INFLUENCE OF WEATHER PARAMETERS ON GROWTH AND YIELD OF RICE VARIETY - JAYA

BY

P. SREELATHA

THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
VELLANIKKARA—TRICHUR
KERALA—INDIA
1989

ACKNOWLEDGEMENT

I wish to place on record my extreme gratitude to **Dr. P. Balakrishna Pillai**, Professor and Head, Department of Agrl. Meteorology and Chairman of my Advisory Committe for his expert guidance, technical advice and encouragement throughout the course of investigation.

I have no words to express my deep sense of gratitude and indebtedness to **Dr. A.V.R. Kesava Rao**, whose inspiring guidance, sustained interest, constructive criticisms, critical suggestions, constant encouragement and timely help made it possible for me to complete this dissertation in time.

My sincere thanks are due to **Sri V.K.G. Unnithan**, Associate Professor of Statistics for all the valuable assistance and suggestions rendered by him.

I am obliged to **Dr. Pushpangathan**, Professor, Instructional Farm, Vellanikkara for his valuable suggestions as a member of the Advisory Committee.

I owe my gratitude to **Dr. C. Sreedharan**, former Associate Dean (i/c) of College of Horticulture and **Dr. C.C. Abraham**, Associate Dean, College of Horticulture, Vellanikkara for providing the necessary facilities to carry out the study.

I am deeply indebted to **Mrs. Sailaja Sasidharan** and **Mr. Sethu Madhavan**, Department of Agricultural Meteorology for extending all possible help and co-operations during the course of this investigation.

I would like to acknowledge the very great help I received from the staff of Department of Agronomy, College of Horticulture, Vellanikkara and Agricultural Research Station, Mannuthy, in the proper conduct of research work.

I wish to place on record my heartfelt gratitude to all my friends and colleagues for their valuable help. My special thanks to **Miss Jessy M.D.** whose constant support has helped me to complete this venture, successfully.

The help offered by the staff of Computer Centre, Kerala Agricultural University for the statistical analysis of the data is also acknowledged.

A word of thanks to ***Sri Joy*** *and* ***'Alex Executive Centre'****, Naduvilal, Trichur, for the neat typing and prompt service.*

The award of K.A.U. Merit Scholarship is gratefully acknowledged.

Finally, I express my heartfelt gratitude to my ***husband, parents, brother*** *and* ***sisters*** *for the constant encouragement, support and affection rendered by them at all stages of investigation, otherwise which, this venture would have remained a dream.*

Vellanikkara,
1 -12-1989.

Sreelatha P.

DECLARATION

I hereby declare that this thesis entitled **Influence of weather parameters on growth and yield of rice variety Jaya** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

College of Horticulture,
Vellanikkara,
1-12-1989.

Sreelatha P.

CERTIFICATE

Certified that this thesis entitled **Influence of weather parameters on growth and yield of rice variety Jaya** is a record of research work done independently by **Smt. P. Sreelatha**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. P. Balakrishna Pillai,
Chairman,
Advisory Committee,
Professor and Head
(Agrl. Meteorology)

Vellanikkara,
1-12-1989.

CERTIFICATE

We, the undersigned, members of Advisory Committee of **Smt. P. Sreelatha**, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled **Influence of weather parameters on growth and yield of rice variety Jaya** may be submitted by **Smt. P. Sreelatha**, in partial fulfilment of the requirement for the degree.

Chairman : **Dr. P. Balakrishna Pillai,**
Professor and Head,
Department of Agrl. Meteorology,
College of Horticulture,
Vellanikkara.

Members : (1) **Prof. V.K.G. Unnithan,**
Dept. of Agricultural Statistics,
College of Horticulture,
Vellanikkara.

(2) **Dr. Pushpangathan,**
Professor,
Instructional Farm,
Vellanikkara.

(3) **Dr. A.V.R. Keshava Rao,**
Asst. Professor,
Dept. of Agricultural
Meteorology,
College of Horticulture,
Vellanikkara.

Mrs. Graceamma Kurien,
Asst. Professor,
Dept. of Agricultural
- Statistics,
College of Horticulture,
Vellanikkara.

H.S. Ram Mohan 20/12/88
(Dr. H.S. Ram Mohan)
External Examiner

CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Rice is the principal food crop of India and it occupies the largest area among food crops. However, the yield per hectare is significantly lower to that of some of the temperate countries like China, Japan and Korea. Thus any improvement in increasing the rice production would go a long way in meeting the country's food problems. The difference in the yield may be mainly due to the prevailing climatic conditions in the monsoon season, during which about 60 - 70 per cent of the total rice is grown. Solar radiation is a limiting factor in the monsoon season and Best (1962) reported that the average solar radiation available during the season in the tropics is only two-thirds of that available in a temperate rice growing area.

In Kerala, the rice crop occupies about 87 percent of the total cultivated area and contributes about 98 percent to the total production of food grains. The average rice yield in the State is only 1.88 tonnes ha^{-1} which clearly points out to the wide yield gap and the immediate task to bridge this gap. The scope of extending the area under rice in the State is very much limited. Therefore, the only scope for increased production is to resort to intensive cultivation for higher productivity.

Though, photoperiod insensitive rice varieties can be grown throughout the year irrespective of the season, their growth and yield vary largely depending upon the various weather factors like rainfall, temperature, solar radiation and relative humidity that prevail during the growing season. Maximum yield is possible only when the crop experiences a suitable combination of these factors in the optimum range. Hence, the time of planting and the prevailing weather conditions play a major role in the final yield of rice. A slight change in planting time, sometimes, may substantially increase the yield of rice. In this respect, no detailed studies have been conducted on rice variety Jaya under Kerala conditions.

Crop yield increases with increase in number of plants per unit area until light penetration in the thick crop canopy does not become a limiting factor and competition among the crop plants for nutrients is not there. Experiments conducted at I.R.R.I. have shown that each variety of rice has an optimum spacing and that closer spacing is more conducive to obtain better yields especially for high yielding strains (Tanaka et al., 1966). Experimental evidence in this respect for the rice variety Jaya is inadequate.

Hence, the present investigation was carried out with the following objectives :

(1) To study the influence of various weather parameters on growth and yield of rice variety Jaya.

(2) To study the influence of time of planting on growth and yield of rice variety Jaya.

(3) To evaluate the performance of rice variety Jaya under two spacings.

(4) To prepare crop weather diagram of rice variety Jaya.

(5) To find out insect-pest, disease outbreaks and soil nematodes in relation to weather parameters.

Review of Literature

REVIEW OF LITERATURE

The present study was carried out to evaluate the influence of various weather parameters and time of planting on the growth and yield of rice variety Jaya and to evaluate the performance of rice variety Jaya under two spacings. The experiment was also conducted to study the insect pest/disease outbreaks and soil nematodes in relation to weather.

Environment is responsible for most of the variations in crop production. Stabilization of crop yield at a high level of productivity becomes feasible only when the interactions between crop and weather are fully understood. Thus the improved knowledge and understanding of the environment in which rice is grown, will help to fully exploit the weather in relation to production. This experiment is thus, aimed at studying the effect of various weather parameters on the yield and yield attributes and also on various growth characters of rice. It was also carried out to record the incidence of pests and diseases in relation to weather. Several researchers have made studies earlier on these above aspects and a brief review of the important works is summarised below:

2.1 Weather and rice

The weather conditions during the crop growth period greatly decide the crop's response to added inputs (Tanaka _et al._, 1964, Mahapatra and Badekar, 1969). To delineate the effects of environment on rice production, a thorough understanding of both the weather and climate is essential. A review of literature on the influence of various weather parameters on rice at various growth stages is given below.

2.1.1 Vegetative stage

2.1.1.1 Temperature

Among the various weather factors that affect the growth and yield of rice, air temperature plays an important part. Each development stage and growth process responds differently to the same temperature conditions (Izhizuka *et al*., 1973).

Low temr

slows down the rate of germination and root development. High temperature during the vagetative stage increase the tiller number and retards the rate of development.

For rice, unlike the other crops, both water temperature and air temperature are important. At germinating and seedling stages, water temperature is more influential than air temperature. And at later stages, both the day time and night time temperatures are important. For upland rice, the optimum temperature for germination is 30°c (Hall, 1966 a) while the lower limit is 20°c (Downey and wells, 1974 a). Dedatta (1970) attributed low average yield in the tropics to warm climate during early growth periods. Sreedharan (1975) reported that a minimum air temperature of 25-26°c is ideal for shoot and root growth. The optimum temperatures for elongation and leaf emergence are 25°c and 30°c respectively (Robertson, 1975). Kang and Heu (1976) also observed that lower temperature during nursery period of rice resulted in higher plant height.

Sato (1972) reported that the drymatter production is favourably influenced by day-night temperature regime of 25°c -20°c for IR8 rice and the leaf area per plant is high at 30°c - 25°c . Kim et al., (1973) reported an increase in height and dry weight of plants at 20°c. The average internodal length is strongly influenced by temperature and is correlated to temperature accumulation between 21°c and 31°c (Downey and wells, 1974 b.) Lin (1976) reported that high temperatures led to increased production of ineffective tillers and also resulted in dwarf plants with small leaves. Increase in tiller production and number of panicles are also reported at 25°c - 20°c day-night temperatures respectively (Wan, 1979). Suzuki (1983) reported a significant positive correlation between the mean temperature and cumulative growth rate (C.G.R) at the initial growth stage. However, with the advancement of growth, the correlation is lowered and it turned to significantly negative for the period from 3 to 6 weeks after heading.

The plant height at harvest is positively correlated to minimum temperature at vegetative phase. The mean minimum temperature 7 to 10 days prior to heading is critical for yield and should be about 19°c to 21°c (Gopalakrishna Pillai, 1974).

Soil and water temperature

As there is always standing water in the rice field from seedling stage onwards, the water temperature in the field acts more effectively on growth of rice than air temperature. The growing point of rice plant is under water until two weeks before heading and differentiation of all vegetative organs and even the early growth of reproductive organs occur in water. According to Adiar et al., (1962) irrigation water temperature should be between 21°C and 31°C. Matsushmia et al., (1964) reported that the duration of vegetative phase is more correlated to soil-water-interface temperature than the minimum air temperature during this phase. Sreedharan (1975) also reported similar results. Dry weight and nutrient uptake of plants are affected more by temperature of growing medium than air temperature (Chae et al., 1980). Bonneau (1982) reported that daily mean water temperature in flooded soil is 2°C more than aerial temperature. Singh et al. (1984) observed an increase in water temperature of 2-3°C in continuous flow submergence which contributed to increased tillering, panicle size and grain number.

Growth and development of root system is also considerably affected by soil and water temperatures. Luxmoore et al. (1970) suggested that under submerged conditions, soil temperature regime is most likely to be the dominant edaphic factor influencing the root growth. Increased degeneration of roots due to variation in temperature regime from 27 - 15°C to 37 - 25°C is reported by Kar et al. (1976).

Tillering is also affected by water temperature. The number of emerging tillers is highest when water temperature is 15 - 16°C at night and the optimum day temperature for tiller development is 31°C (Matsushima et al., 1964). The results of study by Chaudhari and Ghildyal(1970) showed that tiller development is greatly accelerated at 32°/20°C day/night temperatures. A deviation of 5°C to the lower side of 32°C/20°C, more adversely affect the tiller development than a similar deviation to the higher side.

Chatterjee et al. (1969) observed that tillering period lasted only for 40 to 45 days in rainy season as against 50 to 55 days in dry cool season. Analysis of temperature components showed that minimum air temperature has the best negative correlation with growth duration (Vergara et al.(1970). Growth duration is considerably important especially when associated with sowing time. This attains more practical importance where multiple cropping with short duration varieties are to be taken. The duration of growth of rice cultivar determines its specific adaptability to regular crop season in a given location (Chang and Vergara,1971). Biswas et al.(1975) noticed that exposure to low temperature during active vegetative period can extend the time of flowering. The sowing to heading period of rice varies greatly and it is the dominant factor in determining the overall length of growing period (Vergara and Chang, 1976 ; Gao and Zhang, 1977). Kang and Heu (1976) and Chaudhary and Sodhi (1979) reported extended vegetative growth due to low temperature. Temperature regime greatly affects the duration of rice growth (Vergara, 1976; DeDatta, 1981; Gao and Zhang, 1977; Yoshida, 1981). Thermosensitivity is one of the most important varietal characteristics which determine duration of rice growth(Co-ordinating Group of Rice Ecological Researches, 1978).

2.1.1.2 Rainfall

Variability of rainfall affects the rice crop at different stages. If the variability is associated with the onset of rain, stand estblishment and the growth duration of rice are affected. Chandler (1963) observed that many rice varieties respond better to nitrogen in dry season than in wet season. Chatterjee (1970) has made observations on tillering in a number of varieties of rice and found that in rainy season, tillering is continued upto 42-45 days, whereas in dry season it is 50-55 days.

2.1.1.3 Solar radiation

Several reports on the relationship between rice yield with environmental factors, particularly radiation are available (Matsushima, 1970; Murata and Togari, 1973; Yoshida, 1972). Radiation has been reported to influence tillering during vegetative phase and fertiliser response during flowering. The solar radiation requirement of rice crop differ from one stage to another. Low light intensity during the vegetative phase slightly affects the yield and yield components (Yoshida, 1972; Yoshida and Parao, 1976). Sreenivasan and Banerjee (1978) reported that at Aduthurai, sunshine during flowering is highly favourable for enhanced production, whereas, at Coimbatore sunshine in the week prior to transplanting and the two weeks period coinciding with the grand period of elongation are not condusive for better yield. Sreedharan and Vamadevan (1981) reported that LAI reduced to a great extent in plants shaded either from planting to panicle initiation or from flowering to harvest. Shading also causes death of many lower leaves. Upendra Shanker and Gupta (1981) reported a significant positive correlation between height of two varieties of paddy and the duration of sunshine. Ghildyal and Kushevala (1987) made a detailed comparison of rice variety M_3 with the variety Jaya and observed that at both maximum tillering and flowering stages, absorpt of radiation was more in Jaya due to larger leaf area and higher number of tillers per plant. They also found that during maximum tillering stage, net radiation (7 to 8 A.M. period) in Jaya was approximately double than in M_3 but those differences narrowed (30%) during the peak radiation level period (11 A.M. to 12 Noon). This shows that Jaya was a better sink of radiation than M_3 , indicating that much of the radiant energy was used for photosynthesis and other losses.

It appears that temperature in combination with light intensity becomes an important factor for rice growth. Light intensity influences photosynthesis, whereas temperature affects respiration and transpiration. A combination of low daily mean temperature and high light intensity gives a high yield. Venkateswarlu et al. (1977) observed that tillering and panicle number are a function of the environment dominated by light and temperature (in the range of 20 to 30°C).

2.1.1.4 Relative humidity

Rice crop requires a fairly high degree of humidity for proper growth (Ghosh, 1961). Ou (1973) reported that high humid weather during periods of congenial temperature when followed by bright weather, trigger many diseases. Sreedharan (1975) reported that a RH of 80-85% is ideal for shoot and root growth.

2.1.1.5 Wind

A light wind is said to be beneficial as it stirs the air and transports CO_2 to the canopy (Matsubayashi et al.,1963). According to Robertson (1975) wind is an important factor in rice production. Transpiration rates increase under high wind conditions. Suge and Takairin (1982) reported that wind increased ethyline production and ethane production in rice and decreased GA content of roots and shoots.

2.1.2 Reproductive stage

2.1.2.1 Temperature

Yield reduction in rice due to low temperature was recorded in North India due to cold injury. Due to cold weather, significant yield reduction (20-40%) was noticed on account of high spikelet sterility during the rabi season. High pollen sterility caused by prevalence of cold weather during the flowering period resulted in high chaff percentage as reported by Hayase (1969). The most comprehensive work on the effect of cold injury to rice crop has been done in Japan where low temperature is the main limiting factor in rice production. Nishiyama et al., (1969) showed that the critical low temperature for inducing sterility is 15°C - 17°C in highly cold tolerant varieties at meiotic stage of crop growth. Their studies suggested that the critical temperature for sterility is about 15°C - 20°C. Satake and Hayase (1970) found that the stage most sensitive to coolness is the young microspore stage after meiotic division at anthesis. Varietal difference in the chaff percentage under low temperature conditions was reported by Kando (1975). The sterility is primarily due to injuries occuring in anthesis (Satake, 1976).

Sato (1967) reported a high percentage of sterility and empty spikelets in rice crop in Oasis areas of Egypt. Satake and Yoshida (1978) reported that high temperature induces sterility in rice, and heading time is the most sensitive stage to high temperatures. For spikelet fertility, high temperature is the second detrimental factor before anthesis but it is the most detrimental factor during anthesis. It has got little effect after anthesis on spikelet fertility. Panicle development and pollen germination are inhibited by high temperatures. IRRI (1980) reported that at the reduction division stage of rice, two kinds of low temperature injury occuring are, degeneration of spikelets and spikelet sterility. High temperature is a critical factor in rice grain production.

A significant negative correlation between yield and the minimum temperature 30 days after transplanting and a significant correlation between yield and maximum temperature over the 45 days before maturity are reported by Datta and Zarate (1970). Osada <u>et al.</u> (1973) noticed that low temperature during maximum tillering stage produced more panicles. During reproductive stage, within a temperature range of 22 to 31°C, spikelet number per plant increases as the temperature drops (Yoshida, 1973). He also suggested that the optimum temperature for rice shifts from high to low as the growth advances from vegetative to reproductive stages. The rice plant is very sensitive to low temperature about 9 days before flowering (Satake, 1976) and high temperature at flowering (Satake and Yoshida, 1978).

The results of an experiment conducted for 12 years at Pantnagar, U.P., showed that higher maximum and minimum temperatures during tillering, ear initiation and maturity depress the yield of rice (Huda et al., 1975). From the studies conducted under All India Co-ordinated Crop-weather Scheme, Sreenivasan (1979) observed that at Aduthurai, the favourable maximum temperature period is from 10-16 weeks after sowing. Whereas, at Coimbatore the favourable maximum temperature period is the tillering phase and the minimum temperature period is five weeks commencing with flowering. Influence of temperature on sterility is reported by Chaudhary and Sodhi(1979). In the flowering period the sterility is minimum (12-18 per cent) when the mean temperature is 27 -28°C. Whereas, it is maximum (36 per cent) when the mean temperature is above 36°C.

Vergara et al. (1970) reported that minimum temperature rather than mean temperature has the best negative correlation with flowering duration of a variety. Yoshida (1981) observed a 13 day delay in flowering for each degree drop in temperature between 24°C and 21°C in IR 26. Sahu et al., (1983) reported that the average flowering duration ranged from 58 to 91 days in August and December plantings respectively at CRRI, Cuttack. The duration upto 50 per cent flowering was negatively correlated with minimum temperature (Krishnakumar, 1986).

2.1.2.2 Rainfall

Variability of rainfall affects the rice crop greatly at the reproductive stage. If the variability is associated with an untimely cessation at the reproductive or ripening stage, yield reduction is severe. Rainfall variability is more critical for upland rice than for lowland rice. Venkateswarlu et al., (1976) reported high panicle number in rabi(500) compared to kharif(400) season, thus being responsible for high yields in the former. Moraes(1978) reported that the drought of 5 to 20 days duration occuring in Cerrado adversely affects the upland rice and often causes severe damage at the reproductive and ripening stages.

2.1.2.3 Solar Radiation

Solar energy is the major governing factor for photosynthesis and hence drymatter production and yields are dependent on solar radiation to a considerable extent. The low light intensity upto flowering in kharif, imposes a cealing on tillering and reduces drymatter production as compared to rabi season. (Venkateswarlu, 1977; Venkateswarlu et al., 1977).

Several workers pointed out the positive influence of solar radiation received during different critical growth stages on grain yield. Stansel (1966), and Murata and Togari (1973)reported it to be the three weeks before and after flowering. Ghildyal and Jana(1967);and DeDatta and Zarate(1970)reported it to be the one week before harvest and according to Matsushima(1970), it is fifteen days before and twenty five days after flowering. Evans (1972) reported that grain filling was very poor in the absence of light. Low light intensity during the reproductive phase has a pronounced effect on spikelet number and, hence, on yield.

Influence of light on panicle production and grain filling are reported by Yoshida (1972), Osada _et al._ (1973) and Venkateswarlu _et al._ (1977). Wada _et al._ (1973) and Yoshida and Parao (1976) reported that solar radiation and temperature during the reproductive stage (before flowering) have the greatest influence on rice yield because they determine the number of spikelets per square metre. Field studies at IRRI, Los Banos, revealed a high positive correlation of grain number per square metre with solar radiation during twenty five days before flowering (IRRI, 1974).

From his studies in Texas, Stansel (1975) found the most critical sunlight requiring period to be the forty two days centered around the heading stage. During this period a mean yield reduction of 6.5 per cent is observed for every one per-cent reduction in solar radiation. It is reported that low light intensity reduced leaf area development and photosynthetic efficiency of rice crop canopy (Venkateswarlu, 1977). Under low light intensity, translocation of photosynthates to panicles is reduced (Nayak _et al._, 1979; Fagi and De Datta, 1981; Sreedharan and Vamadevan, 1981). Evans and De Datta (1979) noticed the significance of irradiance to grain yield during reproductive stage (30 days before flowering) as well as ripening stage (30 days after flowering). Vijayalakshmi _et al._ (1987) reported that the productivity of October sown rice crop is relatively low (around 1.2 t ha^{-1}) as compared to that of January sown rabi crop. The major constraint for this low productivity is insufficient solar irradiance during kharif.

Day length or photoperiod:

Rice is generally a short-day plant and sensitive to photoperiod. The observations of Venkataraman and Narasimhamoorthy (1973) showed that the variation of only 30 minutes in photoperiod can significantly affect crop development. The long days can prevent or considerably delay flowering (Vergara and Chang, 1976). The photoperiod insensitive rice varieties enable the farmers in the tropics and subtropics, to plant rice at any time of the year without great changes in duration.

2.1.2.4 Relative humidity

Flowering of rice does not occur below 40% RH and is best at 70-80% RH. High humidity during post flowering stage appeared to have a detrimental effect on yield (CRRI, 1967).

2.1.2.5 Wind

Strong winds occuring after heading cause severe lodging and shattering in some rice varieties (De Datta and Zarate, 1970). Strong winds also enhance the spread of bacterial diseases of rice. It reduces boundary layer resistance and increases the photosynthetic efficiency as reported by Viswambharan _et al._ (1989). They also reported that during flowering, excessive wind velocity caused pollen dehydration and consequent spikelet sterility.

2.1.3 Ripening stage

2.1.3.1 Temperature

In general, grain yields are higher when temperature during ripening stage is relatively low, an effect attributed to a more favourable balance between photosynthesis and respiration. Temperature appears to influence the ripening of rice in two ways-first, low temperature favours an increase in weight per grain (Murata, 1964, Nagato et al., 1966) and second, low daily mean temperature increases the length of ripening period. In tropics, where the daily mean temperature ranges from 23 -30°C, duration of ripening becomes about 30 days after the beginning of panicle emergence (Yoshida and Hara, 1977). Yamakava (1962) and Krishnakumar (1986) reported that ripening period is negatively correlated with minimum temperature of that period. Thus, persistent cloudy weather conditions will be more detrimental to grain filling under high temperature because of a shorter ripening period. During ripening, high temperature produces an undesirably chalky appearance in rice kernel and increases the bran thickness.

Higher grain yield in temperate countries than in tropical countries could have generally been attributed to the lower temperature during ripening, which extends the ripening period, so more time for grain filling. Chaudhary and Ghildyal(1970) reported the beneficial effect of the temperature regime 32 /20°C on yield characteristics such as number of spikelets per panicle, minimum sterility, hundred grain weight and grainyield. At low temperature, translocation of photosynthates to grain takes place at a slower rate and thus maturity period gets delayed (Boerma, et al.,1974). In an experiment conducted at IRRI,Los Banos, it is observed that a temperature range of 15-23°C appears to be optimum for normal grain growth in all the rice varieties tested. Below and above this optimum temperature range, grain weight lowered in all varieties(IRRI,1980).Seshu and Cady(1984) tried to predict the yield based on solar radiation and minimum temperature during ripening stage of 30 days after flowering. The predicted yield decreased by 0.075 tha^{-1} for each degree increase in minimum temperature. Low solar energy and high temperature are detrimental to high harvest index (HI). Yield attributes like filled grain percentage, panicle weight and degree of ripening are negatively correlated with minimum temperature during reproductive and ripening stages (Krishnakumar, 1986).

Bhattachary and De Datta (1971) observed that low soil temperature caused the death of lower leaves and chlorosis of upper leaves and retarded drymatter production. However, plant growth and grain yield are least affected by low soil and water temperatures during the period from heading to maturity. The temperature of irrigation water has got a profound influence on duration. When the temperature of water is 18°C or less, a delay in ripening of 7-10 days is noticed (ICID, 1974).

2.1.3.2 Rainfall

Sahu and Murty (1976) reported that drymatter production and grain yield are invariably lower by about 50 and 54 per-cent respectively in wet (July - October) season than in dry (January - May) season. It was also reported that at Pattambi at least one third of variability in yield of virippu can be explained through fluctuations in monthly rainfall (Balakrishna Pillai and Prabhakaran, 1978). Sikder and Gupta (1979) reported an overall reduction of 44.5% in grain yield during kharif compared to rabi season from Chinsurah in West Bengal. Sastri (1986) reported that the length of rainy season determines the duration of rice varieties. From 40 years data, he has calculated the average length of growing season under early, normal and late onset of monsoon and also the average rice productivity for the corresponding years and he concluded that early duration varieties are best for Raipur area in Madhya Pradesh. Thus rainfall decides the variety to be grown in an agroclimatic zone. Viswambharan et al. (1989) reported a negative correlation between yield and number of rainy days during maturity stage.

2.1.3.3 Solar radiation

The intensive research at IRRI demonstrated that the quantity of solar radiation has got profound influence on rice yield, particularly during the last 30-45 days of the ripening period (Moomaw et al., 1967; Rao and Deb, 1974). Sreedharan (1975) reported that the yield attributes such as panicles/square metre, grain yield etc., recorded a positive correlation with solar energy during reproductive and ripening phases. Low solar radiation during ripening phase reduces the grain yield considerably, because of the decrease in percentage of filled grains (Yoshida, 1972; Yoshida and Parao,1976). Many other reports are available about correlation between grain yield and solar radiation received during the reproductive or ripening periods. Sahu et al. (1983) and Nishiyama (1985) observed that solar radiation during ripening stage is having a high positive correlation with grain yield. Krishnakumar (1986) reported that panicles per square metre, grains per square metre, degree of ripening and grain yield are positively correlated with solar energy during ripening period.

2.1.3.4 Relative humidity

High humid weather at the time of harvest poses problems of seed germination in case of varieties which lack seed dormancy. Also storing of wet grains becomes a problem when harvesting coincides with wet weather.

2.1.3.5 Wind

Venkataraman (1979) has made out a case for (i) breeding of varieties resistant to wind fluttering and (ii) erection of wind breaks on bunds of paddy fields. Viswambharan et al. (1989) reported that high wind especially during flowering and maturity stages of rice led to poor yield due to high sterility of spikelets. They also reported a negative correlation between wind velocity and yield of rice.

2.2 Effect of sowing/planting time on rice

Farmers have identified certain optimum time for sowing or transplanting of a crop in a location to get increased production. Even the slight changes in sowing time may substantially change yield and duration of rice crop.

Misra and Khan (1973) revealed that the late sown rice crop generally shown reduced growth, development and vigour. Rajagoplan et al. (1973) and Faw and Johnson (1975) reported the yield performance of some IRRI varieties under different dates of planting at Coimbatore. The crop planted in June generally has higher number of grains and grain weight as compared to October sown crop. Similar results are reported by Suryanarayana et al. (1975) from Karnataka. Majid and Ahmed (1975) and Latif (1982) reported that plant height decreases with delay in transplanting. Sowing on June 15th produced significantly higher grain yield as compared to sowing on July 25 during the Kharif season of both 1975 and 1976 (Dixit and Singh, 1980). Singh and Paliwal (1980), reported that the cultivar chambal and IR 8 give the highest yield when sown on May 26th in Rajasthan. The yield reductions for the four subsequent sowings (June 7, June 20, July 2, July 14) are 1.2, 7.7, 21.8 and 44.6 per cent respectively for chambal. For IR 8, sown on the three dates after June 7th, the yield reductions are 16.8, 31.6 and 51.7 per cent, respectively. Results of experiments conducted at Thanjavoor show that sowing on June 6th gives an yield of 4036 kg ha^{-1} and yield was reduced when sown afterwards (MARC, 1980). During 1980-81, significantly higher yield was obtained from the crop sown on June 16th (MARC, 1981). The best time for direct seeding in Punjab is between May to first week of June (Singh and Garg, 1983). A high yield of 6.89 t ha^{-1} at Navsari in Gujarat was reported by Machhi et al. (1984), when transplanted on June 20th. Narayanaswamy (1985) noticed 22 per-cent reduction in yield at Thanjavoor when transplanting is delayed by a fortnight from June 14th.

Delayed planting of rice in Taiwan decreased the percentage of filled grains (Liou, 1975). Similar results were reported by Majid and Ahmed (1975) and Nho _et al._ (1976). According to Mahapatra and Badekar (1968), Halappa _et al._ (1979) and Ramdoss and Subramanian (1980), early planted crop produced more number of productive tillers than late planted crop. It was also reported that high yielding medium duration varieties gave very good yield when sown in October (KAU, 1980). An experiment was conducted in 1980 at Pattambi to study the effect of different dates of sowing/planting and the consequent seasonal influence on the uptake of nutrients on the important medium and short duration rice varieties. All varieties gave maximum grain yield for sowings made in 3rd of May during the virippu season. During mundakan season, all varieties gave poor yields for the nursery in the 2nd week of October. During punja, for Jyothi, sowing in the last week of December had recorded the highest grain yield while for Triveni, sowing in the last week of January produced maximum grain yield and earliest sowings have given good yields in the case of all the varieties. During mundakan season, nurseries may be raised preferably after the first week of September (RARS, 1981). Similar result was reported in an experiment conducted at ARS, Mannuthy (KAU, 1983).

Viswambharan _et al._ (1989) conducted an experiment at RARS, Pattambi to identify the factors responsible for the low productivity of high yielding varieties of rice raised during the winter seasons in Kerala. The experiment with seven planting dates (August 22, September 5, September 18, October 3, October 16, October 30, November 12) and four popular high-yielding photoperiod insensitive rice varieties (IR 8, IR 20, Jaya and Bharati) showed that the variation in rice yield between the different planting dates were primarily due to spikelet sterility under optimum package of practices. Correlation analysis between weather parameters and grain yield revealed the critical role of certain weather components especially solar radiation, wind and rainfall during flowering and maturity stages of the crop in deciding the final yield. A positive relationship between yield and total solar radiation during 5-15 days before 50% heading, and a negative relationship between yield and number of rainy days 15-30 days before 50% heading were obtained. Yield reductions were more predominant for crops planted on 18th September, 3rd October and 17th October.

Gautham and Sharma (1987), in an experiment conducted during the kharif seasons of 1975, 1976 and 1977 showed the pattern of drymatter accumulation for four rice varieties - Jaya, Ratna, Rasi and Cavery, under two planting schemes and three plant densities. They reported significant increase in drymatter accumulation with increase in plant density. Significant difference in drymatter accumulation was also recorded due to different planting schemes.

It was reported that at Pattambi, early planting (last week of August) of second crop gave maximum yield and delayed plantings were severely affected by pest attack (KAU, 1985). In a field experiment to ascertain the optimum time of planting and spacing for an early maturing popular rice culture, IET 2508, Reddy and Reddy (1986) reported that transplanting during early part of June gave high yield. The grain yield was drastically reduced when transplanted beyond June 10th and before May. Spacing 10 x 10cm and 15 x 10cm were ideal for realising optimum yields. Acikgöz (1987) also reported that yield decreased with delayed sowing in Izmir, Turkey.

Palaniswamy et al. (1968) reported that September plantings of rice cultivars CO-30 and Bhavani were observed to take least number of days for flowering compared to earlier plantings. Biswas et al. (1975) reported delay in flowering due to delayed plantings. Ramdoss and Subramanian (1980) reported similar results and got higher straw yield with delay in sowing. Urkurkar (1983) reported optimum yield for the rice variety Asha, when transplanted between July 11th and 21st (and the water use efficiency for grain yield was highest for rice transplanted between July 11th and 31st. Transplanting rice during mid-July (SWM), late November (NEM) and late February (Summer) was ideal for the respective seasons in Coimbatore in achieving higher yield as reported by Krishnakumar (1986). He also observed that drymatter production followed more or less similar trend of tiller production.

In trials of twenty five varieties sown on 8 dates from November to January for two seasons (16 November 1978,1 December 1978,16 December 1978, 1 January 1979, 16 November 1979, 1 December 1979, 16 December 1979 and 1 January 1980) in Andhra Pradesh, genotype x sowing date interactions were significant for height, panicle length; number of spikelets per panicle and sterility percentage (Mehan et al. (1984). They also reported that with the postponement of date of sowing from November onwards during winter, the days to 50% flowering decreased, whereas grain yield per plant increased.

Maity and Mahapatra (1988) studied varietal response to different planting time during December and January. Varieties used were Palthara, Kuber and Rajani in 1985, Palthara, Rajani, Annapurna and Shankar in 1986. Time of planting affected yield. Transplanting on 25th December, 1985 and 5th January 1986, produced the highest yield. Late and early plantings reduced yield, perhaps, because of temperature.

2.3 Effect of spacing on rice

Yamada (1961) while reviewing the results of spacing studies conducted on transplanted rice grown on less fertilized land in Japan, has concluded that, in general, higher planting density produced more total drymatter and grain per unit area. A significant increase in plant drymatter at all the stages was reported as the plant density increases (IRRI, 1970). Balasubramaniam and Vaidyalingam (1985) reported that a closer spacing of 15 x 10 cm recorded higher grain yield in rice variety CR 1009 at Coimbatore, which was on par with 20 x 10 cm spacing.

Rao and Raju (1987) reported that closer spacing of 15 x 10 cm reduced number of days taken for 50% flowering at Hyderabad. However, grains per panicle decreased in closer spacing. The closer spacing gave higher straw yield but grain yield remained unaffected due to spacing.

In an experiment conducted by Ramaswamy _et al._ (1987) with three spacings (12.5 x 10 cm with 80 hills per square metre, 15 x 10 cm with 66 hills per sqaure metre and 20 x 10 cm with 50 hills per square metre) and 2, 4, 6 and 8 seedlings per hill, it was reported that 12.5 x 10 cm spacing produced significantly higher grain yield, inspite of reduced tillers per hill, panicle weight and number of filled spikelets per panicle because of higher number of tillers per unit area. Increasing the number of seedlings per hill had an adverse effect. All Yield parameters were reduced with more than 2 seedlings per hill.

During the second crop season, 20 x 10 cm spacing was found to be the best for PTB-20 and RP4-14 at Pattambi (RARS, Pattambi, 1975). In an experiment conducted at IARI, New Delhi, highest yield of paddy was obtained when row and plant spacingswere kept minimum at 7.5 x 7.5cm (Parashar, 1976). Lerch (1976) in Cuba has found that increase in plant population decreased the number of tillers and panicles, leaf area and yield per plant but increased total leaf area, drymatter production and paddy yield per square metre and concluded that closely spaced plants utilize more solar radiation for grain production more effectively than those with widely spaced. Devi et al. (1981) reported that closer spacing would be required for the second crop season at Mannuthy, while a wider spacing of 20 cm x 15 cm would be suitablefor the first crop season.

In an experiment conducted at RARS, Pattambi, Usha (1985) reported highest grain yield in plots with N-S orientation and with 20 x 10 cm spacing. This increased production was attributed to more effective utilisation of solar radiation with the uniform exposure of plants to sunlight.

2.4 Effect of weather on the incidence of pests and diseases

Weather conditions influence directly the various growth and development stages of a crop and indirectly, the incidence of pests and diseases (Yoshida and Parao, 1976).

Leaf folder infestation with late transplanting (1 month after farmer's date) was lower than with early (1 month before farmer's date) or simultaneous transplanting as reported by Suharto and Noch (1987). It was reported by Rajendran (1985) that adoption of either a spacing 20 x 10 cm or 20 x 15 cm with recommended practices were found to be highly suitable for effective management of leaf folder attack in rice variety IET 5741.

Early plantings tend to escape seedling maggots and early plantings combined with early maturing varieties provide high crop tolerance to white grub. August planting would be severely affected by Atherigona oryzae. Increasing seed density protects the crop against seed and seedling pest, particularly, if the crop germinates and emerges quickly (Litsinger et al., 1987).

Feeding damage by rice panicle bug was found to be lowest when planted on January 30th (Saroja and Rajan, 1985). It was reported that incidence of rice gall midge was maximum when rice planted on 1st September during second crop season, and incidence was less when planted in August or October (Uthamaswamy and Karuppuchamy;, 1986). Rice bug infestation was highest with late transplanting (Suharto and Noch, 1987). Singh (1988) reported that Rice army worm Mythimna loreyi (Dup.) migrates from rice to other cereal crops in areas where multiple cropping is the practice and climatic variations are extreme. In North India, it attacks rice from June to November, then migrates to wheat, barley, sugarcane, oats in December-May. Temperatures during March (12-32°C) considerably reduced the oviposition period (4-5 days) compared to December - January (10-11 days). It appears that rice army worm reproduction is most affected by temperature.

The vector population of Rice Tungro Virus (RTV) starts increasing in mid-August, reaches its peak between mid-September and early October and then declines. The period favourable for vector multiplication and RTV incidence is September - October (Vidhyasekharan and Lewin, 1986).

Singh _et al._ (1986) reported that Sheath rot disease caused by _Sarocladium oryzae_ is becoming as important disease in rainfed low land rice, especially in delayed plantings. Its occurrence was high in 50 days old seedlings. In general, photoperiod sensitive tall varieties are more resistant than photoperiod insensitive ones. The score was 2.9 for 25 days old seedlings and 5.7 for 50 days old seelings. Dhal and Choudhary (1987) reported that the disease incidence is high in delayed plantings due to low temperature accompanied by low RH during reproductive stage.

A combination of cultural practices - early planting, Synchrnous planting, crop rotation and early maturing varieties - protects the rice crop against most insect pests and diseases (Litsinger _et al._, 1987).

Materials and Methods

MATERIALS AND METHODS

The field experiment designed to study the influence of various weather parameters on the growth and yield of rice variety jaya was conducted at the Agricultural Research Station, Mannuthy during 1988-89. The field selected for the experiment was under bulk crop of paddy for the previous three seasons.

3.1 Materials

3.1.1 Site, climate and soil

The research station is situated at 10° 32' N latitude and 76° 20'E longitude at an altitude of 22 m above Mean Sea Level.

This area enjoys a typical humid tropical climate. The normal annual rainfall is about 2852 mm, 72 per cent of which is received during the S.W. monsoon season and 15 per cent during the N.E. monsoon season; and the rest in the remaining season as summer showers. The annual total number of rainy days is 116. In the S.W. monsoon season, sometimes there will be spells of rainless days and the paddy crop depends entirely on irrigation during such conditions. Dry spells also occur during the N.E. monsoon season. Mainly warm temperature prevails during the virippu season with moderate diurnal temperature range. During the mundakan season, though there is not much variation in the mean daily temperature compared to that

Table - 1. Properties of the soil

Particulars	Value	Method employed
A. Mechanical Composition		
Course sand (%)	27.2	Robinson's International Pipette Method (Piper, 1942)
Fine sand (%)	23.8	
Silt (%)	22.6	
Clay (%)	26.4	
Bulk density	1.52	Core Samples Method (Piper, 1942)
B. Chemical Composition		
Organic carbobn (%)	0.661	Walkley and Black Method (Soil Survey Staff, 1967)
Total N (%)	0.138	Semi Micro-kjeldhal Method (Soil Survey Staff, 1967)
Available P (kg ha^{-1})	32.06	Bray I extractant, molybdophosphoric acid method (Jackson, 1958)
Available K (kg ha^{-1})	172.08	Neutral Normal ammonium acetate extract, flame photometry (Jackson, 1958)
pH	5.84	1:2.5 soil water suspension using a pH meter

of virippu, the difference between the day and night temperature is more and increases towards the end of this season. The relative humidity during the whole of the virippu season is high. Relative humidity during the beginning of mundakan season is high but it decreases towards the end of the season. Moderate winds normally prevail during the virippu as well as mundakan season except for few gusts now and then during the heavy downpour periods. However, the winds will be ranging from high to very high by the end of the mundakan season, sometimes coinciding with the harvest periods. During the virippu season, sky is always cloudy and on an average there will be 4.3 bright sunshine hours per day. Whereas, during the mundakan season, there will be periods of clear sky conditions and the average bright sunshine is 7.9 hours per day.

The soil of the experimental area is moderate to well drained, medium clay loam in texture. The physical and chemical properties of the soil in the field are presented in Table 1.

3.1.2 Season

The experiment was started in May, 1988 and the final harvest was in February, 1989. It covered both the virippu (April - May to September - October) and mundakan seasons (September - October to December - January).

3.1.3 Variety

The variety 'Jaya' selected for the study is one of the early semi dwarf varieties developed in India. It is a photo period insensitive medium duration variety (120-125 days) developed from the cross between TN-1 x T 141. The bran colour is white and grains are long bold. It is a variety having high yield potential.

3.2 Methods

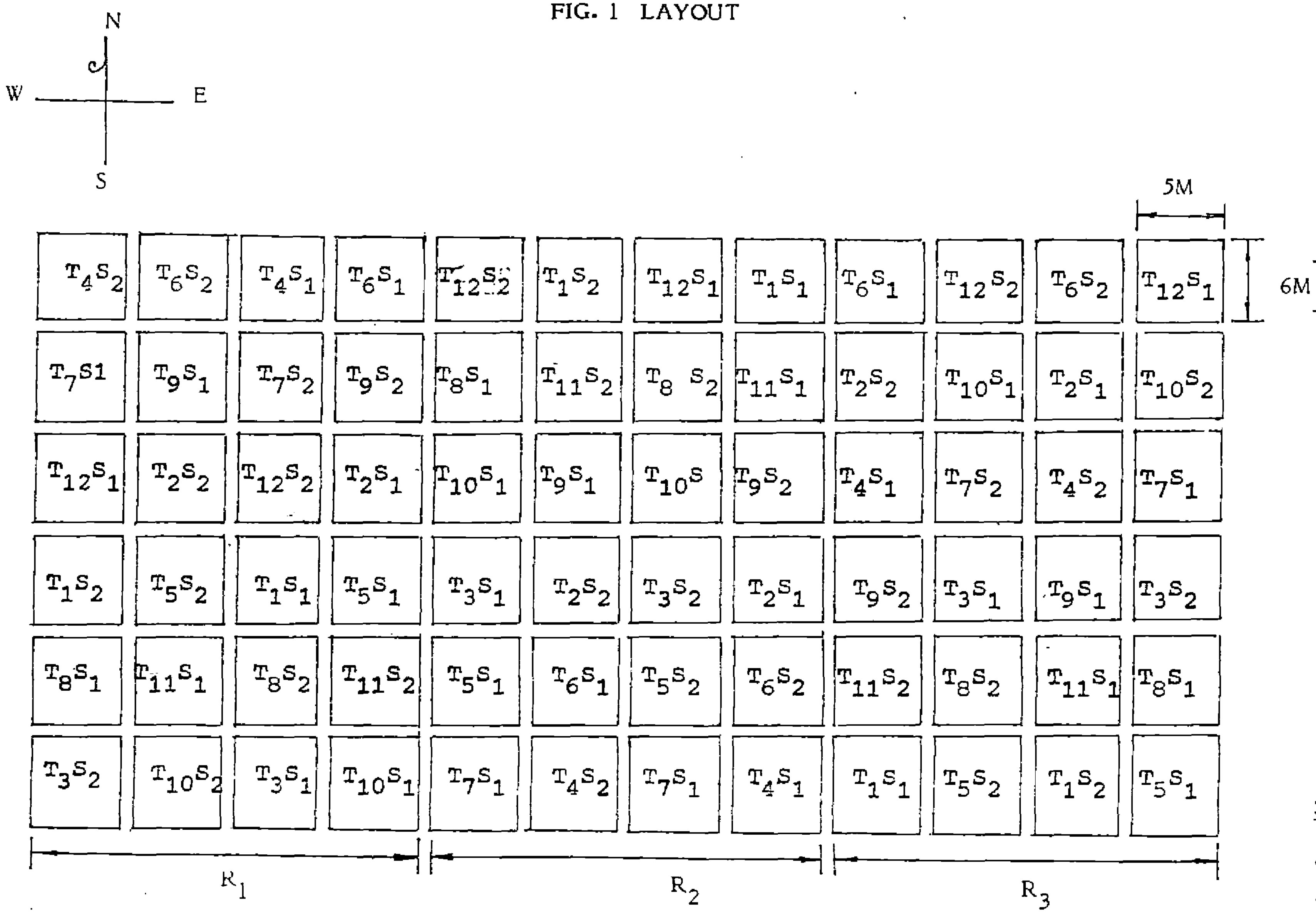
3.2.1 Lay out

The experiment was laid out in split plot design with three replications. The lay out plan is given in the Fig. 1. The treatments consisted of combinations of twelve dates of transplanting in the main plot and two levels of spacing between the plants in the sub plot. The total number of plots were 72.

3.2.1.1 Date of transplanting - Main plot treatments

T_1 - June 18
T_2 - July 2
T_3 - July 16
T_4 - July 30
T_5 - August 13
T_6 - August 27
T_7 - September 10
T_8 - September 24
T_9 - October 8
T_{10} - October 22
T_{11} - November 5
T_{12} - November 19

FIG. 1 LAYOUT



T_4S_2	T_6S_2	T_4S_1	T_6S_1	$T_{12}S_2$	T_1S_2	$T_{12}S_1$	T_1S_1	T_6S_1	$T_{12}S_2$	T_6S_2	$T_{12}S_1$
T_7S1	T_9S_1	T_7S_2	T_9S_2	T_8S_1	$T_{11}S_2$	$T_8\ S_2$	$T_{11}S_1$	T_2S_2	$T_{10}S_1$	T_2S_1	$T_{10}S_2$
$T_{12}S_1$	T_2S_2	$T_{12}S_2$	T_2S_1	$T_{10}S_1$	T_9S_1	$T_{10}S$	T_9S_2	T_4S_1	T_7S_2	T_4S_2	T_7S_1
T_1S_2	T_5S_2	T_1S_1	T_5S_1	T_3S_1	T_2S_2	T_3S_2	T_2S_1	T_9S_2	T_3S_1	T_9S_1	T_3S_2
T_8S_1	$T_{11}S_1$	T_8S_2	$T_{11}S_2$	T_5S_1	T_6S_1	T_5S_2	T_6S_2	$T_{11}S_2$	T_8S_2	$T_{11}S_1$	T_8S_1
T_3S_2	$T_{10}S_2$	T_3S_1	$T_{10}S_1$	T_7S_1	T_4S_2	T_7S_1	T_4S_1	T_1S_1	T_5S_2	T_1S_2	T_5S_1

TREATMENTS :

Time of Planting

T_1	June 18
T_2	July 2
T_3	July 16
T_4	July 30
T_5	August 13
T_6	August 27
T_7	September 10
T_8	September 24
T_9	October 8
T_{10}	October 22
T_{11}	November 5
T_{12}	November 19

Spacing

S_1	20cm x 10cm
S_2	20cm x 15cm

3.2.1.2 Spacing between plants - Sub plot treatments

S_1 - 20 cm x 10 cm

S_2 - 20 cm x 15 cm

3.2.2 Cultural operations

The cultivation practices recommended for 'Jaya' by the Kerala Agricultural University were followed. The land was ploughed twice and the soil was brought to puddled condition. Farm yard manure at the rate of 5000 kg ha^{-1} was applied uniformly as basal dressing. Lime (54 per cent CaO) was applied uniformly at the rate of 600 kg ha^{-1} in two splits - the first dose at 350 kg ha^{-1} as basal dressing at the time of final ploughing and the second dose at 250 kg ha^{-1} as top dressing about one month after planting.

Urea, superphosphate and muriate of potash wereused as fertilisers to supply the required quantity of nitrogen (at the rate of 90 kg N ha^{-1}), phosphorus (at the rate of 45 kg P_2O_5 ha^{-1}) and potassium (at the rate of 45 Kg K_2O ha^{-1}) respectively. The entire dose of P_2O_5, 45 kg of nitrogen and 22 1/2 kg of K_2O were applied as basal dressing. The remaining 45 kg of nitrogen and 22 1/2 kg of K_2O were top dressed 5 to 7 days prior to the panicle initiation stage.

The seeds were sown at a rate of 80 kg ha^{-1} and nurseries were raised prior to each date of transplanting. Twenty five days old seedlings were transplanted with two seedlings per hill. Controlled irrigation and drainage were done as and when required. The plots were hand weeded twice - first at thirty days after transplanting and second at forty five days after transplanting. Pests and diseases were controlled by recommended plant protection measures.

3.2.3 Observations

3.2.3.1 Crop growth characters :

(a) Height of the plant :

The plant height in cm was recorded on the 30th, 60th and 90th day after transplanting. Height of plants was measured from the bottom of the culm to the tip of the largest leaf or tip of the earhead, whichever was tallest.

(b) Number of tillers :

Number of tillers from sample unit (1 square metre) was counted on the 30th, 60th, 90th day after transplanting and at harvest.

(c) Number of days taken for panicle initiation :

Duration in days from transplanting to panicle initiation was recorded.

(d) Number of days taken from panicle initiation to flowering :

Duration from panicle initiation to 50% flowering was recorded.

(e) Number of days taken from flowering to harvest :

The number of days taken for maturity from 50% flowering stage was also recorded.

3.2.3.2 Yield characters

(a) Number of productive tillers :

Number of productive tillers from sample unit (1 square metre) was counted and the percentage of productive tillers to the total number of tillers was worked out.

(b) Length of panicle :

Length of panicle in cm from the neck to the tip of the panicle was measured.

(c) Number of spikelets per panicle :

Number of spikelets per panicle was recorded.

(d) Number of filled grains per panicle :

The number of filled grains per panicle was recorded at harvest. The percentage of filled grains to the total number of grains was calculated.

(e) Thousand grain weight :

One thousand grains were counted, weighed and the weight was recorded in g.

(f) Grain yield :

The grains harvested from each plot were cleaned dried and weighed. From this, yield in kg ha^{-1} was calculated.

(g) Straw yield :

The plotwise weight of sun dried straw was recorded and from this the yield of straw in kg ha^{-1} was calculated.

(h) Drymatter production :

The drymatter production in kg ha^{-1} was calculated.

(i) Harvest index :

The harvest index was calculated by dividing the economic yield with the total biological yield on dry weight basis.

(j) Grain straw ratio :

Grain-straw ratio was also worked out.

3.2.3.3 Incidence of pests, diseases and Nematodes.

Observations on incidence of pests, diseases and nematodes were reported for each treatment as and when noticed.

3.2.3.4 Meteorological parameters

The daily values of the following meteorological parameters were recorded

(a) Maximum temperature

(b) Minimum temperature

(c) Rainfall

(d) Mean relative humidity

(e) Bright sunshine hours and

(f) Mean wind speed

(g) Pan Evaporation

The monthly meteorological data from May, 1988 to February, 1989 are presented in the Appendix I. The crop weather diagrams for both virippu and mundakan seasons were prepared and discussed.

3.2.4 Statistical analysis

The data recorded on plant growth characters, yield and yield attributes were subjected to statistical analysis by applying the analysis of variance technique [Panse and Sukhatma (1985)] for split plot design.

3.2.5 Crop weather relationship

Simple linear correlations between the various growth and yield characters, and the weekly weather parameters for the overlapping periods from 1 to 13 weeks after transplanting were worked out for both the spacings S_1 (20 x 10 cm) and S_2 (20 x 15 cm). The crop growth characters selected are :

(1) Height of plant at 30 DAT
(2) Height of plant at 60 DAT
(3) Height of plant at 90 DAT
(4) Number of tillers at 30 DAT
(5) Number of tillers at 60 DAT
(6) Number of tillers at harvest
(7) Number of days taken from trasplanting to flowering
(8) Number of days taken from flowering to harvest

The yield characters selected are :

(1) Number of productive tillers
(2) Percentage of filled grains
(3) Grain yield
(4) Straw yield
(5) Drymatter production

The weekly values of maximum temperature, minimum temperature, temperature range, rainfall, relative humidity, wind speed and bright sunshine hours are considered as the important weather elements. Multiple linear regression equations were developed between the grain yield and weather elements for both the spacings S_1 and S_2.

A comparison between the yields estimated from these regression equations and the actuals is also made.

Results

RESULTS

The experimental area enjoyed a good monsoon and the total rainfall received during the south-west monsoon season was 2386 mm, whereas during the north-east monsoon season, it was only 128 mm. There were no rains during January and February and the crop depended entirely on irrigation during these months. The daily maximum temperature during the period ranged from 25.4 to 38.2°C and the minimum from 17.0 to 26.8°C. The minimum and maximum relative humidities ranged from 7 to 99 percent. During December and January, the winds were high and the highest wind speed recorded was about 25 km hr^{-1} on 5th January 1989. The duration of bright sunshine ranged from 0 to 11.2 hours. The weekly meteorological data for the experimental period are presented in the Fig. 2 and 3.

In this experiment, the twelve transplantings spread over five calendar months, covered both the virippu and mundakan seasons. The twelve times of planting are T_1 - June 18th planting, T_2 - July 2nd planting, T_3 - July 16th planting, T_4 - July 30th planting, T_5 - August 13th planting, T_6 - August 27th planting, T_7 - September 10th planting, T_8 - September 24th planting, T_9 - October 8th planting, T_{10} - October 22nd planting T_{11} - November 5th planting and T_{12} - November 19th planting. The two spacings adopted as subplot treatments are S_1 - 20x10cm and S_2 - 20x15cm.

The results of the experiment are presented below :

(1) Effect of time of planting, spacing and weather on growth and yield of rice

1.1 Crop growth characters

(a) Plant height :

The analysis of variance for the plant height at 30, 60 and 90 days after transplanting are presented in Appendix II. Plant heights at these times for both

FIG 2. WEATHER CONDITIONS DURING THE CROP GROWTH PERIOD

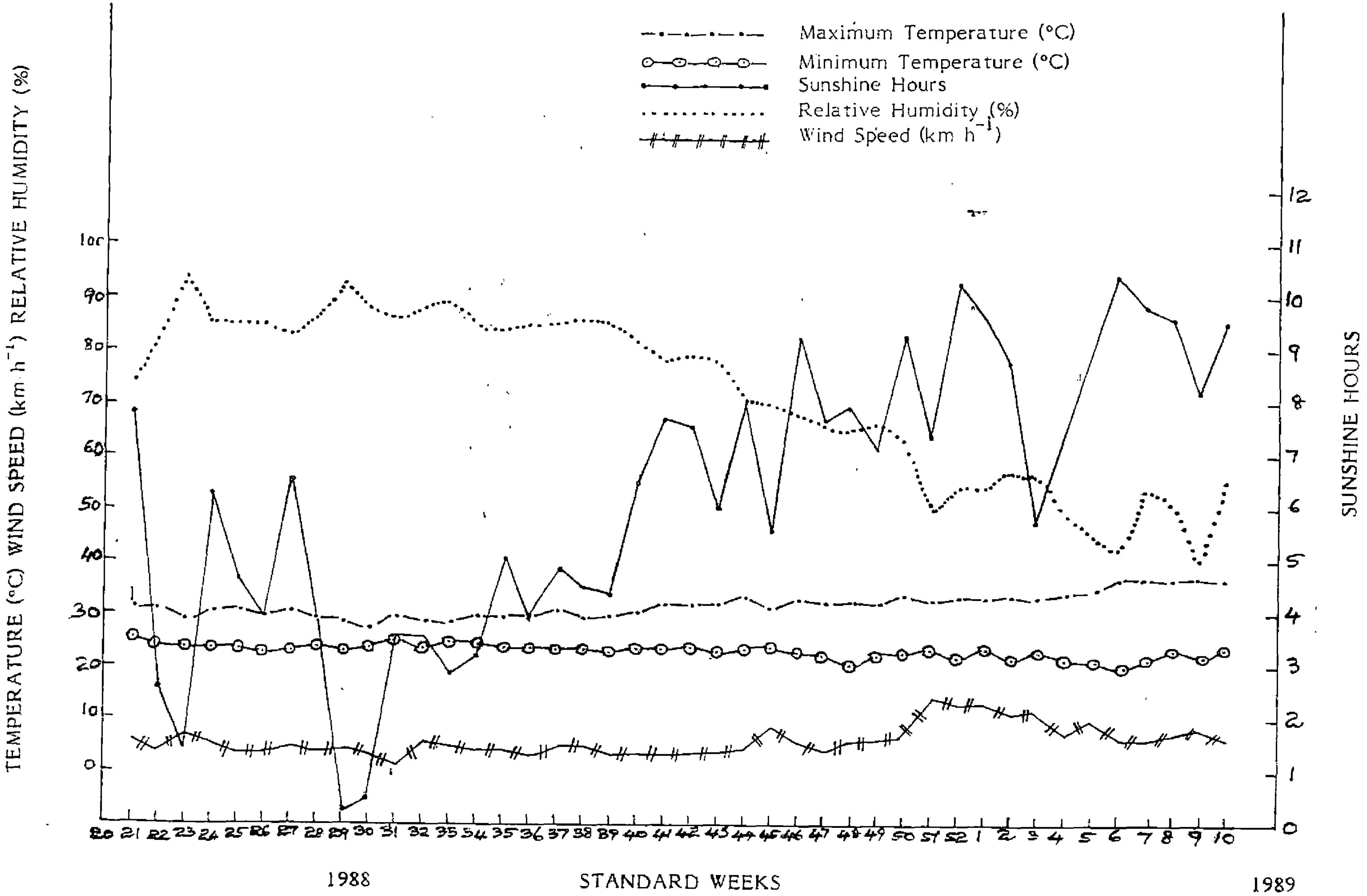
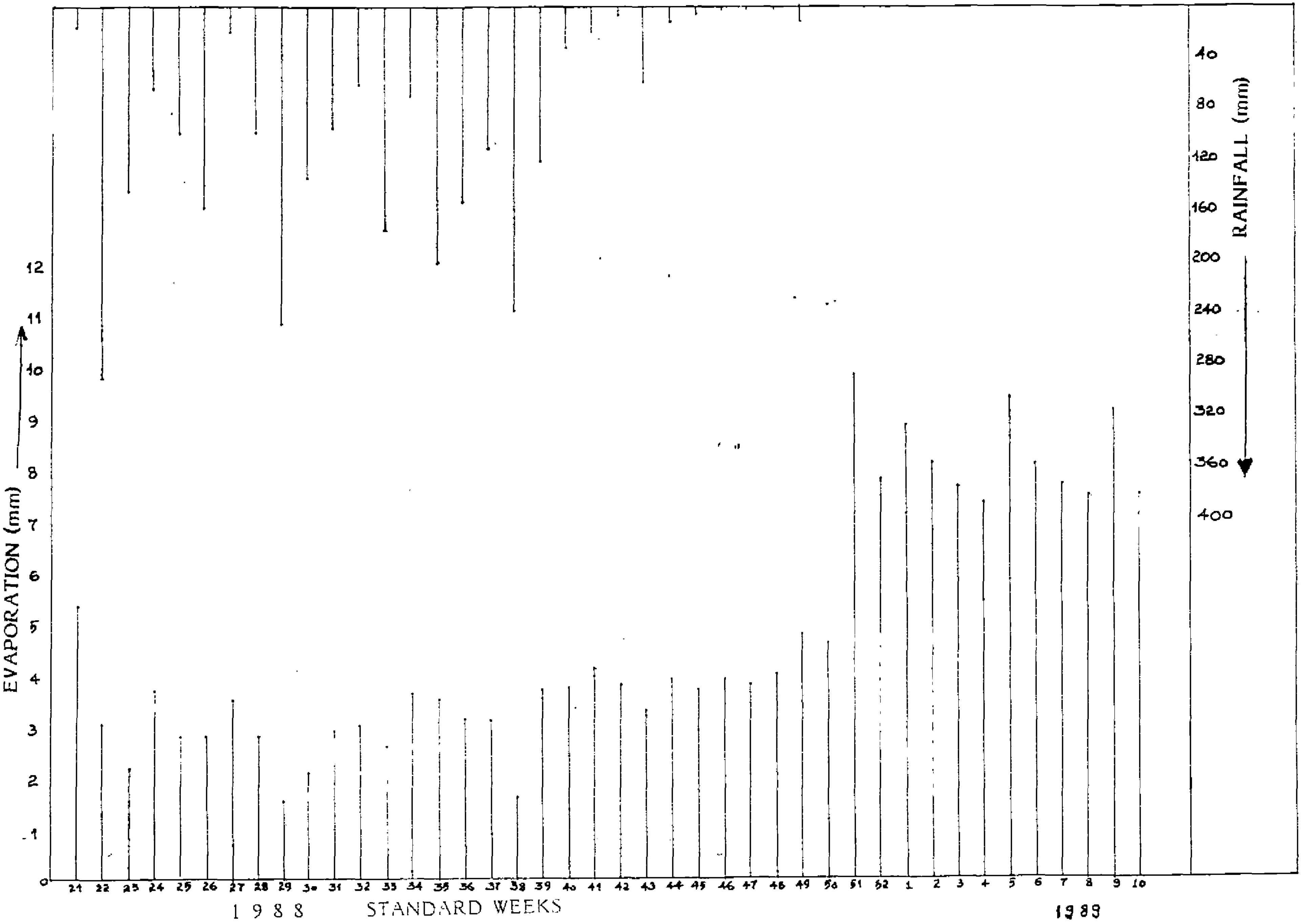


Fig. 3. RAINFALL AND EVAPORATION DURING THE CROP GROWTH PERIOD



the spacings are presented in the Fig. 4 and 5. The effect of time of planting and spacing on height of plant is presented in Table 2.

The mean plant height was significantly influenced by the different times of planting at all stages of growth.

At 30 DAT, T_2 recorded maximum height which was on par with T_3 and the lowest height was recorded by T_{12} which was on par with T_6 and T_7. The two spacings did not differ significantly in plant height. The interaction between time of planting and spacing was found to be significant. For the closer spacing, T_2 recorded maximum height (70.3 cm) which was on par with T_3 and the minimum was recorded by T_6 (44.3 cm) which was on par with T_{12} and T_7. For the wider spacing, again T_2 recorded maximum height (68.3 cm) which was on par with T_3, but the minimum height was observed in T_8 (47.3 cm) which was on par with T_4, T_7 and T_{12}.

At 60 DAT, T_1 recorded the maximum height and T_{12} the lowest height. The sub-plots shsowed significant difference and the closer spacing recorded higher value (74.9 cm) compared to the wider spacing (73.6 cm). The interaction between time of planting and spacing was significant. T_1 recorded a maximum height of 97.4 cm and 93.3 cm for the spacings S_1 and S_2 respectively. Whereas, a minimum height of 56.2 cm in T_{12} and 55.8 cm in T_8 were observed for the spacings S_1 and S_2 respectively.

At 90 DAT, T_1 recorded maximum height and the minimum height was recorded by T_{12} which was on par with T_8. The sub-plots did not

Table - 2. Effect of time of planting and spacing on height of plant (cm) at various stages of growth

	Days after transplanting								
	30			60			90		
	S_1 (20x10cm)	S_2 (20x15cm)	Mean	S_1 (20x10cm)	S_2 (20x15cm)	Mean	S_1 (20x10cm)	S_2 (20x15cm)	Mean
T_1 (June 18th planting)	57.72	58.73	58.23	97.43	93.27	95.35	113.93	102.52	108.23
T_2 (July 2nd ")	70.32	68.33	69.33	81.83	81.07	81.45	96.62	100.82	98.72
T_3 (July 16th ")	67.42	66.53	66.98	82.50	81.07	81.78	96.70	94.27	95.48
T_4 (July 30th ")	55.21	51.64	53.43	71.84	68.60	70.22	84.51	84.43	84.47
T_5 (August 13th ")	56.64	56.56	56.60	73.33	69.49	71.41	88.66	90.83	89.75
T_6 (August 27th ")	44.27	54.30	49.28	81.58	86.63	84.11	98.42	106.35	102.38
T_7 (September 10th ")	47.65	50.16	48.90	69.59	64.85	68.72	90.74	98.24	94.49
T_8 (September 24th ")	61.17	47.30	54.23	67.80	55.80	66.80	86.87	64.83	75.85
T_9 (October 8th ")	56.43	58.53	57.48	77.40	79.60	78.50	95.83	99.10	97.47
T_{10} (October 22nd ")	49.77	53.47	51.62	66.23	68.40	65.82	78.80	79.37	79.08
T_{11} (November 5th ")	53.47	61.13	57.30	64.04	72.10	68.07	74.83	83.03	78.93
T_{12} (November 19th ")	44.87	49.83	47.35	56.17	62.97	59.57	71.10	73.73	72.42
SEm ±	2.15381	2.15381	1.28461	2.23473	2.23473	1.53900	3.38550	3.38550	1.59928
			3.76785	4,62754	4.62754	4.51399	7.00355	7.00355	4.69082
CD (0.05)	4.45832	4,45832							
Mean	55.4[illegible]	56.38		74,98	73.65		89.75	89.79	
SEm±	0.43111	0.43111		0.43717	0.43717		0.69443	0.69443	
CD (0.05)	Ns	Ns		1.27606	1.27606		NS	NS	

Fig. 4. EFFECT OF TIME OF PLANTING ON HT. OF PLANT AT VARIOUS GROWTH STAGES (S_1)

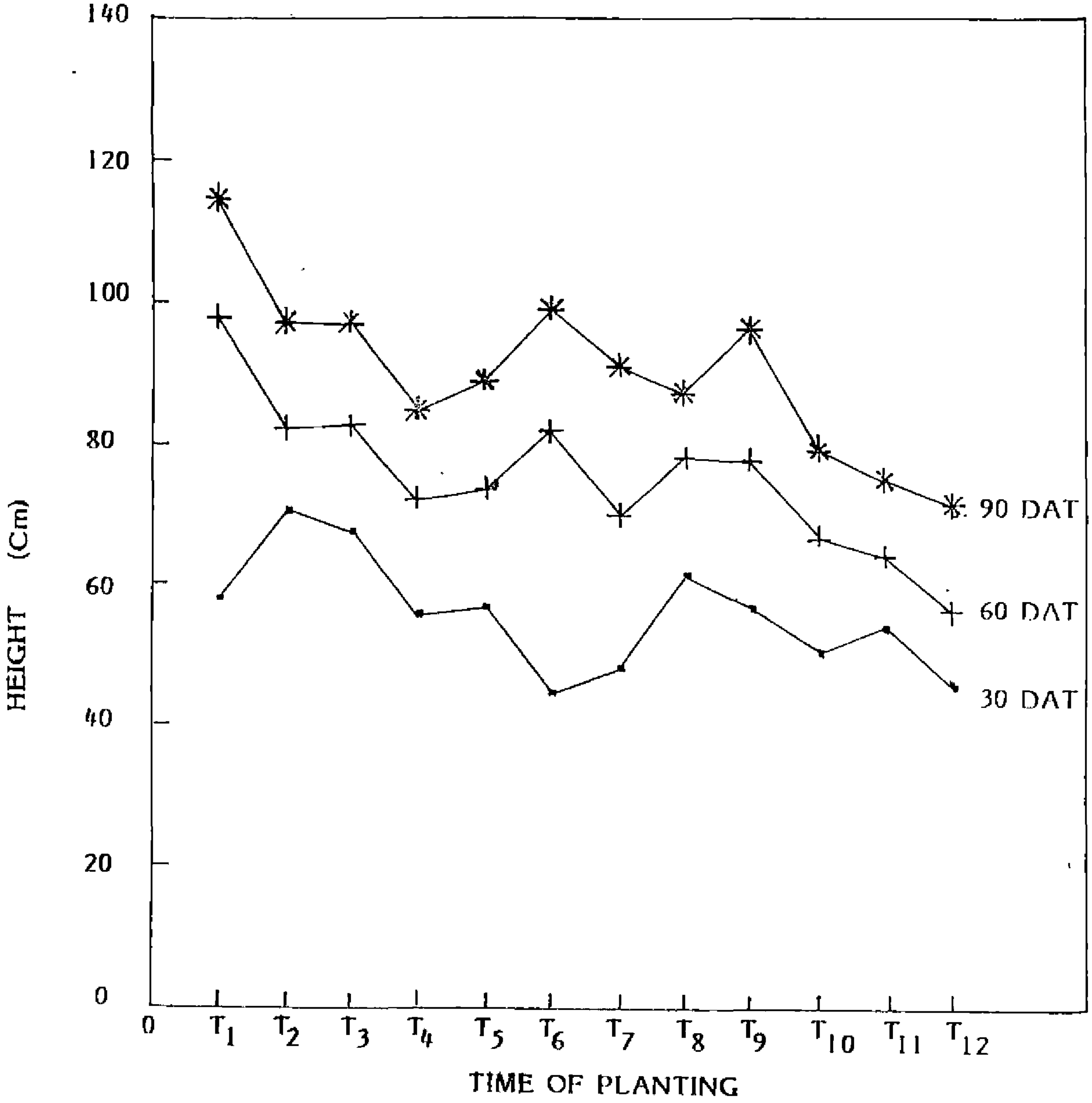


Fig. 5. EFFECT OF TIME OF PLANTING ON HEIGHT OF PLANT AT VARIOUS GROWTH STAGES (S_2 SPACING)

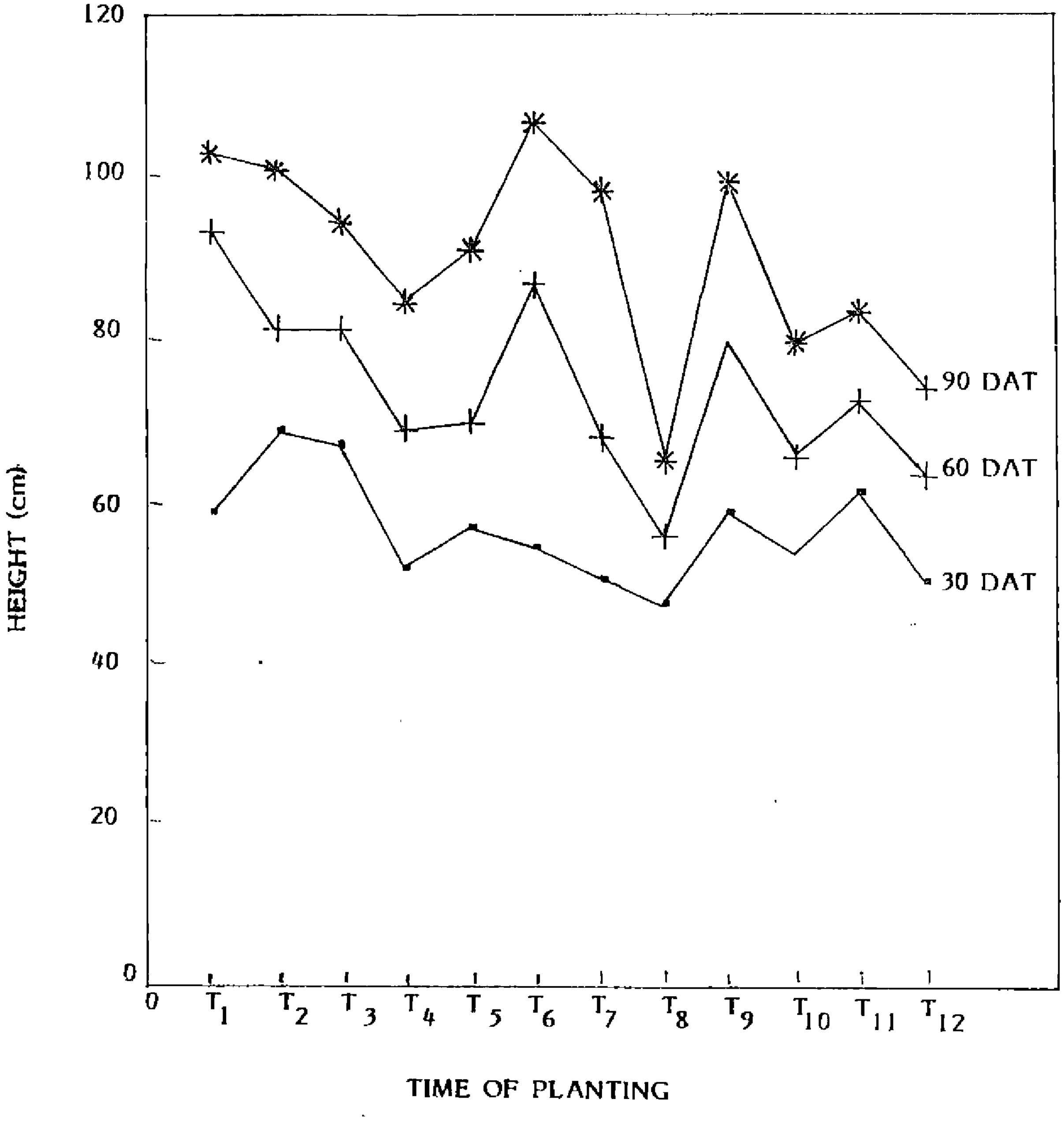


Table - 3. Correlation coefficients between the weather parameters and plant growth characters

Growth Character	Weather parameter	Spacing	Period	Correlation coefficient
Height at 60 DAT	Maximum temperature	S_1	Late vegetative	-0.777**
	"	S_2	"	-0.727**
	Temperature range	S_1	"	-0.748**
	"	S_2	"	-0.671*
Height at 90 DAT	Maximum temperature	S_1	Late vegetative	-0.765**
	"	S_2	"	-0.628*
	"	S_1	Ripening	-0.829**
	"	S_2	"	-0.594*
	Minimum temperature	S_1	Reproductive	+0.743**
	"	S_2	"	+0.837**
	Temperature range	S_1	Late vegetative	-0.752**
	"	S_2	"	-0.637*
	"	S_1	Reproductive & Ripening	-0.835**
	"	S_2	"	-0.612*

* Significant at p = 0.05
** Significant at p = 0.01

show any significant difference in plant height at 90 DAT. The interaction between time of planting and spacing was found to be signifant. For the spacing S_1, T_1 recorded maximum height (113.9 cm) and the minimum was recorded by T_{12} (71.1 cm) which was on par with T_{11}. For spacing S_2, T_2 recorded maximum height (106.4 cm) which was on par with June 18(T_1)and July 2(T_2)plantings. Lowest height wasw recorded by T_8 (64.8 cm).

Correlation coefficients between weather parameters and plant height at various stages of growth for both the spacings are given in the Table 3. The correlation studies indicated that the height at 30 DAT was very slightly influenced by weather parameters of the preceding period. The height at 60 DAT was negatively correlated with the maximum temperature, and temperature range during the period 30 to 60 DAT. The height at 90 DAT was significantly influenced by almost all the weather elements. Significant negative correlations were obtained between the height at 90 DAT and maximum temperature during the late vegetative and ripening stages and temperature range during the late vegetative, reproductive and ripening stages. Rainfall throughout the period had a positive effect on the height at 90 DAT. Significant positive correlation was also obtained with minimum temperature during the reproductive stage.

b) Number of tillers

The analysis of variance for the number of tillers at 30, 60, 90 DAT and at harvest are presented in Appendix III and the mean number of tillers is presented in Table 4.

Table - 4. Effect of time of planting and spacing on number of tillers at various stages of growth

	Days after transplanting									At harvest		
	30			60			90					
	S_1 20x10cm	S_2 20x15cm	Mean	S_1 20x10cm	S_2 20x15cm	Mean	S_1 20x10cm	S_2 20x15cm	Mean	S_1 20x10cm	S_2 20x15cm	Mean
T_1 (June 10th planting)	11.0	9.7	10.33	17.0	15.3	16.17	18.7	16.0	17.33	16.3	15.0	15.67
T_2 (July 2nd ")	9.3	10.0	9.67	11.7	12.3	12.00	13.7	13.7	13.67	13.7	13.7	13.67
T_3 (July 16th ")	8.3	8.7	8.50	11.0	11.7	11.33	13.3	13.3	13.33	13.3	13.3	13.33
T_4 (July 30th ")	8.0	7.7	7.83	9.3	9.7	9.50	10.3	11.0	10.67	10.0	10.0	10.00
T_5 (August 13th ")	8.3	9.7	9.00	10.0	12.3	11.17	11.3	13.3	12.33	10.3	12.7	11.50
T_6 (August 27th ")	9.0	10.3	9.67	12.0	13.7	12.83	12.3	14.3	13.33	12.3	13.0	12.67
T_7 (September 10th ")	9.0	9.3	9.17	11.7	12.3	12.00	12.7	14.0	13.33	11.3	13.0	12.17
T_8 (September 24th ")	10.3	9.0	9.67	11.0	10.0	10.50	11.3	11.33	11.3	11.3	11.0	11.17
T_9 (October 8th ")	7.0	6.3	6.67	9.3	9.33	9.33	10.7	10.67	10.67	9.7	9.0	9.33
T_{10} (October 22nd ")	6.0	5.7	5.83	7.0	7.7	7.3	8.0	9.0	8.5	8.0	10.0	9.0
T_{11} (November 5th ")	6.3	7.7	7.00	7.3	9.7	8.50	9.0	12.3	10.67	9.0	12.3	10.67
T_{12} (November 19th ")	6.7	7.7	7.17	8.7	10.0	9.33	10.0	11.3	10.67	9.7	10.3	10.00
SEm±	0.65756	0.65756	0.31683	0.71426	0.71426	0.45436	0.79261	0.79261	0.39141	0.89228	0.89228	0.44671
CD (0.05)	1.36035	1.36035	0.92928	1.47875	1.47875	1.33266	1.63985	1.63985	1.14802	1.84611	1.84611	1.30729
Mean	8.28	8.47		10.5	11.17		11.78	12.53		11.25	11.94	
SEm±				0.14164	0.14164		0.16197	0.16197		0.18215	0.18215	
CD (0.05)	Ns	Ns		0.41344	0.41344		0.47278	0.47278		.0.53169	0.53169	

The time of planting had significant influence on the number of tillers at all growth stages.

At 30 DAT, T_1 recorded the maximum number of tiller which was on par with T_2, T_6 and T_8. T_{10} recorded the lowest number of tillers which was on par with T_9. The spacings did not differ significantly. The interaction between time of planting and spacing was found to be significant. For the closer spacing, T_1 recorded maximum number of tillers (11) which was on par with T_8. T_{10} recorded the lowest number (6) which was on par with T_9, T_{11} and T_{12}. For the wider spacing, T_6 recorded the maximum number of tillers (10.3), which was on par with T_1, T_2, T_5, T_7 and T_8. T_{10} recorded the lowest number of tillers (5.7) which was on par with T_9.

At 60 DAT, T_1 recorded the maximum number of tillers and T_{10} recorded the lowest number which was on par with T_{11}. The two spacings showed significant difference. S_2 recorded higher number of tillers (11.2) than S_1(10.5). The interaction between the time of planting and spacing was significant. T_1 recorded highest number of tillers of 17 and 15.3 and T_{10} recorded the lowest of 7 and 7.7, both respectively for the spacings S_1 and S_2. For the closer spacing, the lowest values in T_{10} was on par with T_{11}.

At 90 DAT, T_1 recorded the maximum number of tillers and the minimum number was observed in T_{10}. The two spacings showed significant difference. S_2 recorded higher number (12.5) than S_1 (11.8). The interaction between time of planting and spacing was significant. T_1 and T_{10} (17.33 and 8.5) recorded the highest and the lowest number of tillers respecptively, for the spacings S_1 and S_2. For the spacing S_1, the lowest values in T_{10} was on par with T_{11}.

At harvest, T_1 recorded the maximum number of tillers and the minimum number was recorded by T_{10} which was on par with T_4, T_9 and T_{12}. The spacings differed significantly. S_2 recorded higher number of tillers (11.9) than S_1 (11.3). The interaction between time of planting and spacing was found to be significant. For the closer spacing, T_1 recorded the maximum number of tillers (16.3) and the minimum was recorded by T_{10} (8.0) which was on par with T_9, T_{11} T_{12}. For the wider spacing, also T_1 recorded the maximum number (15.0) which was on par with T_2 and T_3 and the minimum was recorded by T_9 (9.0) which was on par with T_4, T_{10} and T_{12}.

Correlation studies indicated that number of tillers at 30 and 60 DAT, and at harvest were significantly influenced by the various weather elements. Maximum temperature and temperature range always had a negative correlation, and rainfall and relative humidity had a positive correlation with the number of tillers, at all the stages. Number of tillers at 30 and 60 DAT was not significantly influenced by minimum temperature. Whereas, at harvest, number of tillers had a significant positive correlation with minimum temperature during the reproductive stage. Table 5 shows the correlation coefficients of the above.

Table - 5. Correlation coefficients between the weather parameters and plant growth characters

Growth character	Weather parameter	Spacing	Period	Correlation coefficient
Number of tillers at 30 DAT	Maximum temperature	S_1	Total period	-0.590*
	"	S_2	"	-0.725**
	Relative humidity	S_1	"	+0.677*
	"	S_2	"	+0.622*
Number of tillers at 60 DAT	Maximum temperature	S_1	Late vegetative	-0.688*
	"	S_2	"	-0.772**
	Rainfall	S_1	Vegetative	+0.626*
	"	S_2	"	+0.785**
	Relative humidity	S_1	Total period	+0.654*
	"	S_2	"	+0.657*
Number of tillers at harvest	Maximum temperature	S_1	"	-0.761**
	"	S_2	"	0.690*
	Minimum temperature	S_1	Reproductive	+0.820**
	"	S_2	"	+0.874**
	Temperature range	S_1	Reproductive	-0.822**
	"	S_2	"	-0.758**
	Rainfall	S_1	Total period	+0.758**
	"	S_2	"	+0.701*
	Relative humidity	S_1	Total period	+0.715**
	"	S_2	"	+0.653*

* Significant at p = 0.05   ** Significant at p = 0.01

c) Duration of growth periods

The number of days from transplanting to panicle initiation, panicle initiation to flowering and flowering to harvest are the three growth periods studied. The analysis of variance could not be done because of lack of variability among replicated values. Hence, only the treatment means were compared and presented in Table 6.

The crop planted on June 18th (T_1) took the least number of days (42) for panicle initiation and that planted on September 24th (T_8) recorded the maximum number of days (54). The number of days taken from panicle initiation to flowering showed little variation among the treatments. The crop planted on September 24th (T_8) and November 19th (T_{12}) took more number of days from panicle initiation to flowering (16) and crop planted on August 13th (T_5) and August 27th (T_6) took the least number of days (11) to flowering. The crop planted on June 18th (T_1) took more number of days from flowering to harvest (46) and that planted on November 19th (T_{12}) took the least number of days (26).

It is interesting to note that the delay in planting has slightly increased the duration from transplanting to panicle initiation and panicle initiation to flowering. Whereas, the period from flowering to harvest has shown a significant decrease with delay in planting.

Correlation coefficients between the weather parameters and the duration from transplanting to flowering and from flowering to harvest

Table - 6. Effect of time of planting and spacing on duration of growth stages

Treatments	Number of days from		
	Transplanting to panicle initiation	Panicle initiation to flowering	Flowering to harvest
T_1 (June 18th planting)	42	13	46
T_2 (July 2nd ")	48	12	40
T_3 (July 16th ")	45	14	41
T_4 (July 30th ")	49	12	39
T_5 (August 13th ")	48	11	38
T_6 (August 27th ")	46	11	40
T_7 (September10th ")	50	14	35
T_8 (September 24th ")	54	16	35
T_9 (October 8th ")	45	15	31
T_{10} (October 22nd ")	49	15	31
T_{11} (November 5th")	50	15	28
T_{12} (November 19th ")	48	16	26
S_1 (20 x 10 cm)	47.6667	13.58333	36.25000
S_2 (20 x 15 cm)	47.91667	13.75000	36.08333

Table - 7. Correlation coefficients between the weather parameters and plant growth characters

Growth character	Weather parameters	Spacing	Period	Correlation coefficient
Duration from transplanting to flowering	Maximum temperature	S_1	Late vegetative & reproductive	+0.687*
	"	S_2	"	+0.757**
	Temperature range	S_1	Late vegetative & reproductive	+0.608*
	"	S_2	"	+0.698*
	Rainfall	S_1	Total period	-0.616*
	"	S_2	"	-0.702*
	Sunshine hours	S_1	Late vegetative & reproductive	+0.650*
	"	S_2	"	+0.712**
Duration from flowering to harvest	Maximum temperature	S_1	Total period	-0.914**
	"	S_2	"	-0.916**
	Minimum temperature	S_1	Total period	+0.850**
	"	S_2	"	+0.845**
	Temperature range	S_1	Total period	-0.887**
	"	S_2	"	-0.882**
	Rainfall	S_1	Total period	+0.675*
	"	S_2	"	+0.683*
	Relative humidity	S_1	Total period	+0.897**
	"	S_2	"	+0.897**
	Sunshine hours	S_1	Total period	-0.658*
	"	S_2	"	-0.669*

* Significant at p = 0.05 ** Significant at p = 0.01

for both the spacings are given in Table 7. These indicate that weather has a very significant influence particularly, on the period from flowering to harvest. Maximum temperature and temperature range during this period had a strong negative correlation whereas, the minimum temperature, rainfall and relative humidity correlated positively. Number of bright sunshine hours had shown a significant negative correlation with duration of this stage.

1.2. Yield characters

The time of planting significantly influenced the yield characters like number and percentage of productive tillers, length of panicle, number of spikelets per panicle, number and percentage of filled grains, grain yield, strain yield, dry matter production, thousand grain weight etc.

a) Number of productive tillers

The analysis of variance for the number of productive tillers is presented in Appendix IV and the mean values in the Table 8. The variation of productive tillers with time of planting for both the spacingsis given in the Fig. 6.

In general, number of productive tillers showed a decreasing trend with delay in planting. T_2 recorded significantly higher number of productive tillers (11.2) which was on par with T_3, and T_{12} recorded the lowest

Table - 8. **Effect of time of planting and spacing on productive tillers**

Treatments	Number of productive tillers	Percentage of productive tillers
T_1 (June 18th planting)	9.20	59.34
T_2 (July 2nd ")	11.21	80.65
T_3 (July 16th ")	10.10	76.30
T_4 (July 30th ")	8.10	79.14
T_5 (August 13th ")	8.17	70.43
T_6 (August 27th ")	9.50	75.15
T_7 (September 10th ")	7.00	56.48
T_8 (September 24th ")	5.17	46.65
T_9 (October 8th ")	6.83	72.13
T_{10} (October 22nd ")	6.83	75.73
T_{11} (November 5th ")	5.33	48.62
T_{12} (November 19th ")	4.67	46.15
SEm±	0.56854	4.08628
CD (p = 0.05)	1.66756	11.98538
S_1 (20 x 10 cm)	7.47222	65.59472
S_2 (20 x 15 cm)	7.52778	62.80667
SEm±	0.22652	1.41156
CD (p = 0.05)	Ns	Ns

Fig. 6. EFFECT OF TIME OF PLANTING ON PRODUCTIVE TILLERS

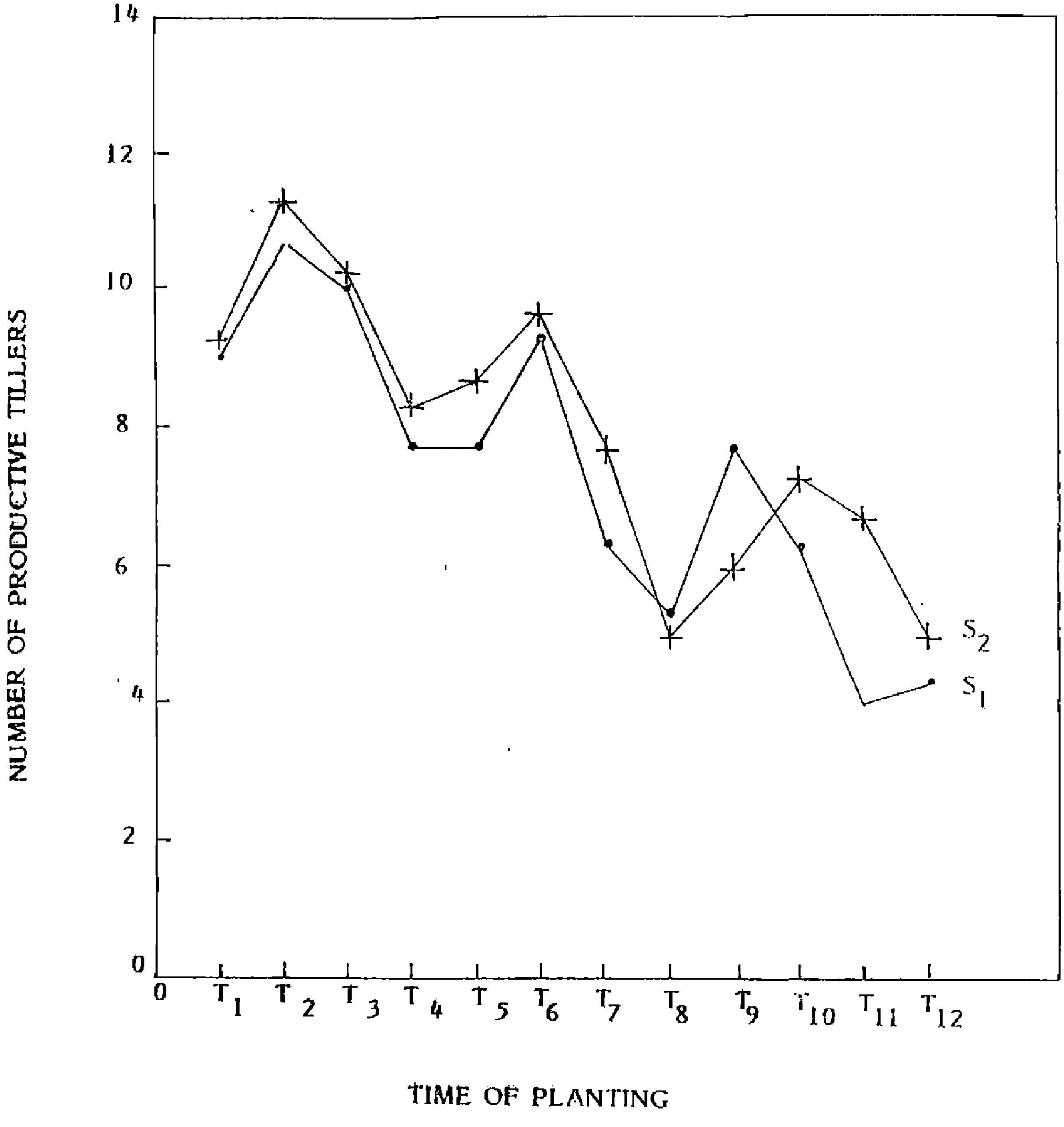


Table - 9. Correlation coefficients between weather parameters and plant yield characters

Yield character	Weather parameter	Spacing	Period	correlation coefficient
Number of productive tillers	Maximum temperature	S_1	Total period	-0.848**
	"	S_2	"	-0.838**
	Minimum temperature	S_1	Total period	+0.878**
	"	S_2	"	+0.789**
	Temperature range	S_1	Total period	-0.868**
	"	S_2	"	-0.835**
	Rainfall	S_1	Total period	+0.839**
	"	S_2	"	+0.840**
	Relative humidity	S_1	Total period	+0.857**
	"	S_2	"	+0.806**
Percentage of filled grains	Minimum temperature	S_1	Ripening	+0.738**
	"	S_2	"	+0.761**
	Temperature range	S_1	Ripening	-0.647*
	"	S_2	"	-0.702*

* Significant at $p = 0.05$

** Significant at $p = 0.01$

number (4.7) which was on par with T_8 and T_{11}. The effect due to spacing and interaction between time of planting and spacing were not significant.

Correlation coefficients for the number of productive tillers are presented in Table 9. Correlation studies indicated that maximum temperature and temperature range had always a negative correlation whereas, minimum temperature, rainfall and relative humidity had a positive correlation, with the number of productive tillers.

b) Percentage of productive tillers

The analysis of variance for the percentage of productive tillers is presented in Appendix IV and the mean values in Table 8.

The percentage of productive tillers in T_2 was highest (80.7%) and was on par with T_3, T_4, T_5, T_6, T_9 and T_{10}. T_{12} recorded the lowest percentage (46.2%) which was on par with T_7, T_8 and T_{11}. The effects due to spacing and interaction between time of planting and spacing were found to be nonsignificant.

c) Length of Panicle

The analysis of variance for length of panicle is presented in Appendix IV and the mean values are given in Table 10.

The length in T_2 was highest (23.2 cm) and on par with T_1 and T_9. The lowest value (18.6 cm) was observed in T_8 which was on par with T_7

Table - 10. Effect of time of planting and spacing on yield characters

Treatments	Length of panicle (cm)	Number of spikelets per panicle	Number of filled grains per panicle	Percentage of filled grains
T_1 (July 18th planting)	23.05	127.50	82.6	64.8
T_2 (July 2nd ")	23.24	116.5	89.2	76.5
T_3 (July 16th ")	22.20	113.7	87.0	76.5
T_4 (July 30th ")	21.85	125.5	88.0	70.1
T_5 (August 13th ")	21.49	125.8	88.8	70.2
T_6 (August 27th ")	21.29	119.8	90.3	74.9
T_7 (September 10th ")	19.76	106.7	59.5	55.5
T_8 (September 24th ")	18.58	101.0	42.5	41.6
T_9 (October 8th ")	23.03	144.3	102.0	71.0
T_{10} (October 22nd ")	21.18	117.2	87.5	75.1
T_{11} (November 5th ")	22.32	138.8	58.5	43.8
T_{12} (November 19th ")	19.15	120.3	53.0	43.4
SEm±	0.29097	5.64935	6.64711	4.30693
CD (0.05)	0.85345	16.57000	19.49651	12.63257
S_1 (20x10cm)	21.51833	119.58333	74.02778	62.21667
S_2 (20x15cm)	21.33889	123.27778	78.02778	63.35972
SEm±	0.15615	2.18758	1.99826	1.47364
CD (0.05)	Ns	Ns	Ns	Ns

and T_{12}. The effects due to spacings and interaction between time of planting and spacing were found to be nonsignificant.

d) Number of spikelets per panicle

The analysis of variance for the number of spikelets per panicle is presented in Appendix IV. The mean number of spikelets per panicle are given in Table 10.

Highest number of spikelets per panicle (144.3) was observed in T_9 which was on par with T_{11}, and the lowest (101.0) was in T_8 which was on par with T_2, T_3, T_7 and T_{10}. The effects due to spacing and interaction between time of planting and spacing were found to be nonsignificant.

e) Number of filled grains per panicle

The analysis of variance for the number of filled grains per panicle is presented in Appendix IV and the mean number of filled grains per panicle are presented in Table 10.

Highest number of filled grains (102) was observed for T_9 which was on par with T_1, T_2, T_3, T_4, T_5 T_6 and T_{10}. The lowest (42.5) was observed in T_8 which was on par with T_7, T_{11} and T_{12}. The effects due to spacing and interaction between time of planting and spacing were found to be nonsignificant.

f) Percentage of filled grains

The analysis of variance for percentage of filled grains is presented in Appendix IV and the mean values are presented in Table 10.

T_2 recorded the highest percentage of filled grains (76.5%) which was on par with T_1, T_3, T_4, T_5, T_6, T_9 and T_{10} and T_8 recorded the lowest value (41.6%) which was on par with T_{11} and T_{12}. The two spacings did not differ significantly in percentage of filled grains. The interaction between time of planting and spacing was also not significant.

The correlation coefficients between percentage of filled grains and weather parameters are given in Table 9. Correlation studies indicated a significant positive correlation between percentage of filled grains and minimum temperature and a negative correlation with temperature range, both during the ripening period.

g) Grain Yield

The analysis of variance for grain yield is presented in Appendix V. The mean values are presented in Table 11a and in Figs. 7 and 8.

The time of planting greatly influenced the grain yield. T_2 recorded the highest grain yield of 3118 Kg ha^{-1}. Next highest yield was recorded by T_{10} (2889 Kg ha^{-1}) which was on par with T_1, T_3, T_4, T_5 and T_6. T_{12} recorded the lowest grain yield of 1431 Kg ha^{-1}.

Maximum temperature, temperature range and wind speed during the total crop growth period correlated negatively with the grain yield whereas, the minimum temperature, rainfall and relative humidity correlated positively. To identify the critical periods, correlations between the

Table - 11(a). Effect of time of planting and spacing on yield characters

Treatments	Grain yield			Straw yield		
	S_1	S_2	Mean	S_1	S_2	Mean
T_1 (June 18th planting)	2705.33	2958.00	2831.67	3722.33	4266.67	3994.50
T_2 (July 2nd planting)	3041.33	3194.33	3117.83	4722.33	4289.00	4505.67
T_3 (July 16th planting)	2777.67	2889.00	2833.33	4244.67	4344.33	4294.50
T_4 (July 30th planting)	2663.67	2930.67	2797.17	3144.67	3533.33	3339.00
T_5 (August 13th planting)	2875.00	2694.33	2784.67	4911.33	4533.33	4722.33
T_6 (August 27th planting)	3013.67	2764.00	2888.83	5122.33	4411.00	4766.67
T_7 (September 10th planting)	2417.00	2319.67	2368.33	3433.33	3478.00	3455.67
T_8 (September 24th planting)	2222.33	1750.00	1986.17	3311.33	3033.33	3172.33
T_9 (October 8th planting)	2777.67	2222.00	2499.83	4766.67	3811.00	4288.83
T_{10} (October 22nd planting)	2861.33	2916.67	2889.00	3944.33	3777.67	3861.00
T_{11} (November 5th planting)	2347.33	2208.33	2277.83	3477.67	3577.67	3527.67
T_{12} (November 19th planting)	1583.33	1277.67	1430.50	3000.00	2511.33	2755.67
SEm±	239.13457		175.81052	440.61527		332.04929
CD (0.05)	494.86632		364.63096	911.93218		688.67020
Mean	2607.14	2510.39		3983.42	3797.22	
SEm±	66.17655			118.24065		
CD (0.05)	Ns			Ns		

Fig. 7 EFFECT OF TIME OF PLANTING ON GRAIN AND STRAW YIELDS

(S_1 Spacing)

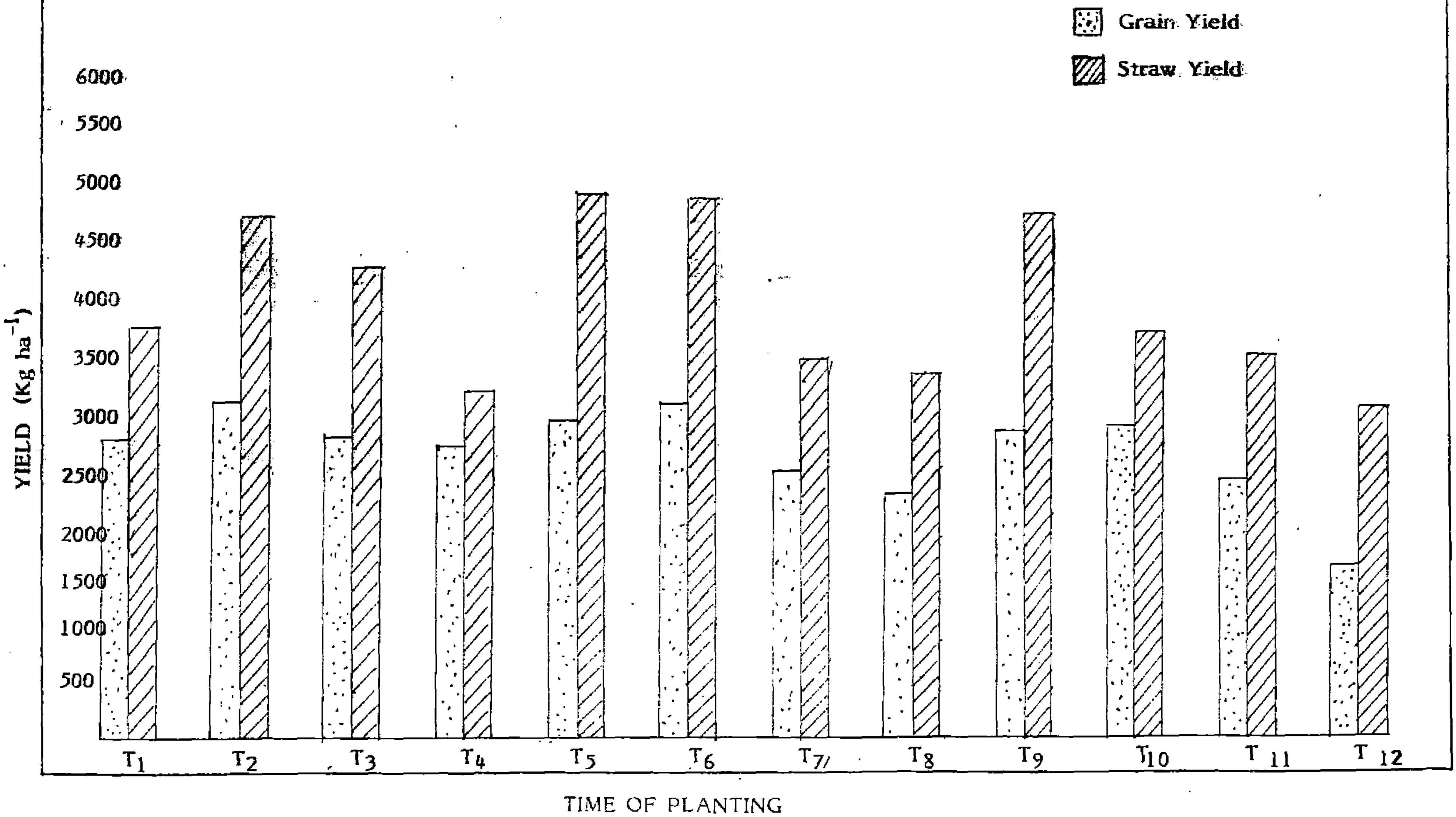


Fig. 8 EFFECT OF TIME OF PLANTING ON GRAIN AND STRAW YIELD

(S_2 Spacing)

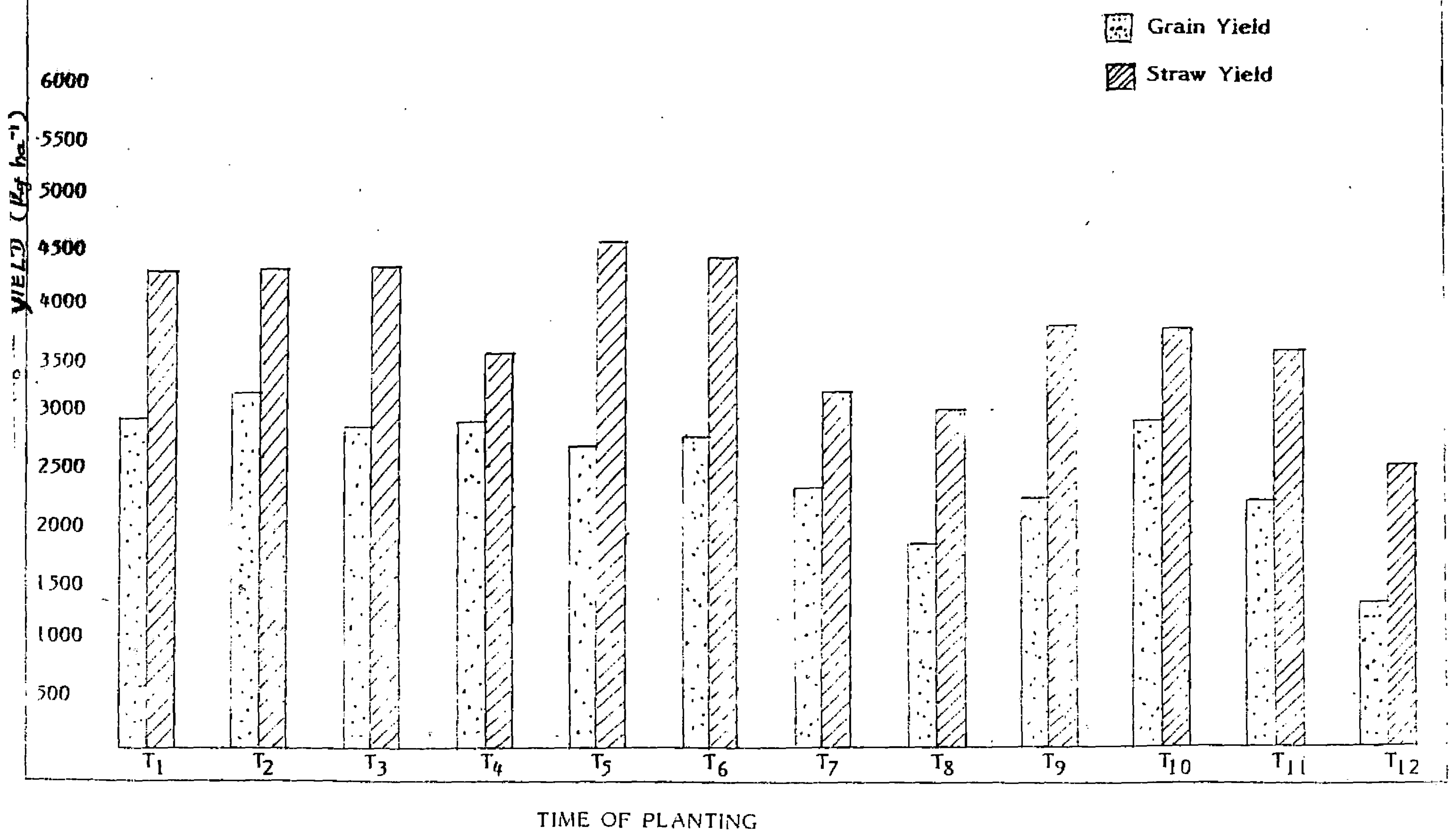


Table - 12. Correlation coefficients between weather parameters and grain yield

Weather parameters	Spacing	Period	Correlation coefficient
Maximum temperature	S_1	Vegetative and early reproductive	-0.603*
"	S_2	"	-0.770**
"	S_1	Ripening	-0.728**
"	S_2	"	-0.814**
Minimum temperature	S_1	Grain filling	+0.857**
"	S_2	"	+0.869**
Temperature range	S_1	Vegetative	-0.628*
"	S_2	"	-0.708**
"	S_1	Maturity	-0.763**
"	S_2	"	-0.840**
Rainfall	S_1	Vegetative	+0.599*
"	S_2	"	+0.677*
Wind speed	S_1	Reproductive	-0.674*
"	S_2	"	-0.612*
Relative humidity	S_1	Reproductive	+0.606*
"	S_2	"	+0.709**

* Significant at p = 0.05 ** Significant at p = 0.01

grain yield and various weather elements for the weekwise overlapping periods, ie single week, two consecutive weeks, three consecutive weeks like that, to harvest were worked out for both the spacings and the correlation coefficients are presented in Table 12.

The analysis indicated that

During the vegetative growth period, maximum temperature and temperature range had a negative correlation whereas rainfall had a positive correlation, with grain yield.

2. During the reproductive stage, relative humidity had a positive correlation whereas, wind speed had a negative correlation with grain yield.

3. During the grain filling stage, minimum temperature had a strong positive correlation with grain yield

4. During the maturity period, maximum temperature and temperature range had a strong negative correlation with grain yield.

Because of the multi-colinearity of variables, only five weather elements ie. maximum temperature (TX) during the vegetative period, relative humidity (RH) and wind speed (WS) during the reproductive stage, minimum temperature (TN) during the grain filling stage and temperature range (TR) during the maturity stage were selected, while working out the multiple regression equation. The regression equation for the closer spacing (S_1) is

$$Y = -563.41\ TX + 303.95\ TN - 81.56\ TR - 135.54\ RH - 193.52\ WS + 25044.74$$

The regression equation for the wider spacing S_2 is

$$Y = -625.51\ TX + 323.56\ TN - 126.42\ TR - 113.12\ RH - 88.54\ WS + 24543.03$$

The multiple correlation coefficient, for S_1 (20 x 10 cm) and S_2 (20 x 15 cm) were 0.984 and 0.941 respectively. For S_1, about 97 per-cent and for S_2, about 89 per cent of total variation in the yield could be explained by the regression.

For a better understanding of the influence of time of planting and spacing on the grain yield, analysis of variance is made for the two seasons virippu and mundakan respectively and presented in Appendix VI. The mean values are presented in Table 11 b.

The effects due to both the times of planting and spacing were highly significant in the mundakan season. October 22nd planting was found to be the best time of planting. The closer spacing was found to be significantly superior to wider spacing. In the virippu season, the effects due to time of planting and spacing were not significant.

Table - 11 (b). Effect of time of planting and spacing on grain yield in (1) Virippu and (2) Mundakan seasons

Treatments	Grain yield kg ha^{-1}		
	S_1 (20 x 10 cm)	S_2 (20 x 15 cm)	Mean
1. T_1 (June 18th planting)	2705.33	2958.00	2831.67
T_2 (July 2 ")	3041.33	3194.33	3117.83
T_3 (July 16th ")	2777.67	2889.00	2833.33
T_4 (July 30th ")	2663.67	2930.67	2797.17
T_5 (August 13th ")	2875.00	2694.33	2784.67
T_6 (August 27th ")	3013.67	2764.00	2888.83
Mean	2846.11	2905.06	
SEm±	213.79227	213.79227	144.47131
CD (0.05)	Ns	Ns	Ns
2. T_7 (September 10th")	2417.00	2319.67	2368.33
T_8 (September 24th ")	2222.33	1750.00	1986.17
T_9 (October 8th ")	2777.67	2222.00	2499.83
T_{10} (October 22nd ")	2861.33	2916.67	2889.00
T_{11} (November 5th ")	2347.33	2208.33	2277.83
T_{12} (November 19th")	1583.33	1277.67	1430.50
Mean	2368.17	2115.72	
SEm±	248.88815	248.88815	185.00937
CD (0.05)	549.06606	549.06606	412.20083

h) Straw yield

The analysis of variance for straw yield is presented in Appendix V and the mean values in Table 11 a and Figs. 7 and 8.

The time of planting greatly influenced the straw yield. Highest straw yield (4767 kg ha^{-1}) was recorded by T_6 which was on par with T_2, T_3, T_5 and T_9. The lowest straw yield (2756 kg ha^{-1}) was observed in T_{12}, which was on par with T_4 and T_8. The effects due to spacing and interaction between time of planting and spacing were found to be non-significant.

Correlation coefficients between straw yield and weather parameters are given in Table 13. The correlation studies with overlapping periods indicated a difference between the two spacings with regards to the influence of weather elements on the straw yield. For the wider spacing S_2, maximum temperature during the vegetative and ripening period, temperature range during the vegetative and maturity periods, wind speed during the vegetative and reproductive periods had a significant negative correlation with straw yield. Whereas, rainfall and relative humidity during the vegetative period, and minimum temperature during the grainfilling stage had a significant positive correlation. For the closer spacing S_1, minimum temperature during the grainfilling stage had a significant positive correlation with straw yield.

Table - 13. Correlation coefficient between weather parameters and straw yield

Weather parameters	Spacing	Period	Correlation coefficient
Maximum temperature	S_1	Vegetative	-0.374
"	S_2	"	-0.724**
"	S_1	Ripening	-0.393
"	S_2	"	-0.743**
Minimum temperature	S_1	Grain filling	+0.592*
"	S_2	"	+0.862**
Temperature range	S_1	Vegetative	-0.383
"	S_2	"	-0.675*
"	S_1	Maturity	-0.439
"	S_2	"	-0.782**
Rainfall	S_1	Vegetative	+0.461
"	S_2	"	+0.710**
Wind speed	S_1	Vegetative	-0.475
"	S_2	"	-0.721**
"	S_1	Reproductive	-0.514
"	S_2	"	-0.701*
Relative humidity	S_1	Vegetative	+0.419
"	S_2	"	+0.708**

* Significant at $p = 0.05$ ** Significant at $p = 0.01$

i) Drymatter production

The analysis of variance for drymatter production is presented in Appendix V and the mean values are given in Table 14.

The effect of time of planting is highly significant on drymatter production. The highest drymatter production (7656 kg ha^{-1}) was recorded by T_6 which was on par with T_1, T_2, T_3, T_5 and T_9 and the lowest was recorded by T_{12} (4186 kg ha^{-1}). The effects due to spacing and interaction between time of planting and spacing were found to be non-significant.

Correlation coefficients between drymatter production and weather parameters are presented in Table 15. The correlation analysis had shown a difference between S_1 (20 x 10 cm) and S_2 (20 x 15 cm) with regards to the influence of weather elements on drymatter production. For the wider spacing S_2, maximum temperature during the vegetative and ripening periods, temperature range during the vegetative and maturity periods, wind speed during the vegetative and reproductive periods had a significant negative correlation with drymatter production. Whereas, rainfall and relative humidity during the vegetative period, and the minimum temperature during the grain filling stage had a significant positive correlation. For the closer spacing S_1, wind speed during the vegetative and reproductive periods, and temperature range during the maturity period had a significant negative correlation. A significant

Table - 14. Effect of time of planting and spacing on yield characters

Treatments	Drymatter production (kg ha^{-1})	Thousand grain weight (g)	Harvest index	Grain straw ratio
T_1 (June 18th planting)	6826.17	30.03	0.41900	0.72717
T_2 (July 2nd ")	7623.50	31.47	0.40983	0.69600
T_3 (July 16th ")	7127.83	30.83	0.39867	0.66550
T_4 (July 30th ")	6136.17	31.40	0.45567	0.83817
T_5 (August 13th ")	7507.00	30.63	0.37217	0.59367
T_6 (August 27th ")	7655.50	30.37	0.37850	0.60917
T_7 (September 10th ")	5824.00	29.15	0.40783	0.69100
T_8 (September 24th ")	5158.50	28.33	0.38300	0.62717
T_9 (October 8th, ")	6788.67	29.23	0.36733	0.58133
T_{10} (October 22nd ")	5916.67	29.28	0.42833	0.75150
T_{11} (November 5th ")	5826.33	26.24	0.39200	0.65283
T_{12} (November 19th")	4186.17	29.03	0.34017	0.51767
SEm±	460.96109	0.21639	0.01585	0.04295
CD (p = 0.05)	956.03322	0.63470	0.03287	0.08907
S_1 (20 x 10 cm)	6451.67	29.62389	0.39708	0.66531
S_2 (20 x 15 cm)	6311.08	29.71111	0.39500	0.65989
SEm±	175.32671	0.09598	0.00619	0.01763
CD (p = 0.05)	Ns	Ns	Ns	Ns

Fig. 9 EFFECT OF TIME OF PLANTING ON DRY MATTER PRODUCTION

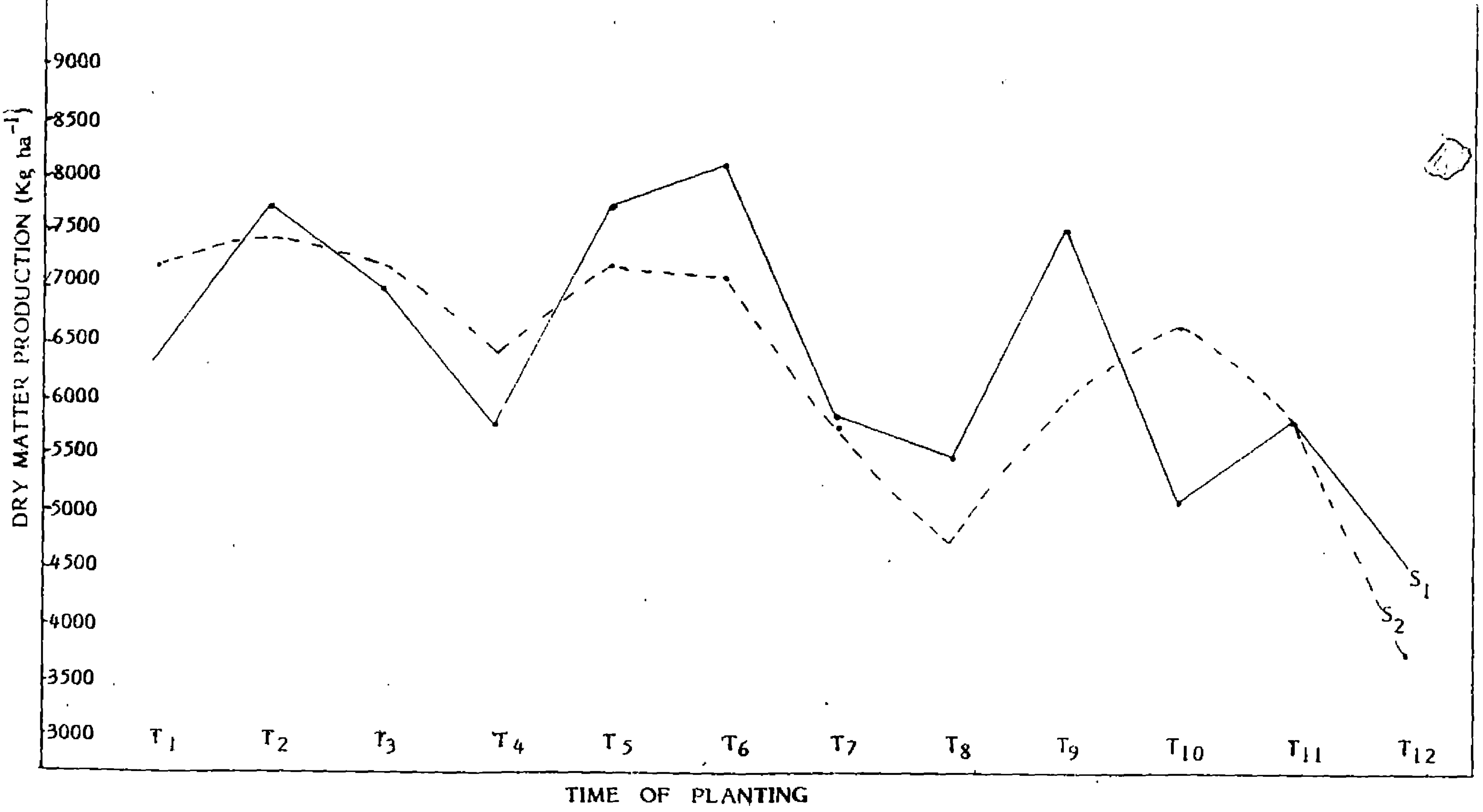


Table - 15. Correlation coefficients between weather parameters and drymatter production

Weather parameters	Spacing	Period	Correlation coefficient
Maximum temperature	S_1	Vegetative	-0.480
"	S_2	"	-0.771**
"	S_1	Ripening	-0.540
"	S_2	"	-0.809**
Minimum temperature	S_1	Grain filling	+0.725**
"	S_2	"	+0.903**
Temperature range	S_1	Vegetative	-0.496
"	S_2	"	-0.717**
"	S_1	Maturity	-0.585*
"	S_2	"	-0.842**
Rainfall	S_1	Vegetative	+0.519
"	S_2	"	+0.714**
Wind speed	S_1	Vegetative	-0.612*
"	S_2	"	-0.746**
"	S_1	Reproductive	-0.639*
"	S_2	"	-0.732**
Relative humidity	S_1	Vegetative	+0.538
"	S_2	"	+0.742**

* Significant at $p = 0.05$ ** Significant at $p = 0.01$

positive correlation was observed between the drymatter production and minimum temperature during the grainfilling stage.

j) Thousand grain weight

The analysis of variance for thousand grain weight is presented in Appendix V. The mean values of thousand grain weight are presented in Table 14.

T_2 recorded the highest weight (31.5 g) which was on par with T_4 and the lowest value (26.2 g) was recorded by T_{11}. The effects due to spacing and interaction between time of planting and spacing were not significant.

k) Harvest index

The analysis of variance for harvest index is presented in Appendix V and the mean values in Table 14.

The time of planting greatly influenced the harvest index. T_4 recorded highest harvest index (0.456) which was on par with T_1 and the lowest value (0.340) was recorded by T_{12} which was on par with T_5 and T_9. The effects due to spacing and interaction between time of planting and spacing were found to be non-significant.

l) Grain straw ratio

The analysis of variance for grain straw ratio is presented in Appendix V and the mean values in Table 14.

The time of planting significantly influenced the grain straw ratio and the highest grain straw ratio (0.838) was recorded by T_4 which was on par with T_{10} and the lowest value (0.518) was observed in T_{12} which was on par with T_5 and T_9. The effects due to spacing and interaction between time of planting and spacing were not significant.

4.2 Crop weather diagram

The crop weather diagram is a factual summary of the week by week progress of the crop growth and the weather conditions experienced by it. The crop planted on July 2nd (T_2) and that planted on October 22nd (T_{10}) recorded highest yields in virippu and mundakan seasons respectively. Hence, the crop and meteorological data for T_2 and T_{10} were considered for preparing the crop weather diagrams for virippu and mundakan seasons. The crop weather diagram for virippu is presented in Fig. 12 and that for mundakan in Fig. 13.

4.3. Weather and incidence of pests, diseases and nematodes

In the early plantings, incidence of pests like leaf roller and rice bug, and brown spot disease were noticed. Whereas, late planted crop

CROP : PADDY

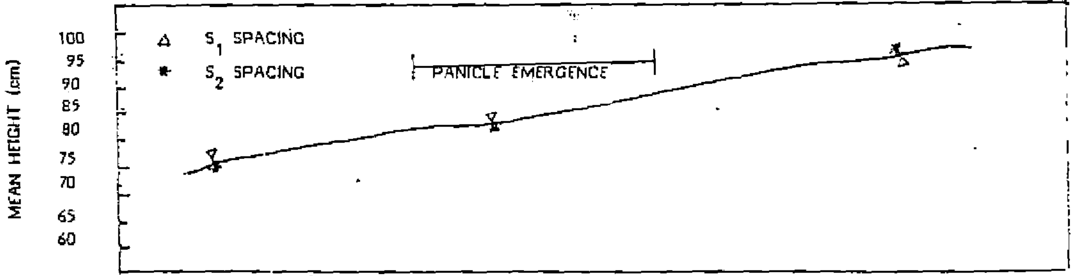
YEAR : 1988-'89

FIG. 12. CROP WEATHER DIAGRAM FOR VIRIPPU SEASON

STATE : KERALA
STATION : VELLANIKKARA
LAT : 10°31'N LONG : 76°13'E

MONTHS			JUNE					JULY				AUGUST				SEPTEMBER			OCTOBER		
STANDARD WEEKS			23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
WEATHER DATA: Average for the week, Temperature °C	MAXIMUM	A	29.1	30.4	30.3	29.7	30.4	29.6	28.2	27.6	29.9	28.9	28.2	29.7	29.6	29.6	30.5	29.6	39.7	30.4	31.8
		N	30.4	29.8	29.3	29.1	28.4	28.7	28.5	28.4	28.6	28.9	28.9	29.3	29.6	29.9	30.0	29.9	27.9	30.3	30.6
	MINIMUM	A	23.4	23.9	23.9	22.6	23.1	23.4	22.8	23.3	24.5	23.9	24.3	24.6	23.6	23.6	23.4	23.4	22.4	23.4	23.3
		N	23.7	23.5	23.1	23.1	22.8	23.1	22.8	23.1	22.8	22.9	23	23	22.9	23.7	23.3	23.2	23.3	23.6	23.4
	RELATIVE HUMIDITY(%)	A	94	85	85	85	83	87	93	88	86	88	89	84	84	85	85	86	85	82	78
		N	86	86	87	87	89	88	89	89	90	87	87	86	84	88	83	84	83	83	81
	WIND SPEED (Km h^{-1})	A	7.4	5.5	3.7	3.9	4.3	4.0	4.5	3.3	1.7	6.2	4.3	4.1	3.5	3.5	4.3	4.9	3.5	3.6	3.4
		N	3.2	3.2	3.0	3.2	2.9	3.3	2.9	3.2	3.4	3.6	3.5	3.6	3.3	3.4	3.5	3.1	3.0	2.8	2.7
	BRIGHT SUNSHINE HOURS (Total for the week)	A	10.3	43.9	33	27.4	46.5	28.1	2.1	3.2	25.5	20.6	22.7	35.6	27	34.4	42.4	28.5	30.7	45.6	53.8
		N	29	25	21	17.0	13	17	15	7	17	20	21	23	27	34	33	29	29	33	35
	PAN EVAPORATION (Average for the week)	A	2.2	3.7	2.8	2.8	3.5	2.9	1.5	2.1	2.9	2.8	2.6	3.6	3.5	3.1	3.1	3.6	3.7	3.7	4.1
		N	5.1	3.5	3.3	2.7	2.7	3.4	3.0	3.8	3.3	3.1	3.3	3.3	3.4	3.6	3.9	3.4	3.9	3.3	3.2
	RAINFALL (mm) (Total for the week)	A	144	58	103	154	20	105	246	135	90	61	178	72	201	154	114	240	123	30	20
		N	151.7	149.7	172.1	176.7	240.9	169.7	182.8	189.9	147.0	131.3	104.3	75.4	64.7	60.0	65.3	63.3	74.9	53.1	30.4
	NUMBER OF RAINY DAYS	A	6.0	5.0	7.0	6.0	4.0	6.0	7.0	7.0	5.0	6.0	7.0	5.0	6.0	4.0	5.0	7.0	6.0	3.0	3.0
		N	5.1	5.4	5.6	5.8	6.1	5.8	5.7	5.8	5.6	5.4	5.3	4.4	3.5	3.7	3.1	3.3	3.5	2.9	2.4
WEATHER REMARKS	CULTURAL OPERATIONS						Manuring				Gap filling		Panicle initiation manuring								Harvest

CROP DATA [ACTUAL]		S1	S2			S1	S2
Dates of	TRANSPLANTING	July 2	July 2	NUMBER	30 DAT	9	10
	PANICLE INITIATION	Aug 19	Aug 19	OF	60 DAT	12	12
	FLOWERING	Aug 31	Aug 31	TILLERS	90 DAT	14	14
	HARVEST	Oct 10	Oct 10	HEIGHT	30 DAT	70.3	68.3
Duration from transplanting	PANICLE INITIATION	48	48	OF	60 DAT	81.8	81.1
	FLOWERING	12	12	PLANT (cm)	90 DAT	96.6	100.8
	HARVEST	40	40	At harvest	No. of Prod. Tillers	11	11
					No. of spikelets/panicle	110	123
					% of filled grains	76	77



YIELD (kg ha^{-1})	S_1	S_2
GRAIN	3041	3194
STRAW	4722	4289
DRY MATTER PRODUCTION	7764	7483

	S_1	S_2
THOUSAND GRAIN WEIGHT (g)	31.3	31.7
HARVEST INDEX	0.392	0.427
GRAIN STRAW RATIO	0.645	0.747

CROPNOTE / SPECIAL REMARKS

The crop experienced moderate weather conditions through out the growth period. Moisture supply was amble enough, during the later stages, to sustain the following low rainfall period. No serious incidence of pests and diseases were noticed.

ROTATION : PADDY/PADDY

SEED RATE : 80 kg ha^{-1} (2 SEEDLINGS/hill)

SPACING S_1 - 20 x 10 cm
S_2 - 20 x 15 cm

TOTAL MANURES (kg ha^{-1})

FYM	5000
UREA	208.7
SUPER PHOSPHATE	250
MURIATE OF POTASH	75

CROP : PADDY
YEAR : 1988-'89

FIG. 13. CROP WEATHER DIAGRAM FOR MUNDAKAN SEASON

STATE : KERALA
STATION : VELLANIKKARA

LAT : 10°31'N LONG : 76°13'E

MONTHS			SEPTEMBER		OCTOBER				NOVEMBER				DECEMBER				JANUARY		
STANDARD WEEKS			39	40	41	42	43	44	45	46	47	43	49	50	51	52	1	2	3	4
Average for the week Temperature (°C)	MAXIMUM	A	29.7	30.4	31.8	31.8	31.7	33.3	31.3	33.2	32.6	32.6	31.9	33.4	32.6	33.0	33.0	33.3	33.1	33.6
		N	29.9	30.3	30.6	30.7	30.8	31.1	31.2	31.2	30.9	31.1	30.7	30.8	30.7	31.1	31.5	31.9	32.3	32.8
	MINIMUM	A	22.4	23.4	23.3	24	22.8	23.4	23.9	23.2	22.6	20.1	22.7	22.8	23.2	21.7	23.5	21.2	22.7	21.2
		N	23.9	23.6	23.4	23.3	23.4	23.1	23.2	22.1	22.9	22.6	22.6	21.8	21.9	21.8	21.1	21.3	21.5	21.6
	RELATIVE HUMIDITY %	A	89	82	78	77	78	71	70	68	66	65	66	63	50	54	54	57	56	49
		N	83	82	81	82	83	80	75	72	71	68	68	66	66	63	59	57	57	68
	WIND SPEED (km h^{-1})	A	3.5	3.6	3.4	3.3	7.3	4.4	9.1	5.4	4.6	5.6	6.5	6.8	14.6	13.9	3.5	10.6	12.3	7.2
		N	3.0	3.8	2.7	3.0	2.7	2.7	3.7	4.8	6.3	6.7	7.4	8.1	9.8	9.8	9.4	9.5	10.7	9.4
WEATHER DATA	BRIGHT SUNSHINE HOURS (Total for the week)	A	30.7	46.2	53.8	53.3	42.1	56.4	39.3	64.8	53.8	55.9	50.1	65.3	51.9	82.3	67	61.8	40.2	51.9
		N	29.0	33	35	34	37.0	40	46	50	51.0	53	44	53.0	52	62.0	57	62.0	64.0	62.0
	PAN EVAPORATION (mm) (Average for the week)	A	3.7	3.7	4.1	3.8	3.3	3.8	3.7	3.9	3.8	3.9	4.8	4.6	9.8	7.8	8.8	8.1	7.7	7.3
		N	3.9	3.3	3.2	3.5	3.3	3.6	3.7	3.9	4.5	4.5	4.6	4.7	5.5	5.9	6.0	6.1	7.3	6.6
	RAINFALL (mm) (Total for the week)	A	123	30	20	7.0	60	7	2.0	2.0	0	0	3.0	12.0	0	0	0	0	0	0
		N	74.9	53.1	54.4	63.1	51.9	52.5	30.3	21.6	27.0	7.0	6.0	9.2	2.4	1.8	0	0	7	2.7
	NUMBER OF RAINY DAYS	A	6.0	3.0	3.0	1.0	2.0	1.0	1.0	0	0	1.0	1.0	0	0	0	0	0	0	0
		N	3.5	2.7	2.4	3.3	2.3	2.6	1.5	1.2	1.0	0.3	0.7	0.4	0.1	0.1	0	0	0.1	0.1

WEATHER REMARKS

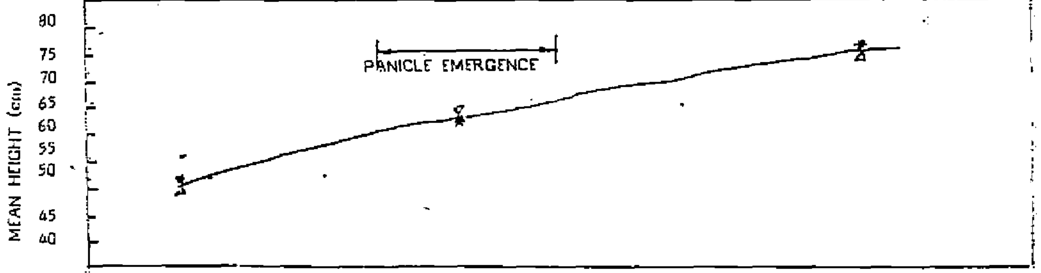
CULTURAL OPERATIONS

Manuring
Gap filling
Panicle initiation manuring
HW HW HW HW HW
Harvest

CROP DATA (Actual)

		S_1	S_1
Dates of	TRANSPLANTING	Oct 22	Oct 22
	PANICLE INITIATION	Dec. 9	Dec. 10
	FLOWERING	Dec 23	Dec 26
	HARVEST	Jan 23	Jan 25
Duration from transplanting	PANICLE INITIATION	48	49
	FLOWERING	14	16
	HARVEST (Days)	31	30

		S_1	S_1
NUMBER OF TILLERS AT	30 DAT	6	6
	60 DAT	7	8
	90 DAT	8	9
HEIGHT OF PLANT (cm) AT 90 DAT	30 DAT	49.8	53.5
	60 DAT	66.2	65.4
	90 DAT	78.8	79.4
At harvest	NO. OF PROD. TILLERS	6	7
	No. of spikelets/panicle	113	121
	% of filled grains	78	72



YIELD (kg ha^{-1})

	S_1	S_2
GRAIN	2861	2917
STRAW	3944	3778
DRY MATTER PRODUCTION	5139	6694

	S_1	S_2
THOUSAND GRAIN WEIGHT (g)	29.2	29.4
HARVEST INDEX	0.420	0.436
GRAIN STRAW RATIO	0.726	0.775

CROP NOTE/SPECIAL REMARKS

The crop experienced comparatively higher temperature ranges during later stages. Low humidity and high winds affected the crop adversely. The crop also experienced rainless days in later periods. Pests and diseases occured were effectively controlled.

ROTATION : PADDY/PADDY

SEED RATE : 80 kg ha^{-1}
(2 Seedlings/hill)

SPACING : S_1 - 20 x 10 cm
S2 - 20 x 15 cm

TOTAL MANURES (kg ha^{-1}) : FYM : 5000
UREA : 208.7
SUPER PHOSPHATE: 250
MURIATE OF POTASH : 75

was infested by pests like gall midge, brown plant hopper, rice bug and diseases like blast and sheath rot. September 24th planting (T_8) was highly infected with pests and diseases. Late plantings showed high attack of rice bug compared to early plantings. No nematode incidence was noticed.

Plate 1. A view of the experimental field

Discussion

Plate 1. A view of the experimental field

Discussion

DISCUSSION

An experiment to study the influence of weather parameters on growth and yield of rice variety Jaya was conducted during May, 1988 to February, 1989 at Agricultural Research Station, Mannuthy.

The results of the experiment are discussed below :

5.1 Effect of time of planting, spacing and weather on growth and yield of rice

5.1.1 Growth characters

(a) Height of plant :

The results indicate that mean height of plant at 30, 60 and 90 days after planting were significantly influenced by time of planting. The mean plant height showed a slight decreasing trend with delay in planting markedly in the later stages of growth. This is in agreement with the findings of Misra and Khan (1973), Majid and Ahmed (1975), Latif (1982) and Krishnakumar (1986). Regarding the spacing effects, at 30 and 90 DAT they did not show any significant difference. At 60 DAT, closer spacing of 20 x 10 cm produced significantly taller plants in the virippu season and the wider spacing (20 x 15 cm) was better in the mundakan season. Regarding the influence of weather, the plant height at 30 DAT was very slightly influenced, whereas, in the later stages, higher temperature always decreased the plant height irrespective of he spacings.

This is in confirmity with the findings of Lin (1976), Kang and Heu (1976). The diurnal temperature range was also negatively correlated with the plant height indicating that the rice crop requires moderate day and night temperatures for proper vegetative growth.

b) Number of tillers :

Generally, early plantings recorded higher number of tillers at all stages of crop growth. The number of tillers at harvest was slightly lower than that at 90 DAT, probably due to mutual shading resulting from the increased leaf area index after maximum tillering stage. This is in agreement with the findings of Krishnakumar (1986). At 30 DAT, the effects due to spacing did not show any significant difference in number of tillers. At 60 DAT, 90 DAT and at harvest, wider spacing (S_2) recorded more number of tillers. In wider spacing over crowding and competition for nutrients were reduced and the light transmission was better. Similar results were obtained in the experiments conducted at the Regional Agricultural Research Station, Pattambi. (RARS, 1975) This also confirms the findings of Usha (1985). Rainfall combined with relative humidity, generally increased the number of tillers at various stages of crop growth. High temperature throughout the crop growth period decreased the number of tillers. This is probably due to the fact that high temperature will decrease the carbohydrate per plant leading to low tiller production. This is in confirmation with the findings of Sato (1972) and krishnakumar (1986).

(c) Duration of growth stages :

The duration of various growth stages was influenced by the time of planting. Spacings did not show any significant influence on duration of growth stages. The duration from transplanting to panicle initiation did not show much variation among the treatments, probably due to the similar weather conditions experienced during this period. However, the period from transplanting to flowering had shown a slight increase in duration with delay in planting. Palaniswamy et al. (1968) reported similar result. The late planted crop took significantly lesser number of days from flowering to harvest. Low rainfall and relative humidity, high maximum temperature and temperature range, and more number of bright sunshine hours shortened the duration of this period for late planted crops. At high temperature, translocation of photosynthates to grain takes place at a faster rate and thus maturity gets shortened. This is in agreement with the findings of Boerma (1974) and Krishnakumar (1986).

5.1.2 Yield Characters

(a) Number and percentage of productive tillers :

The number and percentage of productive tillers showed a decreasing trend with delay in planting. Mahapatra and Badekar (1968), Halappa *et al.* (1974) and Ramdoss and Subramaniam (1980) reported similar results. The spacings did not show any significant difference in number and percentage of productive tillers.

Late planted crop experienced higher maximum temperature and lower minimum temperature and hence, higher temperature range throughout the crop growth period. Particularly, during the later stages of crop growth, the late planted crop experienced 4 - 5°C higher maximum temperature and 2-3°C lower minimum temperature. The temperature range during this period for the late planted crop was almost twice that of the early plantings. Rainfall was low and particularly during the later stages of crop growth, it was almost nil for the late plantings. Relative humidity was also very low during that period. All the above, probably contributed to the reduction in the number and percentage of productive tillers. This is in agreement with the findings of Osada *et al.* (1973) and Lin (1976).

(b) Length of panicle :

Early planted crop produced slightly longer panicles compared to late planted crop. Similar results are reported by Mahapatra and Badekar (1968), Ramdoss and Subramanian (1980) and Krishnakumar (1986). Spacings did not show any significant difference in the length of panicle.

(c) Number of spikelets and filled grains per panicle, and percentage of filled grains :

The number of spikelets per panicle was influenced by the time of planting. However, there was no particular trend observed in the present study. Spacings also did not show any significant difference in number of spikelets per panicle.

The number and percentage of filled grains reduced slightly with delay in planting. Similar results were reported by Palaniswamy et al. (1968), Majid and Ahmed (1975), Liou (1975), Nho et al. (1976) and Krishnakumar (1986). Spacings did not show any significant difference in the number and percentage of filled grains. Higher maximum and lower minimum temperatures during the later period might be the reason for the lesser number of filled grains in the later plantings. This is in agreement with the findings of Kando (1975), Hayase et al. (1969) and Satake and Yoshida (1978). Another reason for the significant lower number of filled grains in later plantings is that source was a limiting factor compared to higher sink. Higher wind speeds and temperature during the period from heading to ripening phase of late planted crops increased the spikelet sterility through higher evaporation rate and disiccation of the spikelets. This decreased the percentage of filled grains. Similar result was reported by Krishnakumar (1986).

(d) Grain yield :

Delay in planting, generally had a negative effect on grain yield. Similar results were reported by Mahapatra and Badekar (1968), Liou (1975), Majid and Ahmed (1975), Nho et al. (1976), Halappa et al. (1979), Ramdoss and Subramaniam (1980) and Krishnakumar (1986).

Among the plantings, T_2 recorded the highest mean grain yield of 3118 kg ha^{-1}. For this treatment, the number of filled grains and the thousand grain weight were superior to others, thus responsible for the highest grain yield. Next highest yield of 2889 kg ha^{-1} was observed for T_{10}. The late planted crop (T_{12}) recorded the lowest yield of 1431 kg ha^{-1} . The variations in the weather conditions at different stages of late planted crop were comparatively more to those of the early plantings. This is particularly true for November 19th planting. This planting experienced fairly good weather conditions during the initial stages. However, it experienced, high temperature ranges, lower rainfall and humidity in the later growth stages. The crop also experienced high winds which increased the pollen dehydration and sterility. These unfavourable weather conditions might be the reason for the very low yield recorded by this planting. Similar results were reported by Choudhary and Ghildyal (1970), Boerma [illegible] (1975), Balakrishna Pillai and Prabhakaran (1978) and Viswambharan _et al._ (1989).

Multiple regression equations developed between grain yield and important weather parameters for both the spacings could explain more than 89 percent of variations in the yield. Figure 10 and 11 show that the estimated yield from the multiple regression equation is in general agreement with the actual yield.

Though, there was a slight decreasing trend in the grain yield with delay in planting, a closer examination of the data revealed two small peaks in yield, one in the virippu season and the other in the mundakan season, indicating the two optimum time of transplanting in the two seasons. Transplanting on 2nd July and 22nd October was found to be the best for getting highest grain yields in the virippu and mundakan seasons respectively. Similar results were reported by Singh and Paliwal (1980), MAEC (1980), ARS (1981), singh and Garg (1983) and KAU (1985). In the mundakan season, closer spacing appeared to be superior. This is in agreement with the findings of RARS (1975), Devi _et al._ (1981), Usha (1985) and Balasubramaniam and Vaithalingam (1985).

Fig. 10. ACTUAL AND ESTIMATED GRAIN YIELD FOR DIFFERENT TREATMENTS (S_1 SPACING)

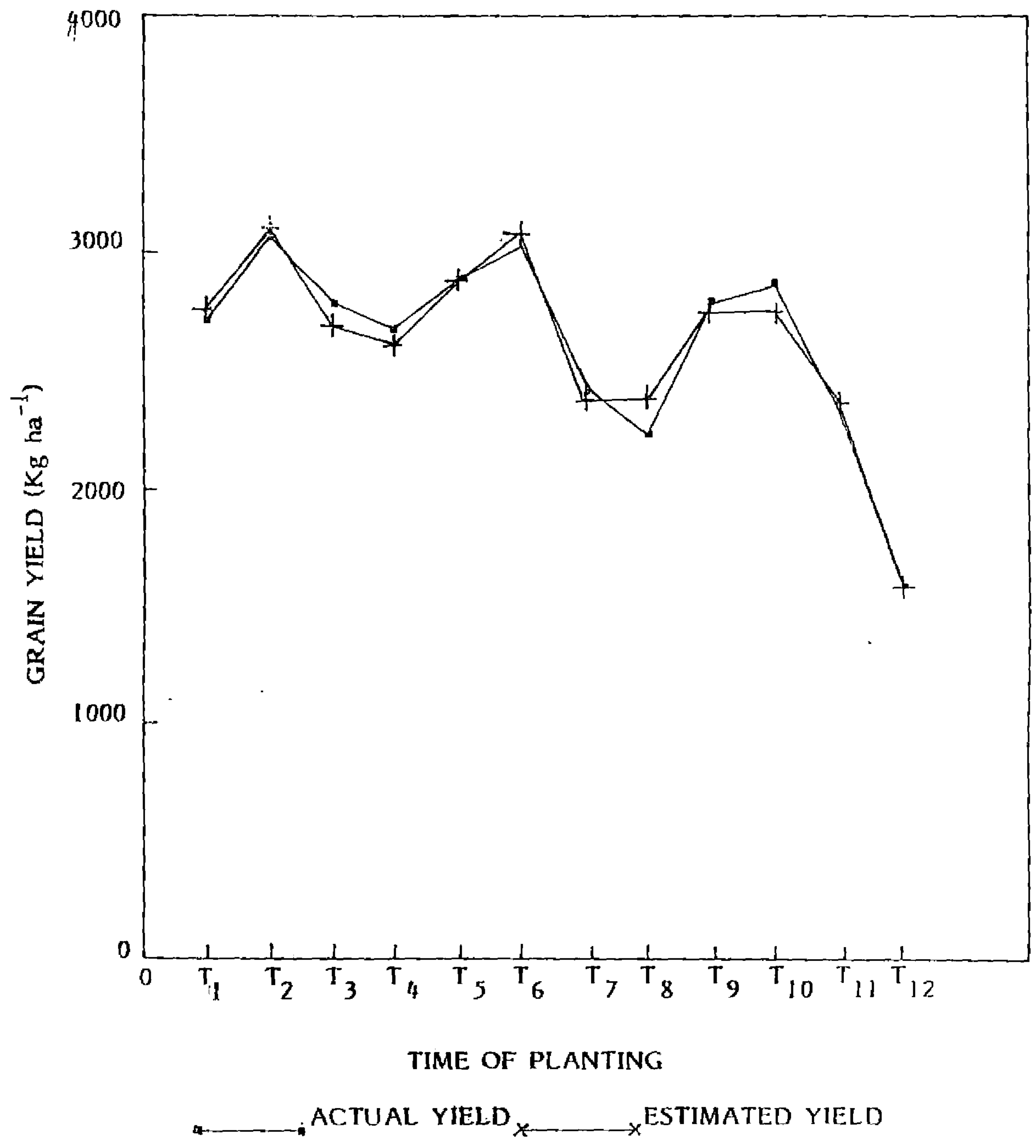
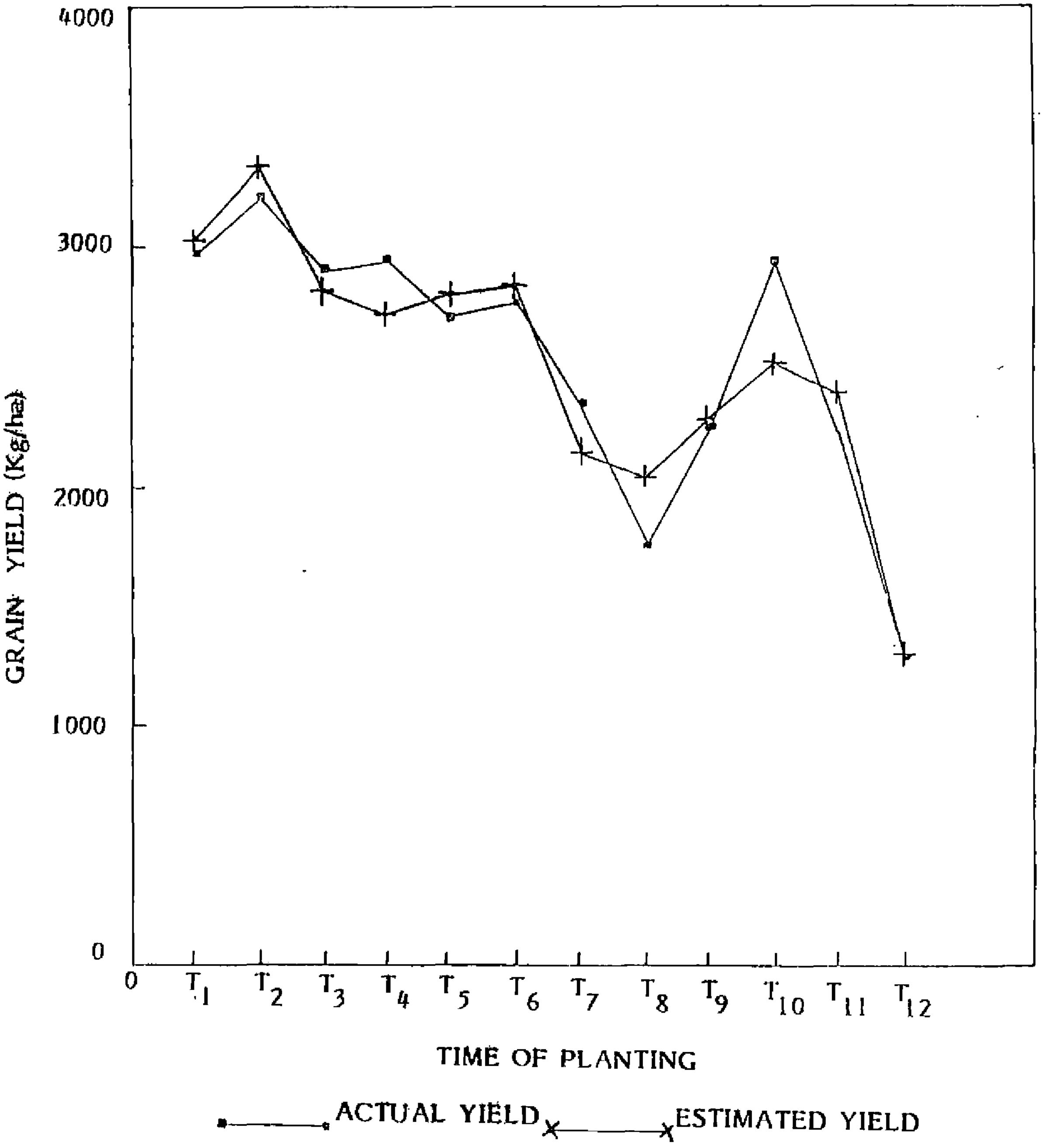


Fig. 11. ACTUAL AND ESTIMATED GRAIN YIELD FOR DIFFERENT TREATMENTS (S_2 SPACING)



(f) Straw yield :

Straw yield showed a slight decreasing trend with delay in planting. Palaniswamy *et al.* (1968) and Krishnakumar (1986) also reported similar results. Spacings did not show any significant difference in straw yield. However, closer spacing had produced comparatively higher straw yield due to the increased plant density. This is in confirmation with the findings of Rao and Raju (1983). Compared to the early plantings, late planted crop experienced higher maximum temperature throughout the growth period, particularly during the vegetative and ripening periods. Temperature range was also high during the vegetative and maturity periods. Also the later plantings experienced higher wind speeds during vegetative and reproductive stages. The early plantings received more rainfall and thus higher relative humidity in the vegetative period. Also they experienced moderate minimum temperatures during the grain filling stage. The decreased straw yield in the later plantings is probably due to the distinct difference in the weather conditions experienced, as mentioned above, compared to the early plantings. It is also interesting to note that compared to the closer spacings the wider spacing responded more to the variations in weather in respect of straw yield.

(g) Dry matter production :

Generally, a slight decreasing trend in dry matter production with delayed plantings was observed. This is in agreement with the findings of Krishnakumar (1986). Favourable weather conditions during the vegetative and reproductive periods were responsible for the luxurious vegetative growth in early plantings. Also, comparatively lower temperatures during the flowering and grain filling stage resulted in higher net photosynthate production. This was exhibited through production of lengthy panicles and higher number of filled grains per panicle. This is in confirmation with the findings of Lin (1975), Faw and Johnson (1975), and Lerch (1976). Higher plant density (S_1) recorded higher dry matter production. This confirms the findings of Yamada (1961), IRRI (1970), Krishnakumar (1986) and Gautham Sharma (1987).

(h) Thousand grain weight :

The thousand grain weight was found to show a decreasing trend with delay in planting. This is in agreement with the findings of Rajagopalan _et al._ (1973), Faw and Johnson (1975), Suryanarayana _et al._ (1975), Lin (1975), and Krishnakumar (1986). The spacings did not show any significant difference in thousand grain weight.

The probable reason for the decreasing trend may be the unbalanced source-sink relation in the late planted crops. The late plantings experienced comparatively higher maximum temperature during the ripening period which shortened the grain filling and maturity stages leading to lesser grain weight. High air temperature accelerates the development of kernel in early stage of ripening period but depresses them at later stages. This hastens the ripening process and reduces the grain weight. This is in confirmation with the findings of Murata (1964), Nagato et al. (1966) and IRRI (1980).

(i) Harvest index :

Harvest index showed a decreasing trend with delay in planting. Spacing did not show any significant difference in harvest index. The higher harvest index in the early plantings indicates that a higher portion of photosynthates was translocated to sink.

(j) Grain straw ratio :

Grain straw ratio showed a decreasing trend with delay in planting. This decreasing trend indicates that the translocation of stored photosynthates to the straw increased with delay in planting and also that net photosynthetic production was lower in late planted crops. Spacings did not show any significant difference in grain straw ratio.

5.2 Crop weather diagram

Crop weather diagram for the virippu and mundakan seasons are shown in fig. 12 & 13. The upper part of the diagrams show, week by week values of different weather elements, together with their normals. Abnormalities of rainfall are underlined. Heavy rains (rainfall twice the normal when actual exceeded 5mm) and low rains (rainfall half the normal when normal exceeded 5mm) are indicated wherever necessary. High winds of more than 15 km hr^{-1} were also indicated. The lower part of the diagram depicts the life history of the crop from sowing to harvest. Suitable insets are provided for information on grain and straw yield. Various operations followed during the progress of the crop are denoted by arrow heads. To aid the assessment of crop performance, a short note is provided on the weather experienced by the crop and the occurence of pests and diseases. Performance of the crops in the virippu and mundakan seasons can be quickly interpreted in terms of weather by examining the crop weather diagrams.

5.3 Weather and incidence of pests, diseases and nematodes

In early plantings, lower incidence of pests and diseases were noticed compared to that in late plantings. This is in agreement with the findings of Litsinger et al. (1987). Rice bug infestation, was found to be high in late plantings. Similar result was reported by Suharto and Noch (1987). As plantings were delayed, gall midge attack was found to be severe. This is in confirmation with the findings of Uthamaswamy and Karuppuchamy (1986). Regarding the disease incidence, early plantings escaped most of the diseases whereas in late plantings, there were incidence of blast and sheath rot. Similar result was reported by Singh et al (1986) and Dhal and Chowdhary (1987).

Results of the experiment indicated that both the times of planting and spacing have a very significant influence on the growth and yield of the high yielding, medium duration rice variety Jaya. The experiment helped in identifying the optimum dates of transplanting in both virippu and mundakan seasons. Transplanting in first week of July in the virippu season and third week of October in the mundakan season can result in higher grain yields. It was also seen that early planting of the mundakan crop (in the last week of August) can also increase the yield. The results also indicated that closer spacing (20 x 10 cm) in the mundakan season will further enhance the grain yield substantially.

Summary

SUMMARY

An experiment was conducted to study the influence of weather parameters on growth and yield of rice variety Jaya during May, 1988 to February, 1989 at Agricultural Research Station, Mannuthy. In this experiment, the first transplanting was done in the middle of June and the last in the middle of November. Thus, the twelve transplantings, spread over five calendar months, covered both the virippu and mundakan seasons. The resuslts of the experiment are summarised below.

1. It was generally observed that the early planted crop had experienced similar weather conditions throughout the various growth stages. During the initial stages of crop growth, the late planted crop also experienced fairly good weather conditions. However, in the later stages, the late planted crop experienced higher temperature ranges and winds, lower rainfall and humidity and thus differed significantly from the early plantings.

2. The various growth characters like plant height and number of tillers at 30, 60 and 90 days after planting and the number and percentage of productive tillers were significantly influenced by time of planting.

3. The mean plant height showed a slight decreasing trend with delay in planting, markedly in the later stages of growth and

spacings did not affect the plant height at 30 DAT and 90 DAT. But at 60 DAT, closer spacing recorded higher plant height.

4. Correlation studies indicated that height at 30 DAT was very slightly influenced by weather parameters. Height at 60 DAT was negatively correlated with maximum temperature and temperature range. At 90 DAT, significant negative correlations were obtained between height and maximum temperature during late vegetative and ripening stages and temperature range during the total crop growth period for both the spacings. Rainfall throughout the period had a positive effect and significant positive correlation was also obtained with minimum temperature during reproductive stage.

5. Early plantings produced maximum number of tillers in both the spacings.

6. For both the spacings, at all the stages, the number of tillers had a negative correlation with maximum temperature and temperature range, and a positive correlation with rainfall and relative humidity. Minimum temperature during the reproductive stage correlated positively with the number of tillers at harvest.

7. Higher number and percentage of productive tillers were recorded by the July 2nd planting. Number of productive tillers showed a decreasing trend with delay in planting.

8. Correlation studies indicated that maximum temperature and temperature range had always a negative correlation with the number of productive tillers, whereas, minimum temperature, rainfall and relative humidity had a positive correlation.

9. The time of planting did not affect significantly the duration from transplanting to flowering but influenced the duration from flowering to harvest.

10. Studies on correlation between the various weather elements and duration of growth phases indicated that maximum temperature, temperature range and sunshine hours had strong negative correlation with the duration of the period-flowering to harvest.

11. The various yield characters like length of panicle, number of spikelets per panicle and number and percentage of filled grains were significantly influenced by timeof planting.

12. July 2nd planting recorded longer panicles which was on par with June 18th and October 8th plantings. The number of spikelets and filled grains per panicle did not show any significant trend.

13. Percentage of filled grains was influenced by time of planting and the highest and lowest values were recorded by the July 2nd and September 24th plantings respectively. Spacings did not differ significantly.

14. Correlation studies indicated that for both the spacings, the minimum temperature and the temperature range during the ripening period had a significant positive and negative correlations respectively with the percentage of filled grains.

15. The time of planting greatly influenced the grain yield. July 2nd planting recorded the highest grain yield followed by October 22nd planting and the lowest yield was recorded by the November 19th planting.

16. Correlation studies between various weather parameters and grain yield, for both the spacings, indicated the following.

    a) during the vegetative growth period, maximum temperature and temperature range had a strong negative correlation whereas, rainfall had a positive correlation,

    b) during the reproductive stage, relative humidity had a positive correlation, whereas, wind speed had a negative correlation,

    c) during the grainfilling stage, minimum temperature had a strong positive correlation and

    d) during the maturity period, maximum temperature and temperature range had a strong negative correlation.

Multiple regression equation developed between various weather parameters and grain yield for the closer spacing could explain about 97 percent of the total variation in the yield whereas, the same for the wider spacing could explain about 89 percent of the total variation.

17. Delay in planting, generally had a negative effect on grain yield. However, two small peaks were obtained in grain yield, one in the virippu and the other in the mundakan season, indicating the two optimum times of transplanting in the two seasons.

18. For the virippu season, July 2nd planting and for the mundakan season, October 22nd planting recorded highest grain yield, higher percentage of filled grains and thousand grain weight. Closer spacing (20 x 10 cm) for mundakan season was found to be better.

19. The time of planting greatly influenced the straw yield. Highest straw yield was recorded by August 27th planting which was on par with July 2nd and August 13th plantings. The lowest straw yield was observed in November 19th planting. Spacings did not show any significant difference in straw yield.

20. Correlation studies indicated that for the wider spacing maximum temperature during the vegetative and ripening periods, temperature range during the vegetative and reproductive periods

had significant negative correlations with straw yield. Whereas, rainfall and relative humidity during the vegetative period, and minimum temperature during the grain filling stage had significant positive correlations. For the closer spacing, only minimum temperature during the grain filling stage had a significant positive correlation with straw yield.

21. The effect of time of planting was significant on drymatter production. The highest drymatter production was recorded by August 27th planting which was on par with July 2nd and August 13th plantings.

22. For the wider spacing, the correlation analysis between weather parameters and drymatter production indicated significant negative correlations with maximum temperature during vegetative and ripening periods, temperature range during the vegetative and maturity periods, wind speed during the vegetative and reproductive periods. Whereas, rainfall and relative humidity during the vegetative period, and the minimum temperature during the grainfalling stage had significant positive correlation. For closer spacing, wind speed during vegetative and reproductive periods, and temperature range during the maturity period

had a significant negative correlation. A significant positive correlation was observed between the drymatter production and minimum temperature during the grain filling stage. All the other parameters had shown though not significant, a trend similar to that of wider spacing.

23. July 2nd planting recorded the highest thousand grain weight.

24. July 30th planting recorded the highest harvest index and grain straw ratio.

25. For the early plantings, incidence of pests like leaf roller and rice bug, and brown spot disease were noticed. For the late plantings, pests like gall midge, brown plant hopper and rice bug, and diseases like blast and sheath rot were noticed.

26. Crop weather diagramms prepared for the virippu and the mundakan season by taking the crop and meteorological data for July 2nd planting and October 22nd planting which recorded the highest grain yield in the virippu and the mundakan seasons respectively, indicated the performance of the crop in relation to weather.

The results of the experiment indicated that both the times of planting and spacing have a very significant influence on the growth and yield of the high yielding medium duration rice variety

Jaya. The experiment helped in identifying the optimum dates of transplanting in both virippu and mundakan seasons. Transplanting in the first week of July in the virippu season and in the third week of October in the mundakan season can give higher grain yield. The results also indicated that closer spacing (20 x 10 cm) in the mundakan season will further enhance the grain yield substantially.

References

REFERENCE

Acikgoz, N. 1987. Effect of sowing time and planting method on rice yield per day. *Int. Rice Res. Newsl.* 12(1):34.

Adiar, K.C.R., Millei, M.D. and Beachell, H.M. 1962. Rice improvement and culture in the USA. *Adv. Agron.* 14:61-104.

Balakrishna Pillai, P. and Prabhakaran, P.V. 1978. Effect of monthly weather parameters on grain yield of paddy at Pattambi in Kerala. *Paper presented at the first Indian Agrometeorological congress organised by the Indian Agrometeorological Society at the Andhra University, Waltair.*

Balasubramaniam, P. and Vaithalingam, R. 1985. Requirement of nitrogen and spacing for the long duration rice varieties. *Madras Agric J.* 72(9):537 - 538.

*Best, R. 1962. Production factors in the tropics. *Neth. J. Agric. Sci.* 10 (Special issue):347 - 353.

Bhattacharya, A.K. and De Datta, S.K. 1971. Effect of soil temperature regimes on growth characteristics, nutrition and grain yield of IR 22 rice. *Agron. J.* 63:443 - 449.

Biswas, S., Kapta, P. and Mitra, D. 1975. Studies on relation between heat unit and flowering in rice. *(Oryza sativa. L.). Indian Agric.* 19:113 - 120.

Boerma, E.B. 1974. Climatic effects on growth and yield of rice in the Murrubidgee valley of New South Wales, Australia. *Rice.* 23 : 385 - 389.

Bonneau, M. 1982. Soil temperature. In: *Constituents and Properties of Soils.* Bonneau, M. and Souchier (Eds.). Academic Press, New York, pp: 367 - 371.

*Chae, J.C., Hew, H. and Lee, J.H. 1980. Effect of air and water temperatures on the growth and nutrient uptake of rice cultivars. *J. Korean. Crop. Sci. Soc.* 25(1):14 - 19.

✓ Chandler, R.F.C. 1963. Analysis of factors affecting rice yield. *Int. Rice Commn. Newsl.* 12:1 - 17.

Chang, T.T and Vergara, B.S. 1971. Ecological and genetic aspects of photo period sensitivity and thermo period sensitivity in relation to the regional adaptability of rice varieties. *Int Rice Commn Newsl.* 20:1 - 10.

Chang, T.T. and Vergara, B.S. 1972. Ecological and genetic information on adaptability and yielding ability in tropical rice varieties. *Rice Breeding.* Inter-Philippines, pp: 431 - 453.

✓ Chatterjee, B.N., Maity, S. and Sengupta, D.C. 1969. An analysis of growth and yield of some exotic and indigenous varieties of paddy. *Proceedings of symposium on higher yield potentialities,* West Bengal, pp:1 - 13.

✓ Chatterjee, B.N. 1970. Tiller production in Paddy and its effect on grain yield. *Rice* 19:245 - 256.

Chaudhary, T.N. and Ghildyal, B.P. 1970. Influence of submerged soil temperature regimes on growth, yield and nutrient composition of rice plant. *Agron. J.* 62:281 - 285.

Chaudhary, T.N. and Sodhi, J.S. 1979. Effect of weather factors on growth of rice planted at different dates in an humid tropical area. *Rice* 28:255 - 263.

Co-ordinating Group of Rice Ecological Researches, 1978. Personal communication

C.R.R.I. 1967. Effect of weather parameters on the growth of paddy. *Central Rice Res. Inst. Rep.*, C.R.R.I. Cuttack.

De Datta, S.K. 1970. The environment of rice production in tropical rice. *Rice Production Mannual.* Revised edition. University of Philippines and International Rice Research Institute. pp:53-67

De Datta, S.K. 1981. *Principles and Practices of rice production.* John Wiley and Sons, New York, pp: 9 - 41.

De Datta, S.K. and Zarate, P.M. 1970. Environmental conditions affecting growth characteristics, nitrogen response and grain yield of tropical rice. *Biometeorology.* 4:71 - 89.

Devi, G.D., Vijayagopal, P.D. and Sasidhar, V.K. 1981. Effect of levels of nitrogen and spacing on the yield of rice. *Agric. Res. J.Kerala* 19(2):96 - 97.

Dhal, N.K. and Choudhary, N. 1987. Effect of planting time and fungicidal spray on sheath rot of rice. *Oryza* 24(3):274 - 276.

Dixit, R.S. and Singh, M.M. 1980. Response of rice to nitrogen levels and sowing times, *Int. Rice Commn. Newsl.* 30:38 - 42.

*Downey, D.A. and B.R. Wells. 1974 a. Some temperature yield relationship in Starbonnet rice - W.Ho. *Inf. Doc. C. Ag. M.* VI/INF - 4.

*Downey, D.A. and Wells, B.R. 1974 b. Heat unit accumulation and internodal measurements as an estimate of optimum nitrogen timings in rice. *W.H.O. Inf. Doc. Ag. M.* III/INF - 5.

Economic Review. 1988. Government of Kerala, Trivandrum.

*Evans, L.T. 1972. Storage capacity as a limitation on grain yield. *Rice breed. International Rice Research Institute, Philippines*: 499 - 511.

Evans, L.T. and De Datta, S.K. 1979. Relation between irradiance and grain yield of irrigated rice in the tropics as influenced by cultivar, nitrogen fertilizer application and month of planting. *Fld. Crop Res.* 2:1 - 17.

Fagi, A.A. and De Data, S.K. 1981. Environmental factors affecting nitrogen efficiency in flooded tropical rice. *Fert Res* 2:53 - 67.

Faw, W.F. and Johnson, T.H. 1975. Effect of seeding date on growth and performance of rice varieties in Arkansas. *Rep. Seri. Agric. Expt. Station.* University of Arkansas. 224 - 300.

Gao, L.Z. and Zhang, L.Z. 1977. Temperature - light response and safe sowing date for late rice varieties. *Bot. J.* 19(1):53 - 59.

Gautam., R.C. and Sharma, K.C. 1987. Drymatter accumulation under different planting schemes and plant densities of rice. *Indian J. Agric. Res.* 21 (2) : 101-109.

Ghildyal, B.P. and Jana, R. K. 1967. Agro-meteorological environment affecting rice yield. *Agron. J.* 59 : 286-287.

Ghildyal, B.P. and Kushevala, H.SA. 1987. Short term micrometeorological studies with stress tolerant and sensitive rice cultivars. *Oryza,* 24 (4): 313-335.

Ghosh, B.N. 1961. Influence of climatic factors on the growth and yield of spring (Boro) and Summer (Aus) paddies. *Indian J. agric. Sci.,* 31 : 1-10.

Gopalakrishna Pillai, 1974.Personal communication

Halappa, G., Khan, T.A., Mahapatra, M. and Venketaraman, M.N.1979. Optimum time of planting high yielding varieties of paddy in kharif season on tankfed tracts of Karnataka. *Mysore J. agric. Sci.* 8(4):158-492.

* Hall, V.L. 1966 a. Temperature and germinating seed. I. Minimum and maximum temperature for growth in four days. *Rice J.* 69:22-23.

* HayaseK.1969. Efficiencies of solar energy conversion and relating characteristics in rice varieties. *Proc. crop Sci. Soc. Japan,* 38:495-500.

Huda, A.K.S., Ghildyal, B.P. Tomar, V.S. and Jain, R.C. 1975. Contribution of climatic variables in predicting rice yield. *Agric. Meteorol.* 15 : 71-86.

I.C.I.D. 1974. World wide survey of experiments and results of consumptive use of water for irrigated rice under different soils and climatic conditions. Vol. I. *Review and Bibliography. International Commission on Irrigation and Drainage*, Central Office, 48 Nagar, Marg, Chanakyapuri, New Delhi.

I.R.R.I. 1970. *Annual Report*. 1969-70. International Rice Research Institute, LOS Banos, Philippines.

I.R.R.I. 1974. *Annual Report* 1973-74. International Rice Research Institute, Los Banos, Philippines, pp.48-63.

I.R.R.I. 1980. Effect of temperature on grain filling. *Annual Report* 1979-80. International Rice Research Institute, Philippines. 296-297.

I.R.R.I. 1980 Proceedings of symposium on Agrometeorology of the rice crop. World Meteorological Organisation and International Rice Research Institute, Los Banos, Philippines. pp. 254.

Jackson, M.L. 1958. Soil chemical analysis. Prentice Hall of India (Pvt.)Ltd., New Delhi. p. 498.

* Ishizuka, Y., Shimazaki, Y., Tanaka, A., Satake, T. and Nakayama, T. 1973. *Rice grown in a cool environment*. Food and Fertilizer Technology Centre, Taipii, Taiwan. pp. 98.

* Kang and Heu. 1976. Studies on the effect of cultural season on rice growth and yield components in Yooguan region. *Res. Rep. Rur. Dev.*Korea 18 : 79-85.

Kar, S.S.B. Varade, Subramanyam, T.K. and Ghildyal, B.P. 1976. Soil physical conditions affecting rice root growth. Bulk density and submerged soil temperature regime effects. *Agron. J.* 68 : 23-26.

K.A.U. 1980. Effect of weather parameters on some high yielding varieties of rice. *Annual Report* 1979-80. Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India. 66-67.

K.A.U. 1983 Time of planting in Rice. *Research Report (1982-'83).* Kerala Agricultural University, Vellanikkara, Trichur. pp.69.

K.A.U. 1985. Identification of factors responsible for low level production of high yielding varieties of rice during mundakan season and formulation of technology for overcoming yield decline. *Annual Reports 1983-84 and 1984-85.* Kerala Agricultural University, Vellanikkara, Trichur.

*Kim, C.Y., Lee, J.H. and Chung, K.Y. 1973. Influence of environmental conditions on the characteristic of aerial parts of rice under different seasonal culture. *Res. Rep. of Rice. Dev.* Korea. 15 : 25-34.

* Kando, 1975. Efficiency of solar energy utilization. JIBP synthesis, *Univ. Tokyo Press.* 11:187-198.

Krishnakumar, V. 1986. Agrometeorological parameters and Hydro-Nutritional Management Practices on Rice Cultivars. Ph.D. thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Latif, P.H. 1982. Differential response of two medium duration rice varieties to time of planting and graded doses of nitrogen. M. Sc. thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur. pp. 149.

Lerch, G. 1976. Effect of some climatic and agronomic factors on yield formation in rice cv. IR-8 in Cuba. *Kulturpflanzi.* 24 : 13-51.

* Lin, S.S. 1976. Effect of high water temperature on ecological and physiological status of 2nd crop rice in Taiwan. *J. agric. Assoc. of China* 95 : 24-35.

* Liou, T.M. 1975. Effect of early and later transplanting on yield components of different cultivars of India in 2nd crop. *Taiwan Agric.* Quarterly. 12(4) : 53-72.

Litsinger, J.A., Barrion, A.T.D. and Sockarana. 1987. Upland Rice insect pests. Their ecology, importance and control. *Int. Rice Research Inst. Res. Paper Series* (123) : 25-26.

✓Luxmoore, K.J., Stolzy, L.H. and Letey, J. 1970. Oxygen diffusion in the soil plant system. IV. Oxygen Concentration Profiles, respiration rate and radial oxygen losses predicted for rice roots. *Agron. J.* 62 : 329-332.

Machhi, R.M., Joshi, R.S., Raman, C. and Naik, D.L. 1984. Effect of date of transplanting and levels of Nitrogen on the yield of paddy (var. Jaya) under partially reclaimed saline soils of coastal region. *J. Indian Soc. Coastal. agric. Res.,* 2 (1) : 1-4.

M.A.R.C. 1980. Agronomic evaluation of new primising pre release varieties/ hybrids of cereals. *Annual Review 1979-80.* Model Agronomic Research Centre, Thanjavur.

M.A.R.C. 1981. Agronomic evaluation of new promising pre-release varieties/ hybrids of cereals. *Annual Report 1980-81.* Model Agronomic Research Centre, Thanjavur.

Mahapatra, I.C. and Badekar, H. 1968. *Tech. Rep.* (1967-68). Central Rice Research Institute, Cuttack. Ag. 3.3. pp.20-22.

Mahapatra, I.C. and Badekar, H. 1969. Environmental reaction of some rice cultivars. *Tech. Rep.* Central Rice Research Station, Cuttack, (1976) 3 (3) : 20-22.

Maity, K. and Mahapatra, P.K. 1988. Response of rice varieties to planting time during the dry season. *Int. Rice Res. Newsl.* 13 (4) : 15.

Majid, A. and Ahmed, S. 1975. Effect of transplanting dates on paddy yield and other plant characters in different rice varieties. *J. Agric. Res.* 13(2): 447-464.

✓ Matsubayashi, M.R. Ito, Takasi, T., Namote, T. and Yamada, N. 1963. *Theory and Practice of growing rice*. Fuji Publishing Co. Ltd., Tokyo. pp. 502.

✓* Matsushima, S., Tanaka, T. and Hoshimo, T. 1964. Analysis of yield determining process and its application to yield prediction and culture improvement of low land rice. 1. XXXI. Combined effects of air temperature and water temperature at different stages of growth on the growth and morphological characteristics of rice plants. *Proc. Corp Sci. Soc. Jpn.* 33 : 135-140.

✓ Matsushima, S. 1970. *Crop Science in Rice. Theory of yield determination and its application.* Auji Publishing Co. Ltd., Tokyo, Japan, p.379.

Mehan, I.K.,. Mushy, V.V.S., Rani, N.S. and Mahajan, P.L. 1984. Evaluation of rice varieties under different dates of sowing during winter. *Indian J. agric. Sci.* 54(5) : 345-352.

Misra, G. and Khan, P.A. 1973. Impact of photoperiod on seasonal sowing in rice. *Proc. Indian Acad. Sci.* 77 : 137-147.

Moonaw, J.C., Boldazo, P.G. and Lucas, L. 1967. Effects of ripening period environment on yields of tropical rice p. 18-25 in *Int. Rice Commun. Newsl.* (Spec. issue) Symposium on problems in development and ripening of rice grain. 11th Pacific Science Congress, Tokyo, 1966.

* Moraes, J.F. 1978. Arroz de Sequerio. Paper presented at the 11 congresso nacional Sobre economia orizicola, Cuiaba; Mato' Grosso. Feb. 1978. (Unpubl. mimeo).

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

Murata, Y. 1975. Estimation and simulation of rice yield from climatic factors. *Agrl. Meteorol.* 15 : 117-131.

Murata, Y. and Togari, Y. 1973. Analysis of the effect of climatic factors upon the productivity of rice in different localities in Japan. *Proe. Crop. Sci. Soc. Japan.* 41 : 372-387.

Nagato, K. and Ebata, M. 1966. Effects of high temperature during ripening period on the development and quality of rice kernel. *Proe. Crop Sci. Soc. Japan.* 34 : 59-66.

Narayanasamy, R. 1985. Studies on the effect of method of sowing, irrigation and seed hardening on kuruvai rice in the Cauvery delta of Thanjavur district. M. Sc. (Ag.) Thesis, *Tamil Nadu Agrl. Univ.*, Coimbatore.

Nayak, S.K., Murty, P.S.S. and Murty, K.S. 1979. Photosynthesis and translocation in rice during ripening as influenced by different light intensities. *J. Nuclear agric. biol.* 8 : 23-25.

Nho, S.P., Whang, C.J., La, J.S. and Jung, J.Y. 1976. Effect of different sowing and transplanting dates and different duration in nursery on yield of Tongil cultivars. Research report of the office of Rural Development. *Crops.* 18 : 93-99.

* Nishiyama, L. N. Ito, H. Hayase, and [illegible] Satake, T. 1969. Protecting effect of temperature and depth of irrigation water from sterility caused by cooling treatment of the meiotic stage of rice plants. (in Japanese). *Proe. Crop Sci. Soc. Jpn.* 38 : 554-555.

* Nishiyama, I. 1985. Relation between rice yield and photosynthetically active radiation during the seed ripening stage in selected prefactures in Japan. *Japanese J. Crop Sci.* 54 : 8-14.

Osada, A., M. Nara AND H. Chakrabandhu. 1973. Seasonal changes in growth pattern of tropical rice. II. Environmental factors affecting yield and its components. *Proc. Crop Sci. Soc. Japan.* 42 : 351-361.

Ou, S.H. 1973. Handbook of rice diseases in the tropics. *The Int. Rice Res. Inst.,* Los Banos, Laguva, Philippines. 58 pp.

Palaniswamy, K.M., Kalyanikutty, T. and Sreenivasan, S. 1968. Effect of some agronomic factors in yield of few Japonica and Indicarice cultures. *Madras Agric. J.* 55 (10) : 440-444.

Panse, V.G. and Sukhatma, P.V. 1985. Statistical methods for agricultural workers. 4th edition, ICAR, New Delhi. p. 353.

Parashar, K.S. 1976. Effect of spacing on the yield of rice. *Ind. J. Agron.* 21 (4) : 467-468.

Piper C.S. 1942. Soil andplant analysis. Hans Publishers, Bombay. pp. 368

Rajagopal, K., Narayanaswamy, P. and Kunler, M.L. 1973. Yield potential of some IRRI varieties under different dates of planting at Coimbatore I Tamil Nadu, India). *Int. Rice Comm. Newsl.* 22 : 1 - 8.

Rajendran, R. 1985. Influence of varieties, nitrogen and spacing on the infestation of rice leaf folder. *Madras Agric. J.* 72 (10) : 586-589.

Ramaswamy, S., Chandrasekharan, B., Sankaran, S. 1987. Effect of spacing and seedlings per hill. *Int. Rice Res. Newsl.* 12 (4) : 49.

Ramdoss and Subramanian, S. 1980. Influence of weather parameters on rice yield. *Madras Agric. J.* (1980). 67 (9) : 608-609.

Ramdoss and Subramanian, S. 1980. Influence of sowing time on yield attributes and yield of rice variety Periyar. *Madras Agric. J.* 67 (9) : 375-378.

Rao, N.N.P. and Deb, A.R. 1974. Influence of sunshine hours on productivity of rice. *Rice*. 24 : 167-177.

Rao, C.P. and Raju, M.S. 1987. Effect of age of seedling, nitrogen and spacing on rice. *Indian J. Agron.* 32 (1) : 100-102.

R.A.R.S. 1975. Annual Report (1974-'75). Regional Agricultural Research Station, Pattambi.

R.A.R.S. 1981. *Annual Report (1980-'81).* Regional Agricultural Research Station, Pattambi.

Reddy, G.V. and Reddy, P.S. 1986. Effect of time of planting and spacing on IET 2508 in Puddled soil during dry season. *Oryza.* 23(1):53-55.

Robertson, G.W. 1975. Rice and weather, *Technical Note No.44.* Secretariat of World Meteorological Organization, Switzerland.

Sahu, C. and Murty, K.S. 1976. Seasonal influence on dry matter production, nitrogen uptake and yield in rice varieties. *Indian Agric.* 1:43-50.

Sahu, C., C.H.N. Rao and K.S. Murty. 1983. Influence of temperature and solar radiation on growth and yield of rice. *Oryza.* 20 : 51-54.

Saroja, R. and Rajan, N. 1985. Effect of planting time on rice panicle bug incidence - *Int. Rice Res. Newsl.* 10 (2) : 17.

Sastri, A.S. R.A.S. 1986. Effect of onset of monsoon on length of growing season and productivity of rainfed rice in Madhya Pradesh. *Int. Rice Res. Newsl.* 11 (3) : 26.

Satake, T. and Hayase, H. 1970. Male sterility caused by cooling treatment at the young microspore stage in rice plants. V. Estimations of pollen development stage and the most sensitive stage to coolness. *Proc. Crop Sci. Soc. Japan.* 39 : 468-473.

* Satake, T. 1976. Sterile - type cool injury in paddy rice plants. pp. 281-300. In. *International Rice Res. Inst.* Climate and Rice. Los Banos, Philippines.

* Satake, T. and Yoshida, S. 1978. High temperature induced sterility in Indica rices at flowering *Japan J. Crop Sci.* 47 : 6-17.

* Sato, K. 1967. The report on the technical support to develop the U.A.R. desert (in Japanese). Overseas Technical Corporation Agency, Tokyo : 100 pp.

Sato, K. 1972. Growth response of rice plant to environmental correlations. 1. The effects of air temperature on growth at the vegetative stage. *Proc. Crop Sci. Soc. Japan,* 41 : 388-393.

Seshu, D.V. and Cady, F.B. 1984. Response of rice to solar radiation and temperature estimated from international yield trials. *Crop Sci.* 24 : 649-654.

Sikder, H.P. and Gupta, D.K.P. 1979. Physiology of grain filling in rice. 5. Effects of season and fetilizers on grain filling in rice. *Indian agric.* 23 : 11-23.

Singh, R. 1988. Effect of prevailing temperature and humidity on rice army worm reproduction during upland crop season. *Int. Rice Res. Newsl.* 13 (3) : 40.

Singh, C.P. and Garg, I.K. 1983. Effect of different methods of planting on the yield of paddy. *J. Res. Punjab Agric. Univ.* 20 : 503-509.

Singh, U.B. and Paliwal, P. 1980. Effects of different dates of sowing in nursery and nitrogen levels on rice yield in Rajasthan. *Indian J. agron.* 25 : 378-381.

Singh, B.N., Sahu, S.P., Prasad, Y. and Singh R.S. 1986. Seedling age in relation to sheath rot (ShR) occurrence in rice. *Int. Rice Res. Newsl.* 11 (4) : 26.

Singh, B.N., S.P. Srivastava and Hazarika, U.K. 1984. Effect of continuous flow of irrigation water on growth and yield of rice growing at higher altitudes. *Indian J. agric. Sci.* 54 : 201-203.

Soil survey staff. 1967. Soil Survey Laboratory Methods and Procedures for collecting soil samples. Soil Survey Investigation Report No. 1, U.S.D.A., U.S. Govt. Printing office, Washington. pp.50.

Sreedharan, C. 1975. Studies on the influence of climatological factors on rice under different water management practices. Ph.D. thesis submitted to the Orissa University of Agriculture and Technology, Bhubaneswar, India.

✓Sreedharan, C. and Vamadevan, V.K. 1981. Fertilization of rice as influenced by weather conditions. *Tropical Ecol.* 22 : 246-255.

✓Sreenivasan, P.S. 1979. Review of work done on crop, weather relation on rice in India. Presented at the International symposium on Agro meteorology of the rice crop. 3-7 Dec. 1979. International Rice Research Institute, Los Banos, Philippines.

✓ Sreenivasan, P.S. and Banerjee, J.R. 1978. Behaviour of the 'Co 25' variety of irrigated rice under two environments, *Agric. Meteorol.* 19 : 189-202.

✓Stansel, J.W. 1966. Rice and light. *Rice J.* 69 : 30-32.

* Stansel, J.W. 1975. Effective utilization of sunlight. In Scif. Decades of Rice Research in Texas. *The Texas Agric. Expt. Station Res.* Monograph. 4 : 43-50.

✓* Suge, H. and Tokairin, H. (1982). Effect of wind on the growth of rice and barley plants. *Rep. Inst. Agrl. Res.* 33 : 1-14.

✓Suharto, H. and Noch, I.P. 1987. Effect of transplanting date on leaf folder (LF). *(Cnaphalocrocis medinalis)* and Rice bug (RB) *(Leptocorisa oratorius)* infestation at Kiningan, West Java, *Int. Rice Res. Newsl.* 12 (5) : 27.

Suryanarayana, C., Rajasekharan, B.C., Venkatasanu, M.N. and Kulkarni, K.R. 1975. Effect of planting dates in the performance of certain Japonica and indica varieties. *Mysore J. agric. Sci.* 9 : 6-14.

Suzuki, M. 1983. Growth characteristics and drymatter production of rice plants in the warm regions of Japan. *JARQ.* 17 *: 98-105.*

Tanaka, A. and Vengala, B.S. 1964. Growth habit and repening of rice plant in relation to environmental conditions in the far east. *Int. Rice Commun. Newsl.* 26 : 42.

Tanaka, A., Kawara, K. and Yamaguchi, J. 1966. Photosynthesis, respiration and plant type of the tropical rice plant. *Int. Rice Res. Inst.* Technical Bulletin No. 7. p. 46.

Upendrashanker and Gupta, B.R.D. 1981. A correlation study of the height of the paddy crop with some weather elements at a few stations in India. *Agric. Meteorol.* 23 : 137-142.

Urkurkar, J.S. 1983. Optimum transplanting time for rice on agrometeorological approach. *Int. Rice Res. Newsl.* 8 (6) : 24.

Usha, K.E. 1985. Influence of crop Geometry on the growth and yield of rice variety - Jaya. M.Sc. thesis submitted to Kerala Agricultural University, Vellanikkara.

Uthamaswamy, S. and Karuppachamy, P. 1986. Management of Rice gall midge with reference to time of planting and varietal resistance. *Madras Agric. J.* 73 (3) : 146-150.

Venkataraman, S. 1979. Personal communication

Venkataraman, S. and Narasimhamurty, K. 1973. On the flowering behaviour of the rice crop at the crop weather stations. *Indian J. Met. Geophys* (1973) 24 (3) : 293-298.

Venkateswarlu, B. 1977. Influence of low light intensity on growth and productivity of rice *(Oryza sativa L.) Pl. Soil* 47 : 713-719.

Venkateswarlu, B., Koteswara Rao and Rao, A.V. 1976. Canopy analysis on the relation between LAI and productivity in low land rice *(Oryza sativa L.) Pl. Soil* 45 : 45-46.

Venkateswarlu, B., Prasad, V.V.S.S. and Rao, A.V. 1977. Effects of light intensity on different growth phases in rice *(Oryza sativa* L.*) Pl. Soil* 47 : 37-47.

Vergara, B.S. 1976. Physiological and morphological adapatability of rice varieties to climate. In *Climate and Rice.*International Rice Research Institute, Los Banos, pp.67-75.

Vergara, B.S., Chu, T.M. and Jispeias, R.N. 1970. Effect of temperature on the anthesis of IR 8 rice. *Int. Rice Commun. Newsl.* 19 (3) : 11-17.

Vergara, B.S. and Chang, T.T. 1976. The flowering response of the rice plant to photoperiod. A review of literature. *Int. Rice Res. Tech. Bull.* pp. 75.

Vidhyasekharan, P. Lewin, H.D. 1986. Forecasting tungro (RTV) epidermic in Tamil Nadu. *Int. Rice Res. Newsl.* 11 (6) : 36.

Vijayalakshmi, C. Natarajaratnam, N. and Sreerangasamy, S.R. 1987. Effect of light stress on yield attributes in rice. *Madras Agric. J.* 74 (2) : 550.

Viswambharan, K., Rajaram, K.P., Alexander, D. and Rajappan Nair, N. 1989. Factors causing winter yield declines in high yielding varieties. *Int. Rice Res. Newsl.* 12 (1) : 12.

* Wada, S., Kunhara, Y. and Houna, A. 1973. Effect of some environmental factors during heading stage in the fertility of grains in rice plant. *Bull. Hokkaido Prefectural Agrl. Expt. Stn.* No. 28.

* Wan, H. 1979. Causes of low yield of the second rice crop in Taiwan and the measures of improvement. In : *Sungching Haich and Dah Jiang Lin* (eds.). National Science Council, Taipai, Taiwan, p. 15-20.

* Yamada, N. 1967. On the relationship between yield and spacing in rice. *Agric. Hortic.* 36 : 13-18.

*Yamakawa, H. 1962. Studies on the ecological variations of the growth of rice plants caused by the shifting of cultivation season in warm region in Japan. *Agric. Bull. Saga Univ.* 14 : 23-159.

✓ Yoshida, S. 1972. Physiological aspects of grain yield. *Am. Rev. Pl. Physiol.* 23: 437-464.

✓ Yoshida, S. 1973. Effects of temperature on growth of the rice plant (*Oryza sativa* L.) in a controlled environment. *Soil Sci. Pl. Nutr.* (Tokyo) 19 : 299-310.

Yoshida, S. 1981. Fundamentals of rice crop science. *Int. Rice. Res. Inst.*, Los Banos, Philippines, p. 47.

✓ Yoshida, S. and Hara, T. 1977. Effects of temperature and light on grain filling of indica and Japonica rice (*Oryza sativa* L.) under controlled environmental conditions. *Soil Sci. Pl. Nutr.* 23 : 93-107.

✓ Yoshida, S. and Parao, F.T. 1976. Climatic influence on yield and yield components of low land rice in the tropics. pp. 471-494. In: *Climate and Rice.* International Rice Research Institute, Los Banos, Philippines.

* Originals not seen

Appendices

APPENDIX - I

Monthly meteorological data during the crop growth period

		Mean temperature (°C)		Relative humidity (%)	Rainfall (mm)	Number of rainy days	Mean sunshine hours	Mean wind speed (km hr^{-1})	Evaporation (mm)
		Maximum	Minimum						
1988	May	33.7	25.4	76	242.6	6	6.2	4.7	144.9
	June	30.0	23.7	86	632.1	25	4.2	5.2	86.3
	July	29.0	23.2	88	545.0	26	3.0	4.0	78.7
	August	29.2	24.3	86	507.8	25	3.7	4.1	97.6
	September	29.9	23.2	85	700.0	24	5.1	4.1	87.5
	October	31.7	23.3	78	116.6	9	7.1	3.4	113.7
	November	32.6	22.9	68	11.0	1	7.9	5.9	116.7
	December	32.6	22.3	57	14.9	2	9.0	10.0	206.3
1989	January	33.4	22.2	54	0	0	8.1	10.9	253.8
	February	36.3	21.2	45	0	0	9.8	7.1	227.7

APPENDIX - II

Analysis of variance for the height of plant at various growth stages

Source	DF	Mean square		
		30 DAT	60 DAT	90 DAT
Replications	2	10.43450	6.52514	0.45121
Main plot (T)	11	276.19214 **	602.32963 **	790.10858 **
Error (a)	22	9.90129	14.21104	15.34622
Sub plot (S)	1	16.84903	31.62777 **	0.03251
Interaction (T x S)	11	55.64191 **	89.11755 **	115.69317 **
Error (b)	24	6.69083	6.88011	17.36021
Total	71			

** Significant at 1 per cent level

APPENDIX - III

Analysis of variance for number of tillers at various growth stages

Source	DF	Mean square			
		30 DAT	60 DAT	90 DAT	At harvest
Replications	2	0.87500	0.04167	0.22222	0.22222
Main plot (T)	11	12.48864 **	32.51515 **	30.65025 **	23.65025 **
Error (a)	22	0.60227	1.23864	0.91919	1.19192
Subplot (S)	1	0.68056	8.00000 **	10.12500 **	8.68056 *
Interaction (T x S)	11	1.46843	2.15152 *	3.33712 **	2.83207
Error (b)	24	0.65278	0.72222	0.94444	1.19444
Total	71				

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX - IV

Analysis of variance for (1) the number of productive tillers (2) percentage of productive tillers (3) length of panicles (4) number of spikelets per panicle (5) number of filled grains per panicle and (6) percentage of filled grains

Source	DF	Mean square					
		(1)	(2)	(3)	(4)	(5)	(6)
Replications	2	0.16667	14.50322	0.00596	21.93056	21.84722	12.38504
Main plot (T)	11	20.72727**	1045.31741**	14.28647**	895.68052**	2301.90396	1311.86521**
Error (a)	22	1.93939	100.18603	0.50799	191.49116	265.10479	111.29788
Subplot (S)	1	0.05556	139.91861	0.57961	245.68057	287.99999	23.51837
Interaction (T X S)	11	3.14646	74.13365	1.83346	223.46844	331.18183	202.05228
Error (b)	24	1.84722	71.73056	0.87779	172.27778	143.75000	78.17841
Total	71						

** Significant at 1 per cent level

APPENDIX - V

Analysis of variance for (1) grain yield (2) straw yield (3) drymatter production (4) thousand grain weight (5) harvest index and (6) grain straw-ratio

Source	DF	Mean squares					
		(1)	(2)	(3)	(4)	(5)	(6)
Replications	2	33906.05449	130159.27076	989194.58389	0.04672	0.00078	0.00785
Main plot (T)	11	1367890.00034**	2509149.07455**	6852768.89801**	12.90775**	0.00571**	0.04440**
Error (a)	22	92728.01399	330770.15876	637455.36804	0.28096	0.00075	0.00553
Subplot (S)	1	168490.12374	624030.73310	355746.12617	0.13694	0.00008	0.00053
Interaction (T x S)	11	110554.57592	292783.81347	1102720.61824	0.67155	0.00051	0.00403
Error (b)	24	78828.03916	251655.29251	553310.10818	0.33166	0.00069	0.00560
Total	71						

** Significant at 1 per cent level

APPENDIX - VI

Analysis of variance for grain yield for (1) Virippu season and (2) Mundakan season

Source	df	1	2
Replication	2	143774.08027	83633.68988
Main plot (T)	5	92387.24708	1471577.07214
Error (a)	10	62615.88573	102685.39190
Sub plot (S)	1	31270.02477	573553.75289**
Interaction (T x S)	5	73518.22853	82435.10246
Error (b)	12	74505.53417	83150.55847
Total	35		

** Significant at 1 percent level

INFLUENCE OF WEATHER PARAMETERS ON GROWTH AND YIELD OF RICE VARIETY - JAYA

BY

P. SREELATHA

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
VELLANIKKARA—TRICHUR
KERALA—INDIA
1989

ABSTRACT

An experiment was conducted at the Agricultural Research Station, Mannuthy, Kerala Agricultural University during May, 1988 to February, 1989 to study the influence of weather parameters on growth and yield of rice variety Jaya.

The experiment was conducted in split plot design with twelve times of planting (June 18, July 2, July 16, July 30, August 13, August 27, September 10, September 24, October 8, October 22, November 5, and November 19) as main plot treatments and two spacings (20 x 10 cm and 20 x 15 cm) as subplot treatments and the treatments were replicated three times.

Observations on all weather parameters were recorded daily. Crop growth characters like plant height and number of tillers at various stages of growth and time taken from transplanting to panicle initiation, panicle initiation to flowering and flowering to harvest were recorded. Yield components like number and percentage of productive tillers, length of panicle, number of spikelets per panicle, number and percentage of filled grains, grain yield, straw yield, drymatter production, thousand grain weight, harvest index and grain straw ratio were recorded. Observations on incidence of pests, diseases and nematodes were also recorded. However, no serious incidence was noticed.

The time of planting greatly influenced all the growth and yield characters. Early plantings, generally recorded taller plants and more number of tillers and productive tillers. The time of planting had a significant influence on the duration taken from flowering to harvest. Number of spikelets and filled grains per panicle did not show any significant trend with delay in planting.

Time of planting significantly influenced percentage of filled grains, thousand grain weight, grain yield, straw yield, drymatter production, harvest index and grain straw ratio. Highest grain yield, was obtained in the July 2nd planting followed by October 22nd and August 27th plantings. Highest straw yield and drymatter production were recroded in August 27th planting. Correlation studies between grain yield and various weather elements indicated that

a) during vegetative growth period, maximum temperature and temperature range had a strong negative correlation whereas rainfall had a positive correlation

b) during the reproductive stage, the relative humidity had a positive correlation whereas wind speed had a negative correlation,

c) during the grain filling stage, minimum temperature had a strong positive correlation and

d) during the maturity period, maximum temperature and temperature range had a strong negative correlation.

For both the spacings, multiple regression equations were develop between grain yield and five weather elements ie., maximum temperature (TX) during the vegetative period, relative humidity (RH) and wind speed (WS) during the reproductive stage, minimum temperature (TN) during the grain filling stage and temperature range (TR) during the maturity stage. The regression equation for the closer spacing S_1 is,

$$Y = -563.41\ TX + 303.95\ TN - 81.56\ TR - 135.54\ RH - 193.53\ WS + 25044.74$$

The regression equation for the wider spacing S_2 is,

$$Y = -625.51\ TX + 323.56\ TN - 126.42\ TR - 113.12\ RH - 88.54\ WS + 24543.03$$

The multiple correlation coefficient for S_1 was 0.984 and for S_2 it was 0.941. For S_1, about 97 per cent and for S_2 about 89 per cent of total variation in the yield could be explained by the regression.

Crop weather diagrams were prepared for the virippu and mundakan seasons using the crop and meteorological data for July 2nd and October 22nd plantings respectively.

In this experiment, the twelve transplantings spread over five calendar months, covered both the virippu and the mundakan seasons. The results of the experiment indicated that both the times of planting and spacing have a very significant influence on the growth and yield of the high yielding medium duration rice variety Jaya. The experiment helped in identifying the optimum dates of transplanting in both virippu and mundakan seasons. Transplanting in the first week of July in the virippu season and in the third week of October in the mundakan season can give higher grain yields. The results also indicated that closer spacing (20 x 10 cm) in the mundakan season will further enhance the grain yield substantially.