 13.73750 kg and this was greater than the average *rabi* yield of 9.56667 kg.

The average yield of Jaya under treatment 3 was

13.28173 kg over the 13 seasons. When *kharif* seasons alone were taken the average was 15.08750 kg. However, the average was reduced to 11.17500 kg in the *rabi* seasons. In the *kharif* seasons, the average yield had a range of 12.32500 kg to 17.40000 kg and the same in the *rabi* seasons was 8.77500 kg to 12.97500 kg.

In the case of treatment 4, the mean yield of Jaya was 13.55750 kg in the *kharif* season and 9.34583 kg in the *rabi* seasons. The overall mean for the 13 seasons was 11.61365 kg. As in the case of other treatment *kharif* was favourable to this treatment also.

The range of mean yield of the paddy for treatment 5 was 13.10000 kg to 17.97500 kg in the *kharif* season and 8.50000 kg to 13.50000 kg. The mean yield for all the seasons was 13.73942 kg. The maximum mean yield was observed in *kharif* 1978 and the minimum in *rabi* 1973.

For treatment 6 the mean values ranged from 15.62500 kg to 9.92500 kg during the *kharif* seasons and between 11.47500 kg and 8.30000 kg in the *rabi* seasons. The overall mean yield was 12.23750 kg. The highest mean value was observed in *kharif* 1978 and lowest in *rabi* 1973

The overall mean of treatment 7 was close to the corresponding figure for treatment 1. The highest mean yield was in *kharif* 1978 and lowest was in *rabi* 1973.

The range of mean yields was 12.30000 kg to 17.20000 kg in *kharif* seasons and 8.75000 kg to 12.37500 kg in *rabi* seasons.

The last treatment had a mean yield of 12.10942 kg in the 13 seasons. The mean yield was 13.47071 kg for *kharif* and 10.52125 kg in the *rabi*.

The seasonal means for the *kharif* seasons ranged from 11.91000 kg to 16.42500 kg where as the range was 8.50000 kg to 12.19688 kg in the *rabi* seasons. When all the treatments were taken into consideration their *rabi* means had a range of 9.34583 kg to 11.34167 kg while their *kharif* means were from 13.47071 kg to 15.79464 kg.

The coefficients of regression of treatment means on the seasonal means are presented in Table 8. This coefficient of regression was 1.10043 for treatment 1, 1.12594 for treatment 2, 0.97084 for treatment 3, 0.97085 for treatment 4, 1.10724 for treatment 5, 0.97074 for treatment 6, 1.04211 for treatment 7 and 0.75523 for treatment 8. All but the second and the last were not significantly different from 1. The other two were significantly different from 1.

The mean daily rainfall in the _kharif_ seasons ranged from 0.80297 cm to 1.86125 cm, the mean temperature from 25.58172°C to 26.48480°C, the mean humidity from 81.87500 to 88.37295, the wind velocity from 3.19855 km/hr to 4.37769 km/hr and the hours of sunshine from 2.81885 to 5.822770 (Table 5).

In order to find out the direct influence of the weather parameters on the yield of the crop the seasonal means of Jaya were correlated with each of the mean daily rainfall, the mean daily temperature and the mean daily humidity (Table 7). These correlations were respectively -0.01452, -0.27018 and 0.61603. Only the last one was found to be significantly different from zero. The wind velocity and the hours of sunshine when each was correlated with seasonal means gave rise to r = 0.25247 and r = -0.41325 respectively. Each of them was found to be non significant.

As the mean rainfall during _rabi_ was small the total rainfall was one of the parameters of weather taken in that season. The minimum total rainfall (Table 6) observed in the _rabi_ was 57.05 cm and maximum was 92.73 cm. The correlation between total rainfall and seasonal means was -0.42526 and this was not significant (Table 7).

The mean daily temperature during these *rabi* seasons were in the range of 24.71960°C to 26.72609°C while the mean daily himidity was from 70.50435 to 76.93044. The mean temperature was found to have a correlation of -0.57013 with the seasonal means while the latter had a correlation of -0.40832, with mean humidity. Only the former correlation(r = -0.57013) was found to be significant.

The wind velocity and hours of sunshine for the *rabi* season were in the interval of 3.44240 km/hr to 3.86271 km/hr and 6.63826 to 7.92240 respectively. Hours of sunshine had significant positive correlation (r = 0.88193) with the seasonal mean yield, whereas the wind velocity did not have any significant correlation (r = -0.50246) with the seasonal mean yields.

The lowest mean daily maximum temperature was 28.52612°C and the highest 30.03784°C during *kharif*. The average daily minimum temperature during these seasons were in the range 22.63731°C to 23.49016°C. The correlations of the mean maximum and mean minimum temperatures with the seasonal means had values almost equal in magnitude but opposite in sign (r= -0.25164 for maximum temperature and r = 0.25206 for minimum temperature). But it was found that both the correlation coefficients were not significant. But for the *rabi* seasons both the correlation coefficients; i.e. the correlation of the average of the daily maximum and the minimum temperature with the seasonal mean yields, were significant. (r = 0.91131** in the case of maximum temperature and r = - 0.68602 ** in the case of minimum temperature). The range for the above two parameters were 30.90174$C to 32.93520°C and 16.50400°C to 22.07881°C respectively.

When the average of daily maximum and minimum humidity were correlated with the seasonal mean yields for the *kharif* and *rabi* seasons only the minimum humidity in the *rabi* seasons showed significance.(Table 7).

The correlation between the maximum humidity and seasonal means for *kharif* was 0.45464. The average minimum humidity had a correlation of 0.54718, with the seasonal means. These correlations were not significant.

In *rabi* season mean daily maximium humidity was in the range 85.20339 to 91.87826. This had a correlation of -0.11095 with seasonal means and this was not significant. The mean daily minimum humidity varied from 53.92800 to 61.98261 and this had a significant correlation of -0.58880.

During *kharif* the average minimum humidity had a correlation coefficient 0.54178 with seasonal means. The correlation between the latter and mean daily maximum temperature was 0.45464. Both coefficients were not significant.

The ANOVA tables of seasonal experiments are given in Table 2. The treatment mean squares for the seasons viz; *kharif* 1973, *kharif* 1974, *kharif* 1975, *rabi* 1975, *rabi* 1976, *kharif* 1977 , *kharif* 1978 *kharif* 1979 and *rabi* 1979 were found to be significant. The mean treatment sum of squares for the seasons, *rabi* 1973, *kharif* 1976, *rabi* 1977 and *rabi* 1978 were found to be non significant.

In the analyses where treatment sum of squares were significant treatments were classified into homogenious subgroups (Table 3).

The mean square errors ranged from 0.32036 to 2.03375. When the mean square errors were tested for homogeneity by Bartlet's test for homogeneity of variances, they were found to be heterogenous.

Since the errors were found to be heterogenous the data were tested for interaction by weighted analysis.

In that analysis the total sum of squares was 4655.68627, sum of squares for places 4118.2946, sum of squares due to treatments 314.95023 and sum of squares due to interaction 222.44148. The degrees of freedom for error was 21. While testing for interaction 342.13618 was found to be a chi-square with 714 degree of freedom and as such interaction was persent.

Since the interaction was present, the means of treatments for the different seasons were set out in a two way table. Further analysis revealed that the treatments were homogenious.

Weather indices were computed for the periods July 1 to October 15 and October 1 to January 15. The reasons for the choice of these periods was that they approximately coincided with the kharif and rabi seasons. For the sake of convenience we shall refer to these periods as winter and summer. The weather indices were computed for 31 winter seasons and 28 summer seasons by two methods, one suggested in this thesis and another by the P/T formula suggested by Lange (Dubey, 1970). The period covered is from 1949 to 1979. These indices are given in Table 10.

For the years 1973 to 1979 exact date of sowing and harvesting of Jaya variety of paddy were available for the two seasons. Hence the weather indices were computed for the actual duration of the crop and are presented in Table 9.

The seasonal means of treatments were correlated with the indices for the *kharif* and *rabi* seasons computed by the two methods. These are presented in Table 11. These correlations were all negative for the *kharif* season. In the case of *rabi* all the correlations except the correlation of the suggested index with means of treatment 7 were negative. The correlation between the index P/T with this treatment was negative (r = - 0.98012) and was significantly different from zero.

The mean yields of the variety for *kharif* was found to have a correlation of 0.26301 with the suggested index and -0.00090 with the P/T index. Both the correlations were not significant.

The suggested index had a correlation of -0.42538 with the *rabi* means of Jaya. The correlation of the P/T index with the *rabi* means was -0.3[illegible]. No significance of these correlations was noted.

The correlation between the number of wet days and the seasonal means of treatments was computed separately for the *kharif* and *rabi*. The correlations are presented in table 12. None of the correlations turned out to be significant.

The multiple correlation of treatment means over rainfall and temperature, during the period of the crop were also computed for the kharif and rabi (Table 13). All of them were found to be insignificant.

The estimated amounts of weekly rainfall with confidence percentages 10, 50, 80 and 90 are given in Table 14 and Table 15. For the sake of comparison estimates by the suggested method and the existing method due to Surendran et al.(1977) are given side by side.

The estimated amounts of rainfall at confidence levels 90%, 80%, 50% and 10% during the week June 11-17 were 0.28 cm, 3.80cm, 8.10cm, 25.08cm respectively by the suggested method. These were respectively 0.284cm, 4.016cm, 8.10cm and 25.112cm by the existing method. This was the situation when confidence levels were attributed by Hazen's method.

During the same week if confidence levels were determined by California method the estimated amounts of rainfall by the suggested method were 0.206cm, 3.196cm, 8.10cm, and 26.19cm with confidence levels 90%, 80%, 50%, and 10% respectively. The existing method estimated the corresponding amount as 0.208cm, 3.332cm, 8.10cm and 26.224cm.

In general, the estimated amounts of rainfall for corresponding periods did not differ much.

The κ (kappa) criterion for determining the nature of the curve which fits given data as suggested by Pearson was computed for the weekly observed rainfall and their logarithms. These values are given in Table 16. They were all negative in both cases.

Table-1. Mean values of the treatments in seasons

Season		Treatments					
		1	2	3	4	5	6
<u>Kharif</u>	1973	13.77500	13.18250	13.81250	13.92750	15.71250	14.33750
<u>Rabi</u>	1973	7.82500	8.10000	8.77500	8.80000	8.50000	8.30000
<u>Kharif</u>	1974	14.22500	13.75000	15.35000	13.45000	15.05000	14.12500
<u>Kharif</u>	1975	16.20000	14.52500	15.62500	14.15000	16.40000	15.52500
<u>Rabi</u>	1975	9.75000	9.35000	10.62500	8.50000	11.82500	10.67500
<u>Kharif</u>	1976	14.17500	13.20000	14.50000	14.00000	15.12000	13.97500
<u>Rabi</u>	1976	13.87500	11.32500	12.97500	10.87500	13.50000	11.47500
<u>Kharif</u>	1977	15.87500	15.17500	16.60000	13.47500	17.20000	14.85000
<u>Rabi</u>	1977	11.02500	11.30000	12.15000	10.80000	12.10000	11.25000
<u>Kharif</u>	1978	18.02500	16.02500	17.40000	14.50000	17.97500	15.62500
<u>Rabi</u>	1978	12.12500	11.20000	11.55000	10.95000	12.25000	10.90000
<u>Kharif</u>	1979	14.00000	10.30500	12.32500	11.40000	13.10000	9.92500
<u>Rabi</u>	1979	11.17500	6.12500	10.97500	6.35000	9.87500	8.05000
Overall mean		13.23412	11.81250	13.28173	11.61365	13.73942	12.23750
<u>Rabi</u> mean		10.96250	9.56667	11.17500	9.34583	11.34167	10.12083
<u>Kharif</u> mean		15.18214	13.73750	15.08750	13.55750	15.79464	14.05179

Table - 1 (Contd.)

Treatments		Seasonal mean
7	8	
15.97250	13.69500	14.30188
8.75000	8.95000	8.50000
14.65000	13.35000	14.24375
15.87500	14.57500	15.35938
11.50000	10.42750	10.33156
14.50000	12.67500	14.01875
11.52500	12.05000	12.19688
15.92500	13.42500	15.31563
12.37500	11.82500	11.58750
17.20000	14.65000	16.42500
11.75000	11.52500	11.53125
12.30000	11.92500	11.91000
9.27500	8.35000	8.77188
13.19981	12.10942	
10.86250	10.52125	
15.20321	13.47071	

Table - 2 Analysis of variance of experiments

Seasons	Source	df	SS	MSS	F
Kharif 1973	Replications	3	26.46156	8.82052	11.59
	Treatments	7	28.24263	4.03466	5.30 **
	Error	21	15.97689	0.76079	
Rabi 1973	Replications	3	2.90750	0.96167	3.03
	Treatments	7	4.34500	0.62071	1.94
	Error	21	6.72750	0.32036	
Kharif 1974	Replications	3	5.61625	1.87208	3.3
	Treatments	7	14.90375	2.12911	3.75 **
	Error	21	11.91875	0.56756	
Kharif 1975	Replications	3	8.94844	2.81567	6.53
	Treatments	7	19.70969	2.98282	6.16 **
	Error	21	9.59906	0.45710	
Rabi 1975	Replications	3	5.83563	1.94521	5.05
	Treatments	7	33.86065	4.83724	12.55 **
	Error	21	8.09594	0.38552	

Table-2(Contd.)

Seasons	Source	df	SS	MSS	F
Kharif 1976	Replications	7	4.06125	1.62042	0.80
	Treatments	3	16.75875	2.39411	1.18
	Error	21	42.70875	2.03375	
Rabi 1976	Replications	3	8.64844	2.88282	4.46
	Treatments	7	34.75219	4.96460	7.68**
	Error	21	13.56902	0.64615	
Kharif 1977	Replications	3	0.88094	0.29365	0.21
	Treatments	7	52.33469	7.47638	5.41**
	Error	21	29.02656	1.38222	
Rabi 1977	Replications	3	10.32250	3.44083	4.58
	Treatments	7	10.79500	1.54214	2.05
	Error	21	15.77750	0.75131	
Kharif 1978	Replications	3	5.47594	1.82531	1.95
	Treatments	7	56.60219	8.08603	8.65**
	Error	21	19.62656	0.93460	

Table-2-(Contd.)

Seasons		Source	df	SS	MSS	F
Rabi	1978	Replication	3	13.60125	4.53375	9.21
		Treatments	7	7.05375	1.00768	2.05
		Error	21	10.33375	0.49208	
Kharif	1979	Replications	3	2.93510	0.97837	0.54
		Treatments	7	51.54040	7.36291	4.04**
		Error	21	38.30370	1.82399	
Rabi	1979	Replications	3	30.85594	10.28531	11.22
		Treatments	7	102.67719	14.66817	16.00**
		Error	21	19.25156	0.91674	

** Significant (p 0.01)

Table-3 Critical values for classification of treatment means into homogenious subgroups by student-Newman - Keul's test.

Season		2	3	4	5	6	7	8
Kharif	1973	1.28326	1.55586	1.72045	1.84152	1.93201	2.00615	2.07048
Kharif	1974	1.10838	1.34381	1.48600	1.59053	1.66869	1.73273	1.78829
Kharif	1975	0.99471	1.20599	1.33361	1.42742	1.49756	1.55503	1.60489
Rabi	1975	0.91350	1.10753	1.22473	1.31088	1.37529	1.42807	1.47386
Rabi	1976	1.18265	1.43385	1.58557	1.67711	1.78051	1.84883	1.80812
Kharif	1977	1.72972	2.09712	2.31903	2.48215	2.60413	2.70406	2.79077
Kharif	1978	1.42232	1.72442	1.90689	2.04103	2.14133	2.22350	2.29480
Kharif	1979	1.98701	2.40906	2.66398	2.85137	2.99145	3.10629	3.20589
Rabi	1979	1.40869	1.7079	1.88863	2.02148	2.12082	2.20220	2.27282

Table-4 Season-wise homogenious sub groups of treatments.

Kharif	1973	Treatment No.	2	8	1	3	4	6	5	7
		Mean	13.1825	13.695	13.775	13.8125	13.9275	14.3375	15.7125	15.9725
Kharif	1974	Treatment No.	8	4	2	6	1	7	5	3
		Mean	13.35	13.45	13.75	14.125	14.225	1465	15.05	15.35
Kharif	1975	Treatment No.	4	2	8	6	3	7	1	5
		Mean	14.15	14.525	14.575	15.525	15.625	15.875	16.2	16.4
Rabi	1975	Treatment No.	4	2	1	8	3	6	7	5
		Mean	8.5	9.35	9.75	10.4275	10.625	10.675	11.5	11.825
Rabi	1976	Treatment No.	4	2	6	7	8	3	5	1
		Mean	10.85	11.325	11.475	11.525	12.05	12.975	13.5	13.875
Kharif	1977	Treatment No.	8	4	6	2	1	7	3	5
		Mean	13.425	13.475	14.85	15.175	15.875	15.925	16.6	17.2

Table-4(Contd.)

Kharif 1978	Treatment No.	4	8	6	2	7	3	5	1
	Mean	14.5	14.65	15.625	16.025	17.2	17.4	17.975	18.025
Kharif 1979	Treatment No.	6	2	4	8	7	3	5	1
	Mean	9.925	10.305	11.4	11.925	12.3	12.325	13.1	14
	Treatment No.	2	4	6	8	7	5	3	1
Rabi 1979		6.125	6.35	8.05	8.35	9.275	9.875	10.975	11.175

Table-5 Mean values of weather parameters - _Kharif_

Season	Rainfall (Mean)	Temperature Maximum	Temperature Minimum	Temperature Mean	Humidity Maximum	Humidity Minimum	Humidity Mean
Kharif 1973	1.26739	29.21154	22.75385	25.98269	95.40769	76.04615	85.72693
Kharif 1974	1.86125	29.90221	23.03529	26.46875	96.46324	76.41176	86.43750
Kharif 1975	1.71918	29.19672	23.49016	26.34344	96.40164	85.34426	88.37295
Kharif 1976	0.80297	30.03784	22.93176	26.48480	94.79054	68.95946	81.87500
Kharif 1977	1.12774	29.86642	22.93431	26.40036	102.04380	76.27007	89.15693
Kharif 1978	1.48306	28.52612	22.63731	25.58172	96.43284	77.43284	86.93284
Kharif 1979	1.57467	29.12899	22.65942	26.08321	94.81159	73.52899	84.17029

Table-5(Contd.)

Wind Velocity	Hours of Sunshine
4.37760	4.74769
4.13456	4.12721
3.89098	2.81885
3.90811	5.82770
3.60949	4.64307
3.59701	4.14701
3.19855	4.73696

Table-6 Mean values of weather parameters - *Rabi*

Season		Rainfall (Total)	Temperature Maximum	Temperature Minimum	Temperature Mean	Humidity Maximum	Humidity Minimum	Humidity Mean
Rabi	1975	78.49	30.90174	21.88000	26.39087	86.81739	60.19130	70.50435
Rabi	1976	57.05	32.93520	16.50400	24.71960	87.76800	53.92800	70.84800
Rabi	1977	92.73	32.01652	21.43565	26.72609	91.87826	61.98261	76.93044
Rabi	1978	61.06	31.43983	22.07881	26.53445	85.20339	57.07627	70.63983

Table-6(Contd.)

Wind Velocity	Hours of Sunshine
3.71043	6.63826
3.44240	7.92240
3.51478	7.47565
3.86271	6.91017

Table-7 Correlation of the seasonal mean yields with various meteorological factors.

Factors	Kharif	Rabi
Rainfall	- .014515	- .425260
Temperature	- .270180	- .570130*
Humidity	0.616030*	- .408320
Maximum temperature	- .251640	0.911310**
Minimum temperature	0.252060	- .686020**
Maximum humidity	0.454640	- .110950
Minimum humidity	0.541780	- .588800*
Wind Velocity	0.252470	- .507460
Hours of sunshine	- .413250	0.881930

* Significant (p 0.05)
** Significant (p 0.01)

Table-8 Regression, Coefficients and their students't values.

Treatment	'b' value	't' value
1	1.10043	0.70720
2	1.12594	2.47317
3	0.97084	0.36844
4	0.97085	0.30191
5	1.10724	2.18751
6	0.97074	0.24583
7	1.04211	0.66687
8	0.75523	4.63965

Table-9 Weather indices for *Kharif* and *Rabi*

Year	*Kharif*		*Rabi*	
	Suggested	P/T	Suggested	P/T
1973	25.59483	.04878	—	—
1974	26.01674	.07032	—	—
1975	25.90686	.06526	78.68029	2.97413
1976	26.13823	.03032	57.22857	2.30789
1977	26.02223	.04272	92.92245	3.46964
1978	25.17638	.05797	61.25169	2.30116
1979	25.66367	.06037	—	—

Table-10 Weather indices for summer and winter

Year	Winter		Summer	
	Suggested	P/T	Suggested	P/T
1949	26.03938	0.04629	17.41871	0.63279
1950	24.81547	0.02443	15.28170	0.54272
1951	24.32439	0.01510	16.45583	0.60265
1952	26.02488	0.01486	16.23574	0.59478
1953	26.05365	0.01909	14.99684	0.54556
1954	25.83579	0.01559	11.46505	0.41957
1955	25.97955	0.01155	19.40055	0.73143
1956	25.54069	0.01390	22.07550	0.81183
1957	25.92020	0.03798	48.03524	1.77268
1958	26.14828	0.03777	35.46623	1.23882
1959	25.54056	0.07698	42.47312	1.58471
1960	25.71809	0.04388	64.08394	2.37927

Table-10(Contd.)

Year	Winter		Summer	
	Suggested	P/T	Suggested	P/T
1961	25.24578	0.07899	32.90821	1.19577
1962	25.10441	0.05862	54.77308	2.04355
1963	25.48182	0.04941	22.83381	0.84729
1964	24.55689	0.05935	43.02376	1.68699
1965	24.62347	0.02973	26.46954	0.95462
1966	26.45987	0.03585	75.73796	2.75318
1967	25.36897	0.05839	21.04422	0.74037
1968	24.99171	0.06752	36.14519	1.35890
1969	25.04747	0.04336	43.67102	1.66655
1970	25.74152	0.05208	28.82496	1.06448
1971	25.44703	0.04576	36.10184	1.43044
1972	26.20394	0.04770	-64.43213	2.29554

Table-10(Contd.)

Year	Winter		Summer	
	Suggested	P/T	Suggested	P/T
1973	25.45665	0.03776	—	—
1974	25.20638	0.07880	—	—
1975	25.84625	0.05479	45.93699	1.60018
1976	26.11598	0.03590	55.44591	2.03878
1977	25.90166	0.03710	92.15571	3.22077
1978	26.36968	0.03959	61.50634	2.25614
1979	22.72166	0.05550	—	—

Table-11 Correlation between seasonal means of treatments and indices.

Treatment	Kharif		Rabi	
	Suggested	P/T	Suggested	P/T
1	-0.50863	-0.24357	-0.73840	-0.00008
2	-0.16807	-0.24570	-0.23635	-0.63211
3	-0.16072	-0.15287	-0.31130	-0.38548
4.	-0.09683	-0.32798	-0.36112	-0.53213
5	-0.30723	-0.42553	-0.67575	-0.13672
6	-0.03931	-0.23326	-0.08233	-0.52089
7	-0.35997	-0.39271	+0.72718	-0.98012*
8	-0.38775	-0.10743	-0.24375	-0.57623

* Significant (p 0.05)

Table-12 Correlation between number of wet days and seasonal means of treatments

Treatment	Kharif	Rabi
1	0.40421	-0.42919
2	0.28080	0.27270
3	0.24030	-0.11534
4	0.39934	0.20292
5	0.30528	-0.59994
6	0.37272	0.02993
7	0.24368	0.93983
8	0.34871	0.13877

Table-13 Multiple correlation of treatment means over rainfall and temperature during the period of the crop

Treatment	Kharif	Rabi
1	0.50933	0.83450
2	0.18608	0.26429
3	0.16101	0.70004
4	0.25081	0.36138
5	0.36507	0.94240
6	0.09064	0.70155
7	0.39678	0.73296
8	0.42957	0.43397

Table-14 Estimated weekly rainfall at Pattambi with different confidence levels by 2 methods (existing and suggested)

(Confidence level by Hazen's method)

Week	10%		50%		80%		90%	
	Existing	Suggested	Existing	Suggested	Existing	Suggested	Existing	Sugg-ested
Jan.1-7	0	0	0	0	0	0	0	0
8-14	0	0	0	0	0	0	0	0
15-21	0	0	0	0	0	0	0	0
22-28	0	0	0	0	0	0	0	0
29-4Feb.	0	0	0	0	0	0	0	0
Feb.5-11	0	0	0	0	0	0	0	0
12-18	0	0	0	0	0	0	0	0
19-25	2.602	2.546	0	0	0	0	0	0
26-4-Mar.	0.008	0.008	0	0	0	0	0	0
Mar.5-11.	0.260	0.222	0	0	0	0	0	0
12-18.	0.966	0.897	0	0	0	0	0	0
19-25.	1.836	1.642	0	0	0	0	0	0
26-1 Apr.	2.504	2.504	0	0	0	0	0	0
Apr.2-8.	6.918	6.886	0.13	0.13	0	0	0	0

Table-14(Contd.)

1	2	3	4	5	6	7	8	9
Apr. 9-15	4.756	4.754	0.8	0.8	0	0	0	0
16-22	4.47	4.442	0.33	0.33	0	0	0	0
23-29	5.076	5.046	1.39	1.39	0	0	0	0
30-6 May.	9.3	10.75	1.3	1.3	0.087	0.086	0	0
May 7-13	7.02	6.952	0.62	0.618	0	0	0	0
14-20	13.965	13.92	2.945	2.917	0.29	0.288	0	0
21-27	12.35	12.23	3.185	3.184	0.365	0.363	0.21	0.209
28-3.June.	20.78	20.73	3.84	3.83	0.78	0.771	0.37	0.3695
June.4-10.	19.58	19.57	9.1	9.1	2.562	2.562	0.788	0.755
11-17.	25.112	25.08	8.1	8.1	4.016	3.89	0.284	0.280
18-24.	27.464	27.24	10.21	10.21	3.757	3.75	2.454	2.452
25-1July.	32.484	32.18	11.51	11.51	7.35	7.348	4.562	4.538
July 2-8.	34.298	34.18	14.38	14.38	5.926	5.923	2.872	2.863
9-15.	27.716	27.71	13.56	13.56	3.588	3.588	1.898	1.882
16-22	27.090	26.96	12.42	12.41	2.932	2.931	1.358	1.766

Table-14(Contd.)

1	2	3	4	5	6	7	8	9
23-29	29.016	29.01	9.81	9.81	4.473	4.322	1.666	1.659
30-5Aug	20.526	20.43	6.03	6.03	2.5	2.5	2.056	2.056
Aug.6-12.	20-892	20-81	7.59	7.59	1.373	1.373	0.828	0.824
13-19.	20.452	20.45	5.92	1.48	1.473	0.936	0.936	0.936
20-26	12.308	12.3	5.24	5.24	1.689	1.658	0.578	0.574
27-2.Sept.	8.472	8.462	2.31	2.31	0.293	0.279	0	0
Sept.3-9.	8.290	8.27	2.52	2.52	0.24	0.237	0	0
10-16.	10.678	10.65	1.92	1.92	0.17	0.169	0	0
17-23.	11.560	11.56	1.62	1.62	0.273	0.273	0	0
24-30.	14.984	14.94	2.39	2.39	0.322	0.303	0	0

Table-14(Contd.)

1	2	3	4	5	6	7	8	9
Oct. 1-7.	7.912	7.906	2.49	2.49	0.957	0.956	0.376	0.37
8-14.	10.458	10.38	3.92	3.92	0.633	0.631	0.278	0.277
15-21	15.858	15.83	4.37	4.37	1.349	0.338	0.738	0.7352
22-28	16.812	16.64	3.9	3.9	0.105	0.105	0	0
29-4 Nov.	11.626	11.59	3.22	3.22	0.842	0.838	0	0
Nov. 5-11.	13.400	13.4	2.48	2.48	0	0	0	0
12-18	9.992	9.97	1.8	1.8	0	0	0	0
19-25	6.856	6.809	0.35	0.35	0	0	0	0
26-2.Dec.	2.660	2.496	0	0	0	0	0	0
Dec. 3-9.	4.8[illegible]4	4.573	0	0	0	0	0	0
10-16.	2.916	2.863	0	0	0	0	0	0
17-23	0	0	0	0	0	0	0	0
24-31	0.208	0.182	0	0	0	0	0	0

Table-15 Estimated weekly rainfall at Pattambi with different confidence levels by 2 methods(existing and suggested)

Week	(Confidence level by California method) 10%		50%		80%		90%	
	Existing	Suggested	Existing	Suggested	Existing	Sugge-sted	Existing	Sugge-sted.
Jan. 1-7	0	0	0	0	0	0	0	0
8-14	0	0	0	0	0	0	0	0
15-21	0	0	0	0	0	0	0	0
22-28	0	0	0	0	0	0	0	0
29-4. Feb.	0	0	0	0	0	0	0	0
Feb. 5-11.	0	0	0	0	0	0	0	0
12-18	0	0	0	0	0	0	0	0
19-25	3.134	3.079	0	0	0	0	0	0
26-4 Mar.	0.016	0.04373	0	0	0	0	0	0
Mar.5-11.	0.52	0.7084	0	0	0	0	0	0
12-18	1.402	1.296	0	0	0	0	0	0

Table-15(Contd.)

1	2	3	4	5	6	7	8	9
23-29.	29.472	31.58	9.81	9.81	3.696	3.534	1.502	1.497
30-5. Aug.	22.182	22.12	6.03	6.03	2.47	2.469	2.052	2.052
Aug.6-12.	22.284	22.2	7.59	7.59	1.346	1.345	0.736	0.7308
13-19	20.604	20.6	5.92	5.92	1.36	1.357	0.912	0.916
20.26	12.756	12.75	5.24	5.24	1.488	1.453	0.486	0.4786
27-2- Sept.	8.824	8.816	2.31	2.31	0.176	0.161	0	0
Sept.3-9.	8.43	8.429	2.52	2.52	0.180	0.176	0	0
10-16	9.948	9.947	1.92	1.92	0.740	0.139	0	0
17-23	11.6	11.6	1.62	1.62	0.246	0.246	0	0
24-30	15.908	15.88	2.39	2.39	0.184	0.163	0	0
Oct. 1-7.	7.608	7.607	2.49	2.49	0.924	0.923	0.272	0.263
8-14.	11.546	11.49	3.92	3.92	0.576	0.573	0.266	0.266
15-21	16.204	16.19	4.37	4.37	1.238	1.226	0.686	0.6841

Table-15(Contd.)

1	2	3	4	5	6	7	8	9
22-28	15.684	15.68	3.9	3.9	0.09	0.09	0	0
29-4.Nov.	12.422	12.4	3.22	3.22	0.764	0.760	0	0
Nov.5-11.	13.48	13-72	2.48	2.48	0	0	0	0
12-18.	10.284	10.28	1.8	1.8	0	0	0	0
19-25	7.572	7.536	0.35	0.35	0	0	0	0
26-2.Dec.	3.58	3.414	0	0	0	0	0	0
Dec.3-9.	4.204	4.2	0	0	0	0	0	0
10-16	3.452	3.402	0	0	0	0	0	0
17-23	0	0	0	0	0	0	0	0
24-31	0.416	0.5927	0	0	0	0	0	0

Table-16 Pearsonian distribution of weekly rainfalls.

Week	'K' Value for existing	Type	'K' Value for Suggested	Type
Jan. 1-7.	There was no rainfall.			
8-14				
15-21				
22-28				
29-4. Feb.	-3.35829	1	-3.32516	1
Feb. 5-11	-3.35748	"	-3.25085	"
12-18	-5.70022	"	-4.99574	"
19-25	-1.67186	"	-1.36586	"
26-4 Mar.	-3.45138	"	-3.37104	"
Mar.5-11.	-5.18851	"	-3.67343	"
12-18.	-2.96490	"	-1.90329	"
19-25	-2.10997	"	-1.46328	"
26-1. April	-2.48615	"	-1.02391	"
April. 2-8.	-0.83570	"	-0.32304	"
9-15	-0.57653	"	-0.03595	"
16-22	-0.57181	"	-0.16907	"
23-29	-1.11783	"	-0.03412	"
30-6 May	-0.93860	"	-0.07158	"

Table-16(Contd.)

1	2	3	4	5
10-16	-0.52063	1	-0.04731	1
17-23	-0.75323	"	-0.04551	"
24-30	-0.44941	"	-0.02748	"
Oct. 1-7	-0.55273	"	-0.00067	"
8-14	-0.87179	"	-0.08475	"
15-21	-0.02962	"	-0.52881	"
22-28	-0.24555	"	-0.09016	"
29-4, Nov.	-0.38266	"	-0.04360	"
Nov. 5-11	-3.16567	"	-0.07473	"
12-18	-0.18716	"	-0.06843	"
19-25	-0.50988	"	-0.13568	"
26-2, Dec.	-4.17755	"	-1.45980	"
Dec. 3-9.	-1.51049	"	-0.80899	"
10-16	-2.77425	"	-1.06617	"
17-23	-3.15430	"	-3.14983	"
24-31	-4.56866	"	-3.28601	"

FIG(1): MEAN YIELD OF JAYA DURING KHARIF (K) AND RABI (R) SEASONS FROM 1973 TO 1979

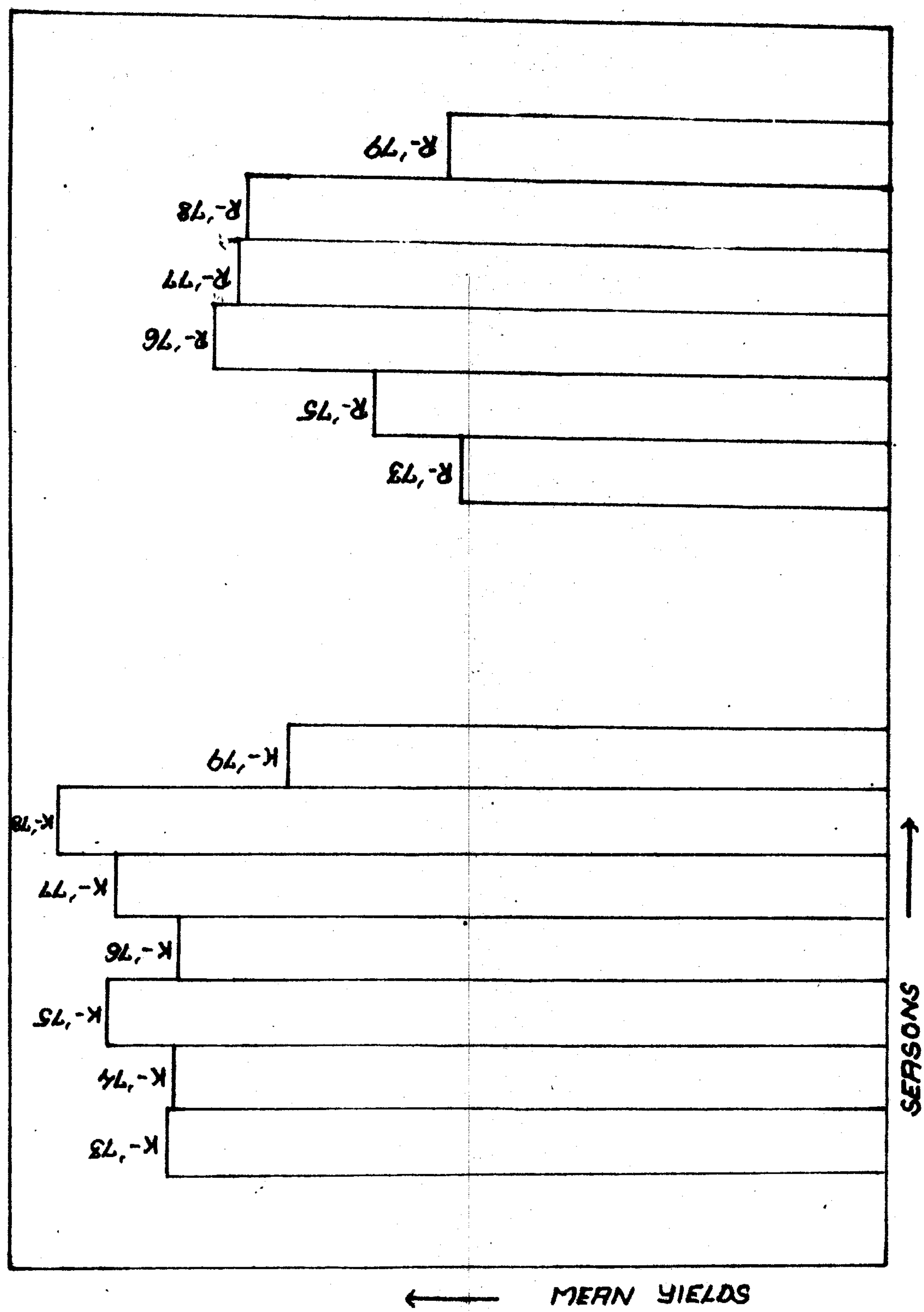
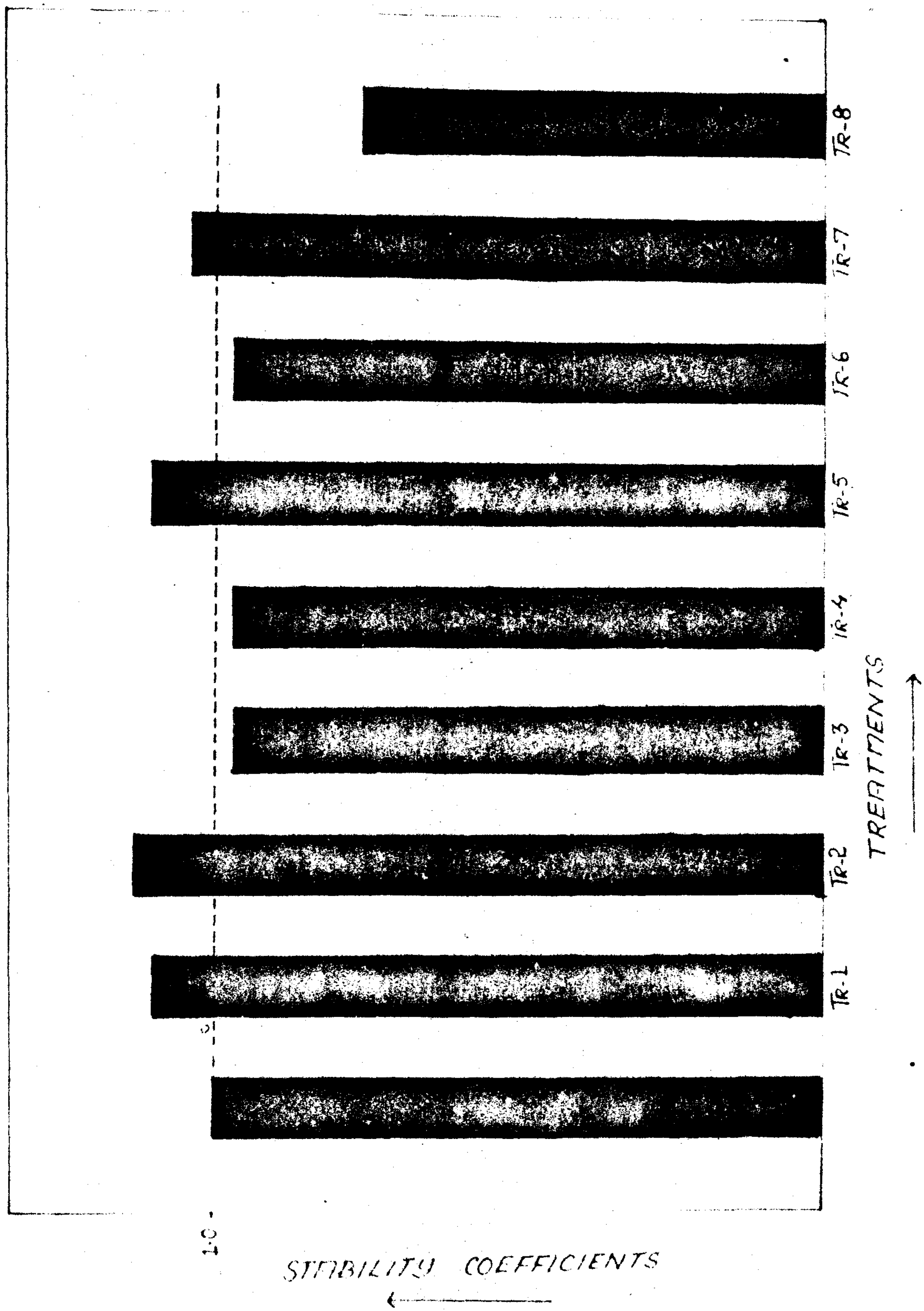


FIG (2): STABILITY COEFFICIENTS OF TREATMENTS



DISCUSSION

DISCUSSION

The treatments were found to be significantly different during *Kharif* 1973. On grouping them into homogeneous subgroups the treatments of 5 and 7 were in one group and the rest in another homogeneous subgroups.

Significant difference was obtained between the treatments during the *Kharif* of 1974. The classification of the treatments into homogeneous sub group revealed that treatments 4 and 8 belonged to the homogeneous subgroups with smaller mean values. All the rest belonged to a homogeneous subgroup with larger means.

In the next *Kharif* also treatments were again significantly different. The means of treatments 2,4 and 8 were smaller than the means of others which belonged to a homogeneous subgroup.

In *rabi* 1975 the treatments were significantly different. The smallest mean was that of treatment 4 and this was significally different from others. The rest of the treatments belonged to two significally different homogeneous subgroups, 1, 2 and 8 in one group and 3,5,6 and 7 in the other.

171487

Significant difference between treatments was observed during rabi 1976 also. There were two distinct homogeneous subgroups. Treatments 2,4,6,7, and 8 formed one homogeneous subgroup of means of smaller value and the other group consisted of 1,3 and 5.

In Kharif 1977 there was significant difference between treatments. They belonged to two distinct homogeneous subgroups, one with the lower mean values consisted of treatments 4 and 8 while the rest formed the other group. This was a repetition of the groups in Kharif 1974.

However in Kharif 1978 treatments differed in their mean values. There were two homogeneous subgroups Treatments 4, 6 and8 were in one group and the rest in the other. The former consisted of means with lower values.

Significant difference was exhibited by the treatments during Kharif 1979. Treatments 2 and 6 belonged to one group and the rest in another homogeneous subgroup.

In rabi 1979 treatments differed in their effect. There were three homogeneous subgroups. Treatments 2 and 4 were in one group. The second consisted of treatments 6, 7 and 8. The last group with the highest means consisted of treatments 1, 3 and 5.

No significant difference was observed between the mean yield of Jaya to the treatment during rabi 1973, kharif 1976, rabi 1977 and rabi 1978.

From the above discussion it is evident that the effect of seasons on the treatments was not uniform. Putting it in the language of design of experiments there was interaction between treatments and seasons.

The analysis of groups of experiments also indicated that there was significant interaction between treatments and seasons.

The stability coefficients of treatments also tell the same story. The treatments 2 and 8 had regression coefficients significantly different from 1. For other treatments they were not significantly different from unity thereby indicating that treatments 1,3,4,5,6 and 7 had average stability overall the seasons. Since treatment 2 had a regression coefficient greater than unity it was adapted only to some seasons, i.e. it gave better yields in some seasons and poorer yield in some other seasons. This was similar to the findings of

Finlay and Wilkinson (1963) in barley varieties. The treatment 8 had coefficient of stability significantly less than 1. Hence it had more than average stability. This was similar to the findings of Raulo and Das (1968) on the effect of farm yard manures on the yield of wheat.

Thus the result obtained by the method of stability coefficients and those obtained by the analysis of groups of experiments are equivalent. Further the method of stability coefficients is easier to apply. Therefore, in all situations requiring the classification of treatments on the basis of interaction with environments the method of stability coefficients may be preferred. This procedure also helps to choose treatments suited to different environments. A treatment with a higher mean yield in an environment and having stability coefficient greater than unity is most suited for that environment. The treatment with stability coefficient less than unity and having higher mean yield is the one suited for all environments.

In the analysis of groups of experiments no significant difference between treatments was observed. Thus the long term effects of the various treatments on the yield of Jaya was the same. This was due to the neutralization of the positive effects with negative effects over the seasons.

The number of wet days did not have significant correlation with the seasonal means of the variety. This is in agreement with the results of Ramiah(1954) for irrigated crops and Ghosh(1970). The total rainfall did not have any significant correlation with seasonal mean yields in both the kharif and rabi seasons. The Jaya variety was, therefore, not influenced by total rainfall under these treatments. This agreed with the observations of Joshi and Kabaria'1972) and Ghosh(1970) but did not agree with Sreedharan(1975)

The mean daily temperature had a significant negative correlation with the seasonal mean yields in the rabi season. This concurred with what is reported by Murata (1964) and Tanaka and Vergara(1967).

The mean daily maximum temperature and the seasonal mean yields were positively correlated in the rabi season. This is in contrast with the findings of Sreedharan(1975).

In the rabi season the mean daily minimum temperature had a significant negative correlation with the seasonal mean yields of the variety. This compares suggested is at least as good as a rainfall index or a P/T index. Further investigation in this respect are, however, warranted.

The weekly rainfalls estimated by the suggested and existing methods were found to be nearly equal for the corresponding weeks.

Pearson's criterion values of the weekly rainfall and its logarithm for corresponding weeks have been found to be equivalent indicating Beta distribution in all cases. This is in variance with the observations of Thomas(1977). The method of fitting Pearsonian curves to rainfall data seems to be the most appropriate one.

The method suggested here as also the method of Surendran <u>et al</u>. (1977) for estimating weekly rainfall with appropriate confidence level assumes that the probability associated with any point of a given interval is the same. In the existing method the observed rainfalls for the weeks are the values determining the intervals whereas in the suggested method logarithms of these values determine the intervals. The assumption of equal probability for any point of a given interval will be more true with the logarithms than with the original values. Hence the suggested method is superior to the well with the observations of Sreedharan (1975).

Significant positive correlation was observed between mean daily humidity and the seasonal mean yields in the *kharif* season. The mean daily maximum humidity did not have any significant correlation with the mean yields of the variety. The mean daily minimum humidity had a significant correlation with the seasonal mean yields in the *rabi* season.

The mean daily wind velocity did not bear any significant correlation with the seasonal mean yields in both the seasons.

Significant positive correlation was found between the seasonal mean yields and hours of sunshine in the *rabi* season. This is in agreement with the report of IRRI(1974).

In general negative though not significant correlation was observed between the indices computed by the suggested as also the usual P/T methods. These two indices are weighted in favour of rainfall and it was observed (Sreedharan 1975), (Ghosh 1970) that rainfall had a negative correlation with yield. Ramiah(1954) did not find any correlation between total rainfall and yield. In the light of these findings the index suggested is at least as good as a rainfall index or a P/T index. Further investigation in this respect are, however, warranted.

The weekly rainfalls estimated by the suggested and existing methods were found to be nearly equal for the corresponding weeks.

Pearson's criterion values of the weekly rainfall and its logarithm for corresponding weeks have been found to be equivalent indicating Beta distribution in all cases. This is in variance with the observations of Thomas(1977). The method of fitting Pearsonian curves to rainfall data seems to be the most appropriate one.

The method suggested here as also the method of Surendran et al. (1977) for estimating weekly rainfall with appropriate confidence level assumes that the probability associated with any point of a given interval is the same. In the existing method the observed rainfalls for the weeks are the values determining the intervals whereas in the suggested method logarithms of these values determine the intervals. The assumption of equal probability for any point of a given interval will be more true with the logarithms than with the original values. Hence the suggested method is superior to the existing one. If the estimates turn out to be almost equal by the two methods as observed here the inference is that the assumption of linearity of the original values is true; ie. the number of years for which the data is available is sufficient to justify the assumption of linearity of the observed values within that interval. This then offers a method for determining the sufficiency of the length of data for estimation. The logarithmic method is more appropriate especially when the number of years for which the data is available is few.

SUMMARY

SUMMARY

Finlay and Wilkinson (1963) initiated a new approach beased on regression for the study of the stability of treatments over seasons or places. To accelerate the linearity of regression the authors had taken logarithms of the observations. In this thesis a new justification has been given for the application of this method for determining stability of the treatments. A treatment has less than average, average or greater than average stability according as the regression coefficient $b \gtreqless 1$.

The above method was used to determine the stability of the 8 treatments of the permanent manurial trials applied to the Jaya variety of paddy in kharif and rabi seasons, from 1973 to 1979 in the Rice Research station, Pattambi.

The mean responses per plot of the variety to the treatments varied considerably. The overall means of the treatments, had a range of 11.61365 kg to 13.73942 kg. The mean responses of the treatments over the kharif varied from 13.47071 kg. to 15.79464 kg. In the rabi seasons the average response was in the range 19.34583 kg to 11.34167 kg.

The mean responses of the variety had a range of 11.91000 kg to 16.42500 kg in the *kharif* and 8.5000 kg to 12.196887 kg in the *rabi*.

The season-wise analysis of the experiments which were in four replicate randomised blocks showed that the treatments were not homogeneous in the various seasons. However the homogeneous subgroups of the treatments differed from season to season. The seasonal effect was thus evident.

The analysis of the groups of experiments showed that there was significant interaction between treatments and seasons. In the regression approach it was found that the regression coefficients of treatments 2 and 8 significantly differed from 1 whereas the remaining 6 treatments had a regression coefficient equal to unity. Since treatment 2 had a regression coefficient greater than unity it was adapted only to some seasons, i.e. it gave better yeilds in some seasons and poorer yields in some other seasons. The treatment 8 had coefficient of stability significantly less than 1. Hence it had more than average stability. Thus the method of analysis of groups of experiments and the regression approach are equivalent. But the latter is easier from the point of view of analysis. The earlier research workers did not undertake a study to compare the two methods and thes gives added importance of the present investigation.

The mean yields of seasons were correlated with the various meteorological factors, viz. mean daily rain-fall, mean daily temperature, mean daily humidity, mean daily maximum temperature, mean daily minimum temperature, mean daily maximum humidity, mean daily minimum humidity, mean daily wind velocity and mean daily hours of sunshine.

In the Kharif season mean daily humidity was significantly correlated with the yield, whereas all other parameters did not have any significant correlation.

In the rabi season mean yield of Jaya had a correlation of -0.57013 with mean daily temperature, 0.91131 with mean daily maximum temperature, -0.6802 with mean daily minimum temperature, -0.5888 with mean daily minimum humidity and 0.88193 with hours of sunshine. All these corelations were significant.

Based on the linear function that accounts for the maximum variation in the dispersion matrix of the variables, a weather index taking into account the rainfall and temperature was suggested. This index and the index P/T have been computed for the periods July 1 to October 15 and October 1 to January 15. The suggested index has been found to be at least as good as the rainfall index.

Weather indices based on the actual duration of the crop were also computed from 1978 to 1979 when the exact dates of sowing and harvesting were available.

The seasonal mean of treatments when correlated with the indices for the kharif and rabi seasons exhibited negative correlations in general. They were not however, significant.

The number of wet days for the seasons did not have any significant correlation with the seasonal mean yields of treatments and hence with the mean yield of the variety.

The multiple correlation of the treatment means over rainfall and temperature during the period of the crop were also computed, but none of them were found to be significant.

For estimating the weekly rainfall of a place an improvement over the method suggested by Surendran *et al*.(1977) was made. The logarithms of observations were considered for the linear interpolation of weekly observations. Weekly amounts of rainfall were estimated at confidence levels 90%, 80%, 50% and 10%. The confidences levels were computed by Hazen's as also by California method.

In general, the estimated amounts of rainfall for corresponding periods did not differ much by the two methods. This has given a procedure for determining the adequacy of the data. If the number of years for which data are available is small the logarithmic method suggested is better than a method due to Surendran *et al*.(1977).

For determining the nature of the distribution of weekly rainfall the criterion K developed by Karl Pearson was computed. The K values showed that the rainfall in all the weeks followed Type I beta distributions. The Pearsonian fit may prove to be highly efficient and accurate as compared to other methods.

REFERENCES

REFERENCES

Bhargava, P.N., Aneja, K.G. and Ghai, R.R.(1978). Influence of moist days on crop production. *J. Indian Soc. agric. Statist.* **30** (2):111-118.

Bhargava, P.N., Narain, P., Aneja, K.G. and Pradhan, A. 1973. A study of the occurance of rainfall in Raipur district with the help of Markov Chain Model. *J. Indian Soc. agric. Statist.* **25** (2): 197-204.

Chatterjee, B.N. and Maiti, S(1979). Climate and soil where rice grows; *Rice production Technology Manual* ; Oxford and IBH publishing company, Bombay: 1 - 5.

Cochran, W.G. and Cox, G.M.(1957). *Experimental designs* Second edition. John Wiley & Sons, Inc., New York.

*Cummings, Jr., Ralph, W. and Ray, S.K.(1969). 1968-69 Food grain production; Relative contribution of weather and new Technology EPW, *Review of Agriculture*, September.

*Dey, A.K.(1975). Rates of growth in agriculture and industry, EPW, June 28.

Dubey, J.P.(1970). Weather indexes. A review of methods of constructing indexes of the effect of weather on crops. *J. Indian Soc. agric.Statist* **22** (2): 103-106.

*Eberhart, S.A. and Russel, W.A.(1966). Stability parameters for comparing varieties. Crop Science 6 (1): 336-340.

Finlay, K.W. and Wilkinson, G.N.(1963). The analysis of adaptation in a plant breeding programme. Aust. Jour. Agril. Res. 14: 742-754.

Grist, D.H.(1975) Rice. Tropical Agricultural Series. Fifth Edition, Longman group Ltd.:12-15.

*Gosh, A.K. (1970). Effect of climatic factors in the growth and production of rice, 13th session. Working party on rice production and protection. International Rice Commission working party. Teheran, Iran.

*IRRI (1974). International Rice Research Institute, Manila, Philippines. 1972.Annual Report, 48-63.

Joshi, S.N. and Kabaria, M.M.(1972). Effect of rainfall distribution on yield of groundnut. Indian J.agric. Sci. 42(8) : 681 - 684.

*Kalamkar, R.J. and Satakopan, J.V.(1940). The influence of rainfall distribution on cotton yields at Government farms at Akola and Jalgoan. Indian J. agric. Sci. 10 (4-6):960-967.

Kendall, M.G. and Stuart, A.(1969). The Advanced Theory of Statistics Vol.I, 3rd Ed. Buther and Tanner Ltd., London: 148-179.

Krishnan, A. and Kushwaha, R.S.(1973). Probability of the periods of rainfall deficency in the arid and semi arid zones of Rajasthan. Indian J. agric Sci. 43 (7): 696-700.

Louis, M.B. (1970). Symmetry in weather crop statistics. J. Indian Soc. agric. Statist. 22 (2): 99-101.

*Murata, Y (1964). On the influence of solar radiation and air temperature upon the local differences in the production of paddy rice in Japan. Proc. Crop Sci. Soc. Japan 33: 59-63.

*Murata, Y and Togari, Y (1972). Analysis of the effect of Climatic factors upon the production of rice in different localities. Proc. Crop Sci. Soc. Japan, 41 : 372 - 387.

National Commission on Agriculture (1976). Report of the National Commission on Agriculture, Part IV Climate and Agriculture. Govt. of India, Ministry of Agriculture and Irrigation, New Delhi. The Controller of publications, Delhi.

Panse, V.G. and Sukhatme, P.V. (1957). Statistical methods for agricultural workers. 2nd ed. Indian Council of Agricultural Research, New Delhi.

Pillai, P.B. (1980). Effect of weather parameters on the grain yield of paddy at Pattambi. National Seminar on Agroclimatology, Dept. of Agronomy TNAU, 68-69.

Patro, T.G., Srivastava, K.L. and Mirsa, C.C. (1975).

Probability analysis at Bhuvaneshwar J.Res.26(2):

*Quareshi, M.R.H. and Husani, S.H.(1955). The correlation of rainfall conditions with the yields of rabi cotton at Raichur. Indian cott. Grow. Rev. 9 (2) : 112 - 117.

*Ramdas, L.A.(1957). Evaporation and potential evapotranspiration over the Indian Sub-continent. Ind. Jour. Agri. Science 26 (2): 131-139.

*Ramaiah, K(1954). Factors affecting rice production. FAO Agric. Development paper 45 Rome:45.

*Ranga Rao, D.S. and Pandit Rao, V.M.(1959). A statistical study of the rainfall data at the four district headquarter stations of the former Bombay State during the period from 1932-32 to 1955-54. Indian J agric Econ. 14 (1): 49-64.

Rao, C.R.(1958). Statistical methods for the comparison of growth curves, Biometrics. 14(1):1-17.

Raulo, S. and Das. M.N.(1978). An alternative approach for interpretation of data collected from groups of experiments. J. Indian Soci. agric. statist. 30(2): 99-107.

*Reddy, V.N.(1978). Growth rates EPW. May 13.

Sahu, B.N.(1969) Performance of dwarf indica and ponlai rice varieties in the rainy and dry seasons at Bhubaneswar. Indian J. agric. Sci. 39 (9):940:954.

Saxena, H.C. and Suredran P.U. (1973). Statistical Inference Second Edition. S.Chand and Co. (P) Ltd., New Delhi.

Sen, P.K. and Dasgupta, D.K. (1970). Studies in water relations of rice. Indian J. agric Sci. 40 (8): 741-745.

Sharma, J.S. (1970). Crop-weather relationship-Areas of study. J. Indian Soc. agric. statist. 22(2): 93-98.

Singh, A. and Pavate, M.V. (1968). Use of rainfall Probabilities in agricultural planning. Indian J. agric. Sci. 38(8): 634-643

Singh, C., Seshagiri, A and Capai, Y.S. (1970). Yield of cotton in relation to the rainfall in Madhya Pradesh. Indian J. agric. sci. 40(8): 678-684.

Sreedharan, C. (1975). Influence of climato-logical factors on growth and yield of rice. Thesis submitted to the OVAT for the award of Ph.D deges.

Sreenivasan, P.S., Naqvi, Q.A. and Banerji J.R. (1970). Crop weather relationship studies. J. Indian Soc. agric. Statist. 22 (2): 101-102.

Sreenivasan, P.S. (1973). Influence of rainfall on yield of cotton in Madhya Pradesh. Indian J. agric. Sci. 43(9) : 854-859.

Sreenivasan, P.S.(1974). Agroclimatology of rice in India cited by Sreedharan (1975).

Stansel, J.W.(1967). Rice grain yields and stages of plant growth as influenced by weather condition. Texas Agr. Exp. Station Progress Report P.R.: 2462.

Surendran. P.U., Sunny, K.L. and Prabhakaran, P.V. (1977). Influence of moist days on crop production. J. Indian. Soc. agric. Statist. 30(2) : 111-118.

*Thornthwaite, C.W.(1948). Geographical Review p 65.

Thomas, E.J.(1977). Prediction of rainfall at Pattambi. Agric. Res. J. Kerala. 15 (2) : 108-111.

*Tullis, F.C. et al. (1934). Panicles of Rexora rice injured at emergence by sun scald. Phytopath. 24: 1043-1044-

*Tanaka, A., Navasero, S.A., Gracia, C.V., Pavaro,F.T. and Ramirez, E (1964). Growth habit of rice plant in the trops and its effect on nitrogen response. The International Rice Research Institute, Los Banos, Laguna, Philippines, Tech.Bull. 3 : 80.

*Tanaka, A. and Vergara, B.S.(1967). Growth habit and ripening of rice plant in relation to environmental conditions in the far east. Int. Rice Commn. Newsl. 26 : 42

Vaidyanathan, A.(1980). On analysis of agricultural growth. J. Indian.Soci.Agric. Statist. 32 (1) : 1 - 24.

*Yamagupta, M.(1958). Studies on the limit of posibility of the increase in number of leaves and grains of the main stem of rice IV. Influence of sunlight intensity. Bull. Fac. Agric. Yamaguti 9 : 1001 - 1010.

*Originals not consulted.

WEATHER PADDY CROP RELATIONSHIP

BY

S. KRISHNAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science (Agricultural Statistics)

Faculty of Agriculture

Kerala Agricultural University

Department of Statistics

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

Mannuthy - Trichur

1981

ABSTRACT

An effective regression method for the examination of the stability of the treatments in repeated experiments was introduced by Finlay and Wilkinson (1963). A new justification for the employment of this method was evolved and this does not require the logarithmic transformation of the data to induce linearity of regression. A treatment has greater than average, average or less than average stability according as the regression coefficient $b \lesseqgtr 1$.

The data from permanent manurial trials conducted at Rice Research Station, Pattambi from 1973 to 1979 were used to show that the method of regression coefficients to study stability and the method of analysis of groups of experiments are equivalent. This was the first attempt in that direction.

Method of analysis of principal components was used to suggest a new weather index based on rainfall and temperature which are considered to be important weather para meters.

The number of wet days did not have any significant correlation with the mean yields of treatments.

In the *kharif* season mean daily humidity was significantly correlated with the yield, whereas all other parameters such as mean daily rainfall, mean daily temperature, mean daily maximum temperature, mean daily minimum temperature, mean daily maximum humidity, m an daily wind velocity and mean daily hours of sunshine did not have any significant correlation.

In the *rabi* season mean yield of Jaya had a correlation of -0.57013 with the mean daily temperature, 0.91131 with mean daily maximum temperature, -0.6802 with mean daily minimum temperature, -0.5888 with mean daily minimum humidity and 0.88193 with hours of sunshine.

A modified procedure was suggested to estimate the weekly rainfall of a place. This was obtained by applying the method of Surendran *et al.* (1977) to logarithms instead of the weekly annual rainfalls. Incidentally it gave a method for suggesting the adequacy of the length of the date for estimation.

Theoretical distributions of the weekly

rainfall at Pattambi were indicated. All of them were found to obey beta distribution.